

**DEENDAYAL PORT AUTHORITY**  
**(Erstwhile: DEENDAYAL PORT TRUST)**



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EG/WK/4751/Part (3 remaining facilities-II) /358

Dated: 12/09/2023

To,  
The Deputy Director General of Forests (C),  
Ministry of Environment, Forest & Climate Change  
Integrated Regional Office, Gandhinagar,  
A wing- 407 & 409, Aryan Bhawan,  
Near CH-3 Circle,  
**Sector 10 A, Gandhinagar – 382 010.**

**Sub:** Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Authority (Erstwhile: Deendayal Port Trust) at Gandhidham, Kutch, Gujarat – **Pointwise Compliance of the conditions stipulated in the EC&CRZ Clearance and Monitoring Report in Datasheet reg.**

**Ref.:** 1) EC & CRZ Clearance accorded by the MoEF&CC, GoI, New Delhi vide no. 10-9/2017-IA-III dated 18/2/2020.  
2) Regional Office, MoEF&CC, GoI, Bhopal letter vide F.No. 6-8/2020 (ENV)/324 dated 30/05/2020 (Received by DPT on 26/06/2020).  
3) DPT letter no. EG/WK/4751/Part (3 remaining facilities)/968 dated 31(13)/7(8)/2020 along with requisite details.  
4) Regional Office (Integrated), Gandhinagar, MoEF&CC, GoI, Bhopal letters dated 31/8/2020 & 18/11/2020 & response thereof from DPT vide letters dated 16/9/2020 & 24/12/2020 respectively.  
5) DPT letter no. EG/WK/4751/Part (3 remaining facilities-II)/42 dated 13/07/2021.  
6) DPT letter no. EG/WK/4751/Part (3 remaining facilities-II)/149 dated 8/2/2022.  
7) DPA letter no. EG/WK/4751/Part (3 remaining facilities-II)/133 dated 06/07/2022  
8) DPA letter no. EG/WK/4751/Part (3 remaining facilities-II)/280 dated 18/04/2023

Sir,

It is requested to kindly refer above cited references for the said subject.

In this regard, it is to state that, DPA vide above mentioned letter dated 31(13)/7(8)/2020 had submitted details/information (including point-wise compliance of stipulated conditions & duly filled in data sheet) asked by the Regional Office (Integrated), Gandhinagar, MoEF&CC, GoI, Bhopal in connection with the EC & CRZ Clearance granted by the MoEF&CC, GoI dated 18/2/2020 for the subject mentioned above. Further, DPA vide above mentioned letters dated 16/9/2020 & 24/12/2020 (Ref. 4 above) had submitted additional details asked by the Regional Office, MoEF&CC, GoI. Subsequently, DPA vide above referred letter had submitted six-monthly compliance report of the stipulated conditions in the said Clearance dated 18/02/2020.

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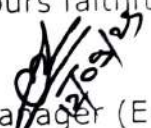
Now, as directed in the Regional Office (Integrated), Gandhinagar, MoEF&CC, GoI, Bhopal above mentioned letter dated 30/05/2020, kindly find enclosed herewith compliance report of stipulated conditions mentioned in the EC & CRZ Clearance granted by the MoEF&CC, GoI dated 18/2/2020 (**Annexure 1**) & Monitoring Report in Data Sheet (**Annexure 2**) (Period up to May, 2023) for kind information and record please.

Further, as per the MoEF&CC, Notification S.O.5845 (E) dated 26.11.2018, which stated that **"In the said notification, in paragraph 10, in sub-paragraph (ii), for the words "hard and soft copies" the words "soft copy" shall be substituted"**. Accordingly, we are submitting herewith soft copy of the compliance report through e-mail ID : [eccompliance-guj@gov.in](mailto:eccompliance-guj@gov.in) .

This has the approval of Chief Engineer, Deendayal Port Authority.

**Encl.:** As above

Yours faithfully,

  
Manager (Env.)

Deendayal Port Authority

**Copy along with point wise compliance of stipulated conditions, to :**

1) Shri Amardeep Raju,  
Scientist E, Ministry of Environment, Forest and Climate Change,  
& Member Secretary (EAC-Infra.1),  
Indira Paryavaran Bhawan,  
3rd Floor, Vayu Wing, Jor Bagh Road, Aliganj,  
New Delhi- 110 003;  
E-mail: [ad.raju@nic.in](mailto:ad.raju@nic.in)

2) Shri Prasoon Gargav,  
Scientist E & Regional Director,  
Central Pollution Control Board,  
Parivesh Bhawan,  
Opp. VMC Ward Office No.10, Subhanpura,  
Vadodara - 390 023.  
Email: [prasoon.cpcb@nic.in](mailto:prasoon.cpcb@nic.in)

3) Shri T. C. Patel,  
Environment Engineer,  
Unit Head, Kachchh ,  
Gujarat Pollution Control Board,  
Paryavaran Bhavan,  
Sector 10A, Gandhinagar- 382 010.  
Email-[kut-uh-gpcb@gujarat.gov.in](mailto:kut-uh-gpcb@gujarat.gov.in)

4) The Regional Officer,  
Gujarat Pollution Control Board,  
Regional Office (East Kutch), Administrative Office Building,  
Deendayal Port Trust, Gandhidham.  
Email Id. [ro-gpcb-kute@gujarat.gov.in](mailto:ro-gpcb-kute@gujarat.gov.in)

# **Annexure -1**

**Subject:** Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Authority (Erstwhile : Deendayal Port Trust) at Gandhidham, Kutch, Gujarat – **Environmental & CRZ Clearance.**

**CURRENT STATUS OF WORK (up to May, 2023)**

Sr.No.	Name of Project	Status
1	<b>Development of Container Terminal at Tuna off-Tekra on BOT Basis:</b>  <i>(Jetty: T-shape 1100m X 54m, Capacity: 2.19 Million TEUs/Annum, Capital Dredging: 13,56,000 M3, Maintenance Dredging 271200 M3/year , Land Area req.: 84 ha, Break water: Length of 1400 m, with 20 m of height, Estimated Cost: 3097 cr.).</i>	<p>The Board of DPA approved the Feasibility Report in its meeting on 19.02.2021.</p> <p>The MoPSW,GoI vide communication dated 21/10/2022 has conveyed approval granted by the Cabinet Committee on Economic Affairs to the project.</p> <p>Accordingly, DPA invited RFQ and RFP and the RFP (Bid) was opened on 27.01.2023. M/s Hindustan Infralog Private Limited, Mumbai was declared as the selected Bidder. The Letter of Award (LoA) was issued to M/s. Hindustan Infralog Private Limited, Mumbai and the same was acknowledged and accepted by them on 30.01.2023. From time to time, on the request of M/s. Hindustan Infralog Private Limited, the time period for execution of Concession Agreement between the Authority and SPV framed by M/s. Hindustan Infralog Private Limited was further extended up to 20.06.2023.</p> <p><b><u>No construction activity started yet.</u></b></p>
2	<b>Providing Railway Line from NH 8A to Tuna Port.</b> <i>(Length – 11 km, Estimated cost: 94 cr.)</i>	<b><u>Work completed.</u></b>
3	<b>Construction of Port Craft Jetty &amp; Shifting of SNA Section.</b>  <i>(Dredging : 27357.00 m3, Estimated Cost: 23.17 cr. )</i>	<b><u>Work completed.</u></b>



## Annexure 1

### COMPLIANCE REPORT (up to May 2023)

**Subject:** Compliance of conditions stipulated by the Ministry of Environment, Forests & Climate Change (MoEF&CC), GoI in Environmental & CRZ Clearance granted for "**Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Trust (Erstwhile: Kandla Port Trust) at Gandhidham, Kutch, Gujarat.**"

**Reference:** Environment and CRZ clearance accorded by the MoEF&CC, GoI vide file no. 10-9/2017-IA-III dated 18/2/2020.

Sr.No.	A. Specific Conditions	
I	Consent to Establish/ Operate for the project shall be obtained from the State Pollution Control Board as required under the Air (Prevention and Control of Pollution) Act, 1981 and the Water (Prevention and Control of Pollution) Act, 1974.	<p>The compliance with regard to Point no. I to IV had already been submitted by Deendayal Port Authority vide <b><u>communication no. EG/WK/4751 /Part (Remaining three facilities)/911 dated 3/12/2018</u></b> immediately after issuance of Minutes of the EAC (Infra.2) meeting held on 10/8/2018 (Agenda Item no. 33.4.12) vide which, the EAC (Infra.2) has recommended the subject proposal of DPA for grant of Environmental &amp; CRZ Clearance to the MoEF&amp;CC, Gol.</p> <p>However, a copy of the forwarding letter dated 3/12/2018 of DPA submitting requisite details, duly acknowledged by the MoEF&amp;CC, Gol, Regional Office, Bhopal, dated 26/12/2018 had already been forwarded along with the compliance report submitted earlier.</p>
li	The project proponents will submit a declaration under Oath that the Railway line will not pass through mangrove area.	
lii	A detailed traffic management and traffic decongestion plan to ensure that the current level of service of the roads within a 05 kms radius of the project is maintained and improved upon after the implementation of the project. This plan should be based on cumulative impact of all development and increased habitation being carried out or proposed to be carried out by the project or other agencies in this 05 Kms radius of the site in different scenarios of space and time and the traffic management plan shall be duly validated and certified by the State Urban Development department and the P.W.D. and shall also have their consent to the implementation of components of the plan which involve the participation of these departments.	
lv	A detailed marine biodiversity impact assessment report and plan shall be drawn up and implemented to the satisfaction of the State Biodiversity Board and the CRZ authority. This shall be prepared through the NIOS or any other institute of repute on marine, brackish water and fresh water ecology and biodiversity. The report shall be based on a study of the impact of the project activities on the intertidal biotopes, corals and coral communities, molluscs, sea grasses, sea weeds, sub-tidal habitats, fishes, other marine and aquatic micro, macro and mega flora and fauna including benthos, plankton, turtles, birds etc. as also the productivity. The data collection and impact assessment shall be as per standards survey methods and include underwater photography.	

<b><i>The project proponent shall obtain all the documents/certificate mentioned in para (i) to (iv) above and submitted/uploaded online to the Ministry's Regional Office, Bhopal before starting implementation of the project.</i></b>		
V	Construction activity shall be carried out strictly according to the provisions of the CRZ Notification, 2011. No construction work other than those permitted in Coastal Regulation Zone Notification shall be carried out in Coastal Regulation Zone area.	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed.</p> <p>For project at Sr. no. 1 of the EC &amp; CRZ Clearance, no construction activity started yet. However, the selected BOT operator will carry out construction activities strictly as per the provisions of the CRZ notification, 2011. Further, no activity other than those permissible in Coastal Regulation Notification will be carried out in the CRZ area.</p>
Vi	All the recommendations and conditions specified by the Gujarat Coastal Zone Management Authority who has recommended the project vide letter No. ENV-10-2015-249-E (T cell) dated 19.06.2017 shall be complied with.	<p>The specified CRZ recommendation letter ENV-10-2015-249-E (T cell) dated 19.06.2017 pertains to other organization i.e. Cargo Motors Pvt. Ltd. and does not pertain to DPA. However, the GCZMA had recommended the project for grant of CRZ Clearance vide letter no. ENV-10-2015-248-E (T-cell) dated 29/06/2016. The pointwise compliance of stipulated conditions mentioned therein is attached herewith as <b>Annexure I</b>.</p>
Vii	The project proponent shall ensure that the project is in consonance with the new CZMP prepared by the State Government under the provisions of the CRZ Notification, 2011.	<p>The MoEF&amp;CC, Gol accorded EC &amp; CRZ Clearance for the subject proposal of DPA dated 18/2/2020. Project at Sr. No. 2 &amp; 3 is completed. However, for the project at Sr.No. 1, implementation of the project will be carried out as per the EC &amp; CRZ Clearance accorded by the MoEF&amp;CC, Gol.</p>
Viii	Notification GSR 94(E) dated 25.01.2018 of MoEF&CC regarding Mandatory Implementation of Dust Mitigation Measures for Construction and Demolition Activities for projects requiring Environmental Clearance shall be complied with.	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed. Further, for the project at Sr. No. 1, the selected BOT Operator will implement dust mitigation measures.</p> <p>DPA had already issued a general circular vide dated 3/9/2019 regarding Construction and Demolition Waste Management for strict implementation in DPA (Copy of the same has already been communicated with the last compliance report submitted).</p> <p><b><u>General Measures taken by DPA in Port area at Kandla :</u></b> DPA effectively implemented applicable measures for dust mitigation as under:</p> <ol style="list-style-type: none"> <li>1) All the vehicles carrying Construction material and waste are being covered.</li> <li>2) Construction material and waste are being stored in the earmarked area.</li> </ol>

		<p>3) Wind-breaker of appropriate height has been provided.</p> <p>4) DPA has installed Mist Canon at the Port area to minimize the dust.</p> <p>5) Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done.</p>
ix	The Project proponent shall ensure that no creeks or rivers are blocked due to any activities at the project site and free flow of water is maintained.	The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. For project at Sr. No. 1 (construction not yet started), no creeks or rivers will be blocked due to any activities at the project site and free flow of water will be maintained.
x	No solid, semi solid cargos would be handled.	<p><b>Project at Sr. No.1, i.e., Development of Container Terminal at Tuna off-Tekra on BOT Basis – Containerized cargo will be handled.</b></p> <p><b>Project at Sr .no. 2, i.e., Providing Railway Line from NH 8A to Tuna Port. – For movement of cargo in connection with the Dry Bulk Terminal at Tuna Tekra.</b></p> <p><b>Project at Sr. no.3, i.e. Construction of Port Craft Jetty &amp; Shifting of SNA Section – For parking of Port crafts.</b></p>
xi	Dredging shall not be carried out during the fish breeding season.	Point noted for compliance
xii	Dredging, etc. shall be carried out in the confined manner to reduce the impacts on marine environment including turbidity.	Point noted for compliance
xiii	Dredged material shall be disposed safely in the designated areas	Point noted for compliance
xiv	Shoreline should not be disturbed due to dumping. Periodical study on shore line changes shall be conducted and mitigation carried out, if necessary. The details shall be submitted along with the six monthly monitoring report.	<p>Dredging material shall be disposed of at the designated location as identified by the CWPRS, Pune.</p> <p>DPA issued a work order vide no. EG/WK/4751/Part (EC- Shoreline study) Dated: 12/10/2021 to NCSCM, Chennai for Shoreline Change Study for Deendayal Port Authority, Kandla, Kachchh District, Gujarat, to Study the Effect of Dumping, if any reg. The final Report submitted by the NCSCM, Chennai, has already been communicated with the last six monthly compliance report submitted vide letter dated 06/07/2022.</p>
xv	While carrying out dredging, an independent monitoring shall be carried out by Government Agency/Institute to check the impact and necessary measures shall be taken on priority basis if any adverse impact is observed.	Point noted for compliance
xvi	Water will be received from high service reservoir near Bhachau and Narmada Canal through pipeline of Gujarat Water supply and Sewerage Board. 5.0 KLD water will be used for various purposes during the project. Rain	<p>Water requirements will be met through procurement from GWSSB or private tankers.</p> <p>The project is to be implemented at Deendayal Port Authority, Kandla, Kachchh District, Gujarat.</p>

	<p>water harvesting shall be followed as per local byelaw and harvested water shall be stored, treated and reused to reduce the additional water requirement since Chennai is a water deficient area, besides use of water efficient appliances.</p>	<p>The treated domestic sewages from STP (1.5 MLD) at Kandla are utilized for plantation / Gardening.</p> <p>Further, rainwater harvesting has already been made by DPA.</p> <p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed. For project at Sr. No. 1 (construction not yet started), the selected BOT operator will explore the possibility for Rain water harvesting for additional water requirement if any.</p>
xvii	<p>The concerns expressed during the public hearing held by the M/s Kandla Port Authority for development of 3 remaining integrated facilities (Stage I) within the existing Kandla Port needs to be addressed during the project implementation. These would also cover socio-economic and ecological and environmental concerns, besides commitment by the management towards employment opportunities.</p>	<p>Not applicable, as public hearing exempted. Further, the details of CSR activities undertaken/to be undertaken by DPA are placed at <b>Annexure II</b>.</p>
xviii	<p>The Marine biodiversity impact assessment report and management plan prepared by Gujarat Institute of Desert Ecology (GUIDE), Bhuj and approved by NIO and its mitigation measures for protection of sand dune vegetation, mangroves, sea grasses, macrophytes and phytoplankton etc. as given in the EIA-EMP Report shall be complied with in letter and spirit.</p>	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed. Further, for the project at Sr.No.1, construction not yet started.</p> <p>No industrial effluent is generated in the port area. The domestic sewage generated is treated in the STP (1.5 MLD) at Kandla. The treated sewages from STP of DPA are utilized for plantation / Gardening.</p> <p>DPA has entered into 'Selling Agency' agreement with M/s. MSTC (Govt. of India Enterprise), Vadodara on 04/01/2022 for disposal of scrap, surplus items, unserviceable equipment etc. The copy of the MoU has already been communicated with the last compliance report submitted.</p> <p>DPA had already issued circulars dated 3/9/2019 regarding Plastic Waste Management &amp; Construction and Demolition Waste Management for strict implementation in DPA (The copy of the Circular has already been communicated with the last compliance report submitted).</p> <p>Further, DPA has appointed GEMI, Gandhinagar for the work of "Preparation of Plan for Management of Plastic Wastes, Solid Waste, including C&amp;D waste, E-waste, Hazardous waste, including Biomedical and Non-Hazardous Waste in the Deendayal Port Authority" vide Work Order dated 24/01/2023. The work is in progress.</p>

		<p>DPA had assigned the work to GUIDE, Bhuj for continuous monitoring of Marine Ecology since the year 2017 and the final reports are being submitted from time to time to the Regional Office, MoEF&amp;CC, Gol, Gandhinagar &amp; to the MoEF&amp;CC, Gol, New Delhi along with six monthly compliance reports submitted.</p> <p>Further, DPA assigned work to M/s GUIDE, Bhuj, vide work order dated 3/5/2021 for <b><i>“Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme covering all seasons on various aspects of the Coastal Environs covering Physico-chemical parameters of marine water and marine sediment samples coupled with biological indices, as per the requirements of EC &amp; CRZ Clearances</i></b> reg. (for three years (2021-2024)). The copy of the final report for the year 2021-22 has already been communicated with the compliance report submitted vide letter dated 06/07/2022. The second season report for the year 2022-2023 submitted by M/s GUIDE is attached herewith as <b>Annexure III</b>.</p> <p>For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&amp;CC, Gol, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as <b>Annexure IV</b>.</p> <p>DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005. The copy of the details has already been communicated with the earlier compliance reports submitted.</p> <p>In addition to the above, DPA appointed M/s GUIDE, Bhuj for “Regular Monitoring of Mangrove Plantation carried out by DPA” (period 15/9/2017 to 14/9/2018 vide work order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021). The final report submitted by M/s GUIDE, Bhuj, for the years 2017 to 2018 and 2021 to 2022 has already been submitted in the six monthly compliance communicated vide letter 06/07/2022.</p> <p>DPA is already having Environment Management cell. Further, DPA has also</p>
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		appointed expert agency for providing Environmental Experts from time to time. Presently, DPA appointed M/s Precitech Laboratories, Vapi for providing Environmental Experts vide work order dated 5/2/2021. In addition, it is relevant to submit here that, DPA had appointed Manager (Environment) on contractual basis for the period of 3 years and further extendable to 2 years (Copy of the details has already been communicated with the last compliance report submitted).
xix	A continuous monitoring programme covering all the seasons on various aspects of the coastal environs need to be undertaken by a competent organization available in the State or by Authoritying to the National Institutes/renowned Universities/accredited Consultant with rich experiences in marine science aspects. The monitoring should cover various physico-chemical parameters coupled with biological indices such as sand dune vegetation, mangroves, sea grasses, macrophytes and phytoplankton on a periodic basis during construction and operation phase of the project. Any deviations in the parameters shall be given adequate care with suitable measures to conserve the marine environment and its resources.	<p>DPA had assigned the work to M/s GUIDE, Bhuj for continuous monitoring of Marine Ecology since the year 2017 and the reports in this regard are being submitted from time to time to the Regional Office, MoEF&amp;CC, GoI, Gandhinagar &amp; to the MoEF&amp;CC, GoI, New Delhi along with six monthly compliance reports submitted.</p> <p>Further, DPA assigned work to M/s GUIDE, Bhuj, vide work order dated 3/5/2021 for <b><i>“Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme covering all seasons on various aspects of the Coastal Environs covering Physico-chemical parameters of marine water and marine sediment samples coupled with biological indices, as per the requirements of EC &amp; CRZ Clearances</i></b> reg. (for three years (2021-2024)). The copy of the final report for the year 2021-22 has already been communicated with the compliance report submitted vide letter dated 06/07/2022. The second season report for the year 2022-2023 submitted by M/s GUIDE is attached herewith as <b>Annexure III</b>.</p>
xx	Continuous online monitoring of for air and water covering the total area shall be carried out and the compliance report of the same shall be submitted along with the 6 monthly compliance report to the regional office of MOEF&CC.	<p>For regular monitoring of environmental parameters, since the year 2016, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&amp;CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as <b>Annexure IV</b>.</p> <p>DPA has already initiated the action for inviting the tenders for carrying out online ambient air quality monitoring system (24 X 7).</p>
xxi	Ambient air quality shall be maintained at prescribed levels. The existing ambient air	For monitoring of environmental parameters, DPA has been appointing NABL Accredited

	quality stations shall have a system of reporting exceedances separately to the Pollution Control Board.	laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, Gol, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as <b>Annexure IV</b> .
xxii	The project configuration should integrate and dovetail with the State Plan and not implemented unless the state plan is prepared and dovetailing ratified.	The Gujarat Coastal Zone Management Authority had already recommended the proposal vide letter dated 29/6/2016. Based on the same, the MoEF&CC, Gol has issued EC & CRZ Clearance for the subject proposal of DPA.
xxiii	Marine ecology shall be monitored regularly also in terms of sea weeds, sea grasses, mudflats, sand dunes, fisheries, echinoderms, shrimps, turtles, corals, coastal vegetation, mangroves and other marine biodiversity components as part of the management plan. Marine ecology shall be monitored regularly also in terms of all micro, macro and mega floral and faunal components of marine biodiversity	<p>DPA had assigned the work to M/s GUIDE, Bhuj for continuous monitoring of Marine Ecology since the year 2017 and the reports in this regard are being submitted from time to time to the Regional Office, MoEF&amp;CC, Gol, Gandhinagar &amp; to the MoEF&amp;CC, Gol, New Delhi along with six monthly compliance reports submitted.</p> <p>Recently, DPA assigned work to M/s GUIDE, Bhuj vide work order dated 3/5/2021 for <b><i>“Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme covering all seasons on various aspects of the Coastal Environs covering Physico-chemical parameters of marine water and marine sediment samples coupled with biological indices, as per the requirements of EC &amp; CRZ Clearances</i></b> reg. (for three years (2021-2024)). The copy of the final report for the year 2021-22 has already been communicated with the compliance report submitted vide letter dated 06/07/2022. The second season report for the year 2022-2023 submitted by M/s GUIDE is attached herewith as <b>Annexure III</b>.</p>
xxiv	Spillage of fuel I engine oil and lubricants from the construction site are a source of organic pollution which impacts marine life, particularly benthos. This shall be prevented by suitable precautions and also by providing necessary mechanisms to trap the spillage.	DPA is already having an Oil Spill contingency plan & accordingly, necessary precautions will be taken to prevent spillage of Fuel/Engine oil and lubricants.
xxv	The handling of Hazardous Cargo should follow the provisions of the MSIHC Rules 1989 as amended. An onsite management plan shall be drawn up and integrated with that off site management plan. This shall be to the satisfaction of the state pollution control board, the Factory Department and the District Management.	<p>Before Loading or Unloading of Dangerous Goods, Notification of Dangerous Goods is being carried out by Vessel Master &amp; Vessel Agents as per Dock Workers (Safety, Health &amp; Welfare) regulation 1990 regulation No.76.</p> <p>The notification covers mainly below documents:</p> <ol style="list-style-type: none"> <li>1. Undertaking from Master of the Ship</li> <li>2. Ship Particular</li> </ol>

		<p>3. MSDS of dangerous Goods 4. Stowage Plan 5. Crew List</p> <p>DPA already has a Disaster Management Plan in place. Copy of the same has already been communicated with the earlier compliance report submitted.</p>
xxvi	<p>Necessary arrangements for the treatment of the effluents and solid wastes/ facilitation of reception facilities under MARPOL must be made and it must be ensured that they conform to the standards laid down by the competent authorities including the Central or State Pollution Control Board and under the Environment (Protection) Act, 1986. The provisions of Solid Waste Management Rules, 2016, E-waste Management Rules, 2016, and Plastic Waste Management Rules, 2016 shall be followed</p>	<p>No industrial effluent is generated in the port area. The domestic sewage generated is treated in the STP (1.5 MLD) at Kandla.</p> <p>DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" and "Dry Solid Waste (Non- Hazardous)" from Vessels calling at Deendayal Port through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars regarding the reception facilities at Swachh Sagar portal.</p> <p>DPA has entered into 'Selling Agency' agreement with M/s. MSTC (Govt. of India Enterprise), Vadodara on 04/01/2022 for disposal of scrap, surplus items, unserviceable equipment etc. The copy of the MoU has already been communicated with the last compliance report submitted.</p> <p>DPA had already issued circulars dated 3/9/2019 regarding Plastic Waste Management &amp; Construction and Demolition Waste Management for strict implementation in DPA (The copy of the Circular has already been communicated with the last compliance report submitted).</p> <p>Further, DPA has appointed GEMI, Gandhinagar for the work of "Preparation of Plan for Management of Plastic Wastes, Solid Waste, including C&amp;D waste, E-waste, Hazardous waste, including Biomedical and Non-Hazardous Waste in the Deendayal Port Authority" vide Work Order dated 24/01/2023. The work is in progress.</p>
xxvii	<p>Compliance to Energy Conservation Building (ECBC-2017) shall be ensured for all the building complexes. Solar/wind or other renewable energy shall be installed to meet energy demand of 1 % equivalent.</p>	<p><b>The projects mentioned in the EC &amp; CRZ Clearance dated 18/2/2020 are mainly related with construction of jetty/berth (Container Terminal &amp; Port Craft Jetty) &amp; associated activities and the project related with laying of Railway line.</b></p> <p>DPA has emerged as the First Indian major port to install a wind power project. 6 MW wind power project have been commissioned at Village Sukhpur, District - Amreli, Gujarat on 31.03.2017 and 14 MW wind power project commissioned at Village Jodiya, District - Jamnagar, Gujarat on 30.03.2019</p>

		<p>Major Energy needs of port and colony are met from the captive wind generation project.</p> <p>DPA has commissioned a 45 kWp Solar Plant at Gandhidham on 7th July, 2022.</p> <p>DPA has installed 400 KWP solar plant and 600 KWP to be installed this year by PPP operator.</p> <p>4000 Acres of land has been identified for developing 150 MW Hybrid (Solar Cum Wind) Energy Park.</p> <p>DPA is also planning to install RE Hybrid Park of total 70 MW for captive utilization in phase manner.</p>
xxviii	All the recommendations mentioned in the rapid risk assessment report, disaster management plan and safety guidelines shall be implemented.	The available Safety Measures implemented at Deendayal Port to overcome any unpredictable hazards has already been communicated with the earlier six monthly compliance report submitted vide letter dated 06/07/2022. Further, it is assured that all the recommendations mentioned in the Rapid Risk Assessment Report, Disaster Management Plan & safety Guidelines will be implemented.
xxix	Measures should be taken to contain, control and recover the accidental spills of fuel and cargo handle.	DPA already has an Oil Spill Contingency Plan. The copy of the same has already been communicated with earlier compliance reports. In addition to it, DPA also has equipment for Oil Spill Response System.
xxx	Necessary arrangement for general safety and occupational health of people should be done in letter and spirit.	Point Noted. Personal Protective Equipment's for general safety are provided to the workers as well as visitors for their protection.
xxxi	KPT shall take up massive greenbelt development activities in and around Kandla and also within the KPT limits.	<p>DPA had already taken up the greenbelt Development activity through Forest Department, GoG, at the cost of 352.32 lakhs (Green Belt development in DPA area in an area of 31.942 Ha.)</p> <p>Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I) (5000 plants) " vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The work is completed. <b>Further, DPA assigned work to GUIDE, Bhuj vide work order dated 23/06/2023 for "Green belt development in Deendayal Port Authority and its Surrounding Areas(Phase II) (10000 plants). The work is in progress.</b></p>
xxxii	All the mitigation measures submitted in the EIA report shall be prepared in a matrix format and the compliance for each mitigation plan shall be submitted to the	Compliance of mitigation measures suggested in the EIA report in the matrix format is attached herewith as <b>Annexure V</b> .

	Regional Office, MoEF&CC along with half yearly compliance report.	
xxxiii	As per the Ministry's Office Memorandum F.No. 22-65/2017-IA.III dated 1st May 2018, an amount of Rs. 8.04 Crore (@0.25% of project Cost) shall be earmarked under Corporate Environment Responsibility (CER) for the activities such as drinking water, sanitation, health, education, skill development, roads, solar power, rain water harvesting, avenue plantation and plantation in the community areas. The activities proposed under CER shall be restricted to the affected area around the project. The entire activities proposed under the CER shall be treated as project and shall be monitored. The monitoring report shall be submitted to the regional office as a part of half yearly compliance report, and to the District Collector. It should be posted on the website of the project proponent.	DPA is in process of appointing expert agency for <b><i>"Planning and Implementation of the activities to be undertaken under Corporate Environment Responsibility by the Deendayal Port Authority in consonance with EMP"</i></b> .  It is assured that, as per condition stipulated, the activities under CER will be implemented in consonance with EMP activities.
xxxiv	The project is recommended for grant of Environmental and CRZ Clearance subject to final outcome/legal opinion on the Order dated 22nd November, 2017 of Hon'ble NGT in the Original Application No. 424 of 2016 (Earlier O.A. No. 169 of 2015) and Original Application No. 11 of 2014 in the matter of M/s. Mehdad & Anr. Vs. Ministry of Environment, Forests & Climate Change & Ors. and Shamsunder Shridhar Dalvi & Ors. Vs. Govt. of India & Ors.	Point Noted
<b>B</b>	<b><u>GENERAL CONDITIONS:</u></b>	
i	Appropriate measures must be taken while undertaking digging activities to avoid any likely degradation of water quality.	Point noted
ii	Full support shall be extended to the officers of this Ministry/Regional Office at Bhopal by the project proponent during inspection of the project for monitoring purposes by furnishing full details and action plan including action taken reports in respect of mitigation measures and other environmental protection activities.	It is assured that full support shall be extended to the Officers of this Ministry/Regional Office at Bhopal/ Gandhinagar by the project proponent during the inspection of the project for monitoring purposes.
iii	A six-Monthly monitoring report shall need to be submitted by the project proponents to the Regional Office of this Ministry at Bhopal regarding the implementation of the stipulated conditions	DPA has been regularly submitting the compliance reports of stipulated conditions to the Regional Office of MoEF&CC, Gol.
iv	Ministry of Environment, Forest and Climate Change or any other competent authority may stipulate any additional conditions or modify the existing ones, if necessary in the interest of environment and the same shall be complied with	Point Noted.
v	The Ministry reserves the right to revoke this clearance if any of the conditions	Point noted



	stipulated are not complied with the satisfaction of the Ministry	
vi	In the event of a change in project profile or change in the implementation agency, a fresh reference shall be made to the Ministry of Environment, Forest and Climate Change.	Point Noted
vii	The project proponents shall inform the Regional Office as well as the Ministry, the date of financial closure and final approval of the project by the concerned authorities and the date of start of land development work.	For project at Sr. No. 1, construction not yet started. However, the stipulated condition will be complied with.
viii	A copy of this clearance letter shall also be displayed on the website of the concerned State Pollution Control Board.	Point noted
7	All other statutory clearances such as the approvals for storage of diesel from Chief Controller of Explosives, Fire Department, Civil Aviation Department, Forest Conservation Act, 1980 and Wildlife (Protection) Act, 1972 etc. shall be obtained, as applicable by project proponents from the respective competent authorities	Point noted.
8	The project proponent shall advertise in at least two local Newspapers widely circulated in the region, one of which shall be in the vernacular language informing that the project has been accorded Environmental and CRZ Clearance and copies of clearance letters are available with the State Pollution Control Board and may also be seen on the website of the Ministry of Environment, Forest and Climate Change at <a href="http://www.envfor.nic.in">http://www.envfor.nic.in</a> . The advertisement should be made within Seven days from the date of receipt of the Clearance letter and a copy of the same should be forwarded to the Regional office of this Ministry at Bhopal. The Clearance letter shall also be displayed at the Regional Office, District Industries Centre and Collector's Office/ Tehsildar's office for 30 days.	DPA has already given advertisement in two local newspapers viz. KUTCHMITRA (In Gujarati) dated 23/2/2020 and in the Indian Express (In English) dated 22/02/2020 and also forwarded to the Regional Office, MoEF&CC, Bhopal vide letter dated 27/2/2020. Copy of the advertisement has already been communicated with the earlier six-monthly compliance report submitted vide letter dated 06/07/2022.
9	A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zilla Parishad/Municipal Corporation, Urban Local Body and the Local NGO, if any, from whom suggestions/representations, if any, were received while processing the proposal. The clearance letter shall also be put on the website of the company by the proponent.	Copy of the clearance letter dated 18/2/2020 was communicated to the concerned authorities along with the compliance report submitted vide letter 31(13)/7(8)/2020 and the same has been uploaded on the website of DPA.
10	This clearance is subject to final order of the Hon'ble Supreme Court of India in the matter of Goa Foundation Vs. Union of India in Writ Petition (Civil) No.460 of 2004 as may be applicable to this project	Point Noted.

11	Any appeal against this clearance shall lie with the National Green Tribunal, if preferred, within a period of 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.	Point noted
12	Status of compliance to the various stipulated environmental conditions and environmental safeguards will be uploaded by the project proponent in its website.	DPA has been uploading the status of compliance of stipulated environmental conditions on its website <a href="http://www.deendayalport.gov.in">www.deendayalport.gov.in</a> .
13	The proponent shall upload the status of compliance of the stipulated Clearance conditions, including results of monitored data on their website and shall update the same periodically. It shall simultaneously be sent to the Regional Office of MoEF&CC, the respective Zonal Office of CPCB and the SPCB.	DPA has been regularly uploading the status of compliance with the stipulated clearance conditions including results of monitored data on the website <a href="http://www.deendayalport.gov.in">www.deendayalport.gov.in</a> . Simultaneously, DPA has been submitting the six-monthly compliance report to the Regional Office of MoEF&CC, Gol and GPCB.
14	The project proponent shall also submit six monthly reports on the status of compliance of the stipulated Clearance conditions including results of monitored data (both in hard copies as well as by e-mail) to the respective Regional Office of MoEF&CC, the respective Zonal Office of CPCB and the SPCB	DPA has been submitting the six-monthly compliance report on the status of compliance with the stipulated Clearance conditions, including the monitored data, to the Regional Office of MoEF&CC, Gol and GPCB.
15	The environmental statement for each financial year ending 31" March in Form-V as is mandated to be submitted by the project proponent to the concerned State Pollution Control Board as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall also be put on the website of the company along with the status of compliance of Clearance conditions and shall also be sent to the respective Regional Office of MoEF&CC by e-mail.	DPA regularly submitted the Environmental statement in Form V to the GPCB. A copy of the Environmental Statement submitted to the GPCB (the year 2022-23) for the entire DPA area is attached herewith as <b>Annexure VI</b> . Further, DPA also uploaded the said Environmental statement in Form V in the website <a href="http://www.deendayalport.gov.in">www.deendayalport.gov.in</a> .
16	The above stipulations would be enforced among others under the provisions of Water (Prevention and Control of Pollution) Act 1974, the Air (Prevention and Control of Pollution) Act 1981, the Environment (Protection) Act, 1986, the Public liability (Insurance) Act, 1991 and EIA Notification 1994, including the amendments and rules made thereafter	<p>DPA has obtained consolidated consent and authorization vide GPCB (Consent Order no-AWH-110594 dated of issue-8/12/2020, with a validity period upto 21/7/2025)– Detailed Order issued by the GPCB vide outward no. 581914 dated 22/1/2021 &amp; subsequently, issued Correction in CC&amp;A order vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/588116 dated 9/4/2021.</p> <p>For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&amp;CC, Gol, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as <b>Annexure IV</b>.</p>

		Public Liability Insurance is renewed time to time as required. The Public Liability Insurance has been renewed and is valid till 23/07/2023. The same has already been communicated with the last compliance report submitted.
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# **Annexure -I**

**Annexure 1****COMPLIANCE REPORT (up to May, 2023)**

**Subject:** Compliance of conditions stipulated in CRZ recommendations issued by GCZMA for the proposal "Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Authority (Erstwhile: Deendayal Port Trust) at Gandhidham, Kutch, Gujarat".

**CRZ Recommendations: Letter No.** ENV-10-2015-248-E (T - Cell) dated 29/6/2016 of Director (Environment) & Member Secretary, GCZMA, Forest & Environment Department, GoG.

<b>Sr. No.</b>	<b>Conditions in CRZ Recommendation Letter</b>	<b>Compliance</b>
	<b>Specific Conditions</b>	
1	The provisions of the CRZ notification of 2011 shall be strictly adhered to by the KPT. No activity in contradiction to the Provisions of the CRZ Notification shall be carried out by the KPT.	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed.</p> <p>For project at Sr. no. 1, no construction activity started yet. However, it is assured that DPA will strictly adhere to the provisions of the CRZ Notification, 2011 and no activity other than those permissible in Coastal Regulation Notification, 2011 shall be carried out in the CRZ area.</p>
2	All necessary permissions, under various laws/Rules/Notifications issued there under from different Government Departments/agencies shall be obtained by M/s KPT before commencing any enabling activities for proposed project.	DPA obtained CTE/NOC from the GPCB vide No. PC.CCA-KUTGH-1231(2)I GPCB ID 44000 dated 4/12/2017 (Copy of the same has been communicated with the last compliance report submitted). Further, DPA had obtained CTE validity extension (CTE-125870) from GPCB vide Order dated 27/04/2023 with validity up to 15/11/2025 ( <b>Copy enclosed as Annexure A</b> ). MoEF&CC, GoI accorded EC & CRZ Clearance for the subject proposal of DPA dated 18/2/2020.
3	The KPT shall have to ensure that there shall not be any damage to the existing mangrove area.	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed.</p> <p>For Project at Sr. No. 1, construction activity not yet started. However, the letter of Award was issued to the selected bidder i.e. HIPL and execution of concession agreement is under process. Thereafter, construction activity to be started by BOT operator.</p>



		Further, DPA has already prepared a mangrove preservation plan for the entire Kandla area.
4	The KPT shall effectively implement the Mangrove Development, Protection & Management Plan for control of indirect impact on mangrove habitat.	<p>DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005. The copy of the details has already been communicated with the earlier compliance reports submitted.</p> <p>Further, the Study on the present Status, Conservation and Management Plan for Mangroves of Kandla Port region submitted by M/s GUIDE, Bhuj, had already been communicated to the GCZMA &amp; to the MoEF&amp;CC, GoI.</p> <p>In addition to the above, DPA appointed M/s GUIDE, Bhuj for "Regular Monitoring of Mangrove Plantation carried out by DPA" (period 15/9/2017 to 14/9/2018 vide work order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021). The final report submitted by M/s GUIDE, Bhuj, for the years 2017 to 2018 and 2021 to 2022 has already been communicated with the earlier six monthly compliance submitted.</p>
5	The KPT shall have to make a provision that mangrove areas get proper flushing water and free flow of water shall not be obstructed.	It is hereby assured that necessary provisions will be made so that mangrove areas get proper flushing water and free flow of water shall not be obstructed.
6	The KPT shall have to abide by whatever decision taken by the GCZMA for violation of CRZ Notification.	Point noted
7	No dredging, reclamation or any other project related activities shall be carried out in the CRZ area categorized as CRZ I (i) and it shall have to be ensured that the mangrove habitats and other ecologically important and significant areas, if any, in the region are not affected due to any of the project activity.	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed.</p> <p>For Project at Sr. No. 1, construction activity not yet started. However, the letter of Award was issued to the selected bidder i.e. HIPL and execution of concession agreement is under process. Thereafter, construction activity to be started by BOT operator.</p> <p>DPA had authorised the work to M/s GUIDE, Bhuj for continuous monitoring of Marine Ecology since the year 2017 and the final reports are being submitted from time to time to the Regional Office, MoEF&amp;CC, GoI, Gandhinagar &amp;</p>

		<p>to the MoEF&amp;CC, GoI, New Delhi along with six monthly compliance reports submitted.</p> <p>Further, DPA issued a work order to M/s GUIDE vide its letter no. EG/WK/ 4751 /Part (Marine Ecology Monitoring) /11 dated 03/05/2021 for Regular monitoring of Marine Ecology in and around Deendayal Port Authority (Erstwhile Deendayal Port Trust) and continuous Monitoring Program covering all seasons on various aspects of the Coastal Environs for the period 2021-24. The copy of the final report for the year 2021-22 has already been communicated with the last compliance report submitted vide letter dated 06/07/2022. The second season report for the year 2022-2023 submitted is attached herewith as <b>Annexure B</b>.</p>
8	The KPT shall participate financially in installing and operating the Vessel Traffic Management System in the Gulf of Kachchh and shall also take the lead in preparing and operational sing and regularly updating it after getting it vetted by the Indian Coast Guard.	Deendayal Port Authority had already contributed Rs. 41.25 crores for installing and operating the VTMS in the Gulf of Kachchh.
9	The KPT shall strictly ensure that no creeks or rivers are blocked due to any activity at Kandla.	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed.</p> <p>For Project at Sr. No. 1, construction activity not yet started. However, the letter of Award was issued to the selected bidder i.e. HIPL and execution of concession agreement is under process. Thereafter, construction activity to be started by BOT operator.</p>
10	Mangrove plantation in an area of 50 ha. Shall be carried out by the KPT within 2 years in time bound manner on Gujarat coastline either within or outside the Kandla port Trust area and six monthly compliance reports along with the satellite images shall be submitted to the Ministry of Environment and Forest as well as to this Department without fail.	<p>As per the directions of the GCZMA and MoEF&amp;CC, GoI, till date, DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005, which includes 50 Hectares mangrove plantation as per stipulated condition.</p> <p>Further, DPA appointed M/s GUIDE, Bhuj for "Regular Monitoring of Mangrove Plantation carried out by DPA" (period 15/9/2017 to 14/9/2018 vide work order dated 1/9/2017 and 24/5/2021 to 23/5/2022 vide work order dated 3/5/2021). The final report submitted by M/s GUIDE, Bhuj, for the years 2017 to 2018 and 2021 to 2022 have already been submitted in the six monthly compliance communicated vide letter 06/07/2022.</p>

11	No activities other than those permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.	The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. For Project at Sr. No. 1, construction activity not yet started. However, no activities other than those permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.
12	No ground water shall be tapped for any purpose during the proposed expansion modernization activities.	Water requirements will be met through procurement from GWSSB or private tankers. It is hereby assured that no groundwater shall be tapped.
13	All necessary permissions from different Government Departments / agencies shall be obtained by the KPT before commencing the expansion activities.	DPA has already obtained the necessary Environmental & CRZ Clearance for three project activities dated 18/2/2020. Further, Consent to Establish from GPCB had already been obtained from GPCB (CTE – 89537) vide no. PC/CCA-KUTCH-1231 (2)/GPCB ID 44000/429717 dated 4/12/2017. Further, DPA had obtained CTE validity extension (CTE-125870) from GPCB vide Order dated 27/04/2023 with validity up to 15/11/2025 ( <b>Copy enclosed as Annexure A</b> ).
14	No effluent or sewage shall be discharged into sea/creek or in the CRZ area and it shall be treated to conform to the norms prescribed by the GPCB and would be reused /recycled within the plant premises.	DPA already has a Sewage Treatment Plant capacity of 1.5 MLD. The treated wastewater is utilized for plantation/gardening purposes. Further, BOT Operator will provide necessary arrangements for a sewage treatment facility.
15	All the recommendations and suggestion given by the Mantec Consultants Pvt. Ltd. in their Comprehensive Environment Impact Assessment report for conservation / protection and betterment of environment shall be implemented strictly by the KPT.	DPA has installed Mist Canon at the Port area to minimize the dust. Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done.  For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as <b>Annexure C</b> .  For ship waste management, DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" and "Dry Solid Waste (Non- Hazardous)" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow

		<p>DG Shipping circulars regarding the reception facilities at Swachch Sagar portal.</p> <p>Further, DPA has appointed GEMI, Gandhinagar for the work of "Preparation of Plan for Management of Plastic Wastes, Solid Waste, including C&amp;D waste, E-waste, Hazardous waste, including Biomedical and Non-Hazardous Waste in the Deendayal Port Authority" vide Work Order dated 24/01/2023. The work is in progress.</p> <p>DPA assigned work to M/s GUIDE, Bhuj, for regular monitoring of Marine Ecology since the year 2017 (From 2017 – 2021), and final reports of the same are being submitted regularly to the Regional Office, MoEF&amp;CC, GoI, Gandhinagar as well as to the MoEF&amp;CC, GoI, New Delhi along with compliance reports submitted.</p> <p>Further, it is to submit that DPA issued a work order to M/s GUIDE vide its letter no. EG/WK/ 4751 /Part (Marine Ecology Monitoring) /11 dated 03/05/2021 for Regular monitoring of Marine Ecology in and around Deendayal Port Authority (Erstwhile Deendayal Port Trust) and continuous Monitoring Program covering all seasons on various aspects of the Coastal Environs for the period 2021-24. The copy of the final report for the year 2021-22 has already been communicated with the last compliance report submitted vide letter dated 06/07/2022. The second season report for the year 2022-2023 submitted is attached herewith as <b>Annexure B.</b></p> <p>As already informed, DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares). The work is completed.</p> <p>Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The final report submitted by GUIDE, Bhuj is attached herewith as <b>Annexure D.</b></p> <p>For dredged material management, DPA has been assigning work to M/s GUIDE, Bhuj for analysis of dredged material since the year 2017 and the reports are being submitted from time to time along with compliance reports submitted.</p>
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16	The construction and operational activities shall be carried out in such a way that there is no negative impact on mangroves and other coastal /marine habitats. The construction activities and dredging shall be carried out only under the constant supervision and guidelines of the Institute of National repute like NIOT.	<p>The Projects at Sr. No. 2 &amp; 3 of the EC &amp; CRZ Clearance have already been completed.</p> <p>For Project at Sr. No. 1, construction activity not yet started. However, the letter of Award was issued to the selected bidder i.e. HIPL and execution of concession agreement is under process. Thereafter, construction activity to be started by BOT operator.</p> <p>Further, DPA has already prepared a mangrove preservation plan for the entire Kandla area.</p>
17	The KPT shall contribute financially for any common study or project that may be proposed by this Department for environmental management / conservation / improvement for the Gulf of Kutch.	Point noted.
18	The construction debris and / or any other of waste shall not be disposed of into the sea, creek or the CRZ areas. The debris shall be removed from the construction site immediately after the construction is over.	<p>For Project at Sr. No. 1, construction activity not yet started. However, the construction debris and/ or any other waste will not be disposed of into the sea and the debris will be removed from the construction site after construction is over.</p> <p>Further, it is relevant to mention here that, DPA had already issued general circular vide dated 3/9/2019 regarding Construction and Demolition Waste Management for strict implementation in DPA (Copy has already been communicated with the last compliance report submitted).</p>

19	The construction camps shall be located outside the CRZ area and the construction labour shall be provided with the necessary amenities, including sanitation, water supply and fuel and it shall be ensured that the environmental conditions are not deteriorated by the construction labours.	For Project at Sr. No. 1, construction activity yet not started. However, construction camps with necessary amenities will be located in the already nearby developed areas. Further, due care shall be taken so that the environmental conditions are not deteriorated by the construction labours.
20	The KPT shall regularly updates its Local Oil Spill Contingency and Disaster management Plan in accordance with the National Oil Spill and Disaster Contingency Plan and shall submit the same to the MoEF, GoI and this department after having it vetted through the Indian Coast Guard.	Point noted. <ul style="list-style-type: none"> <li>▪ Deendayal Port already has an updated Disaster Management Plan (A copy of the Plan has already been submitted with the earlier compliances).</li> <li>▪ Further, the Local Oil Spill Contingency Plan is already available with Deendayal Port Authority.</li> <li>▪ DPA has also executed MOU with Oil Companies, i.e., IOCL, HPCL, BPCL etc., for combating the Oil Spill at Kandla</li> </ul>
21	The KPT shall bear the cost of the external agency that may be appointed by this Department for supervision/monitoring of proposed activities and the environmental impacts of the proposed activities.	Agreed with the condition
22	The KPT shall take up massive greenbelt development activities in and around Kandla and also within the KPT limits.	<p>DPA has planted about one lakhs trees in roadside dividers, colony areas at Kandla and Gopalpuri, in the greenbelt area of Gandhidham &amp; Adipur Township, Sewage Treatment Plants at Gopalpuri &amp; Kandla and extensive green belt development plans initiated at different locations in Township areas.</p> <p>DPA entrusted work of greenbelt development in and around the Port area to the Forest Department, Gujarat, at the cost of Rs. 352lakhs (Area 32 hectares), and the work is completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The final report submitted by GUIDE, Bhuj is attached herewith as <b>Annexure D</b>.</p> <p>Further, DPA assigned work to GUIDE, Bhuj vide work order dated 23/06/2023 for "Green belt development in Deendayal Port Authority and its</p>

		Surrounding Areas(Phase II) (10000 plants). The work is in progress.
23	The KPT shall have to contribute financially for talking up the socio-economic upliftment activities in this region in construction with the Forest and Environment Department and the District Collector/District Development Officer.	Already CSR works are being attended to by DPA. The details of CSR activities undertaken/to be undertaken by DPA are placed in <b><u>Annexure F.</u></b>
24	A separate budget shall be earmarked for environmental management and socioeconomic activities and details there of shall be furnished to this Department as well as the MoEF, GOI. The details with respect to the expenditure from this budget head shall also be furnished.	DPA has already kept Rs. 274 lakhs in B.E. 2023-24 under the scheme "Environmental Services & Clearance thereof".
25	A separate environmental management cell with qualified personnel shall be created for environmental monitoring and management during construction and operational phases of the project.	<p>DPA is already having Environment Management cell. Further, DPA has also appointed expert agency for providing Environmental Experts from time to time. Recently, DPA appointed M/s Precitech Laboratories, Vapi for providing Environmental Experts vide work order dated 5/2/2021. In addition, it is relevant to submit here that, DPA has appointed Manager (Environment) on contractual basis for the period of 3 years and further extendable to 2 years (Copy of the details has already been communicated with the last compliance report submitted).</p> <p>Further, for monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&amp;CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as <b><u>Annexure C.</u></b></p>
26	An Environmental reports indicating the changes, if any, with respect to the baseline environmental quality in the coastal and marine environment shall be submitted every year by the KPT to this Department as well as to the MoEF&CC,GOI.	For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order

		<p>dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as <b>Annexure C</b>.</p> <p>DPA has been submitting the environmental monitoring report along with the six-monthly compliance report to IRO, MoEF&amp;CC, GoI.</p>
27	The KPT shall have to contribute financially to support the National Green Corps Scheme being implemented in Gujarat by the GEER Foundation, Gandhinagar, in construction with Forests and Environment Department.	Agreed with the condition.
28	A six monthly reports on compliance of the conditions mentioned in this letter shall have to be furnished by the KPT on regular basis to this department/MoEF, GOI.	DPA has been regularly submitting six monthly compliance reports of the stipulated conditions to GCZMA and the Regional Office, MoEF&CC, GoI.
29	Any other condition that may be stipulated by this department from time to time for environmental protection/management purpose shall also have to be complied with by the KPT.	Agreed with the condition.



# **Annexure -II**

## CSR Activities at Decadavul Port Trust

## Details of CSR

Sr. No	Year	Board Resolution For Budget Provision	Board Approved Budget Provision	Board Resolution for approval of the CSR activities	Board Approved Amount For CSR Activities	Actual exp. upto Nov'20 (Rs. In Lakhs)	Net balance (Rs. In Lakhs)	Remarks
1	2	3	4	5	6	7	6-7	
1	2011-2012	369 of 28.03.2012	3.00 Cr					
2	2012-2013	17 of 31.05.2012	4.00 Cr					
3	2013-2014	99 of 30.09.2013	6.43 Cr	64 of 30.08.2012	564.00 Lakh	564.00	Nil	Works completed
4	2014-2015	322 of 21.11.2014	1.07 Cr	20 of 16.04.2015	236.22 Lakh	188.18	8.04	Works in progress
5	2015-2016	151 of 12.02.2016	1.50 Cr	48 of 12.08.2016	28.00 Lakh	5.00	23.00	Works in progress
6	2016-2017	138 of 06.01.2017	2.60 Cr	52 of 2.8.2017	140.30 Lakh	146.00	-5.70	Works completed
7	2017-2018	41 of 2.08.2017	7.02 Cr	15 of 04.05.2018	155.10 Lakh	115.37	39.73	Works in progress
8	2018-19	51 of 07.08.2019	6.70 Cr	111 of 4.12.2018	154.90 Lakh	50.50	104.40	Works in progress
					1278.52 Lakh	1069.05	209.47	
9	2019-20	58 of 10.10.2019	5.49 Cr	92 of 06.12.2019	1838.57 Lakh	Nil		MoS approval is awaited
		Total	37.81 Cr		3117.09 Lakh	Spent in PM Fund for COVID-19-800 Lakhs		

Year-wise details of CSR works undertaken by DPT during 2012 – 13 to 2019 – 20 are given in **Tables 7.3a, 7.3b, 7.3c, 7.3d, 7.3e, 7.3f and 7.3g.**

**Table 7.3a: CSR Works Undertaken by DPT during 2011-12 and 2012 – 13**

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	Repair of road from Dr. Baba Saheb Ambedkar Circle to NH 8A (via Ganesh Nagar)	518
2	Repair of road from S.T. Bus Stand to Sunderpuri Cross Road via Collector Road	
3	Repair of road from NH 8A Railway Crossing to Maninagar (along railway track)	
4	Repair of road from Khanna Market Road (Collector Road) to Green Palace Hotel	
5	Construction of internal roads at “Shri Ram” Harijan Co-operative Housing Society (near Kidana)	
6	Construction of cremation ground and graveyard with other facilities at Vadinar	19.44
7	Providing cement concrete internal roads in Village Vadinar Stage - I	16.16
8	Approach road provided for developing tourism at Village Veera near Harsidhi Mata Temple	4.65
9	Water tank along with R.O. provided near developing tourism area	0.30
10	Creating facilities of flooring and steps surrounding lake to stop soil erosion and attract tourists at Village Veera.	4.80
	<b>TOTAL</b>	<b>563.35</b>

**Table 7.3b: CSR Works Undertaken by DPT during 2014-15**

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	Construction of community hall – cum – school at Maheshwari Nagar, Gandhidham	51.90
2	Renovation of “Muktidham” (cremation ground) at Kandla	10.65
3	Sunderpuri – 1 Valmiki Community Hall	5.00
4	Sunderpuri – 2 Valmiki Community Hall	5.00
5	Ganeshnagar Community Hall	10.00
6	Jagjivan Maheshwari Community Hall	10.00
7	Various works of road at Sapnanagar	99.19
8	Construction of compound wall in the dam of Jogninar Village	14.48
	<b>TOTAL</b>	<b>206.22</b>

**Table 7.3c: CSR Works Undertaken by DPT during 2015-16**

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	Construction of Bus Stand at Vadinar Village	10.00
2	Providing drainage system at Vadinar Village	6.00
3	Providing and laying of water supply lines in Vadinar Village	6.00
4	Road from Gandhidham Post Office to Merchantile Marine Department Office along with toilet facilities	60.00
5	Construction of toilets for girls / women at Khari Rohar, Village	3.00
6	Construction of toilets for girls at Mathak Primary School, Mathak, Village	3.00
	<b>TOTAL</b>	<b>88.00</b>

**Table 7.3d: CSR Works Approved by DPT Board for 2016-17**

Sl. No.	Name of Work	Cost (Rs. In lakhs)
1	RCC community hall at Harsidhi Mata Temple, Village Veera, Anjar Taluka	19.00
2	Fabricated Community Hall at Sanghad Village, Anjar Taluka	21.00
3	CSR Works for Shri Maheshwari Meghavad Samaj, Gandhidham at graveyard behind Redison Hotel	8.00
4	CSR Works for Shri Dhanraj Matiyadev Mukti Dham, Sector 14, Rotary Nagar, Gandhidham	30.50
5	CSR Works for Nirvasit Harijan Co-operative Housing Society, Gandhidham Health Cum Education Centre	41.00
6	CSR Works for Shri Rotary Nagar Primary School, Gandhidham	2.80
7	CSR Works at NU-4, NU-10(B) Sapnanagar & Saktinagar, Golden Jubilee Park at Gandhidham	18.00
	<b>TOTAL</b>	<b>140.30</b>

**Table 7.3e: CSR Works Approved for 2017-18**

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
1	CSR Works at Shri Ganesh Nagar High School, Gandhidham	Principal, Shri Ganesh Nagar Govt High School, Gandhidham	38.30 Lakhs
2	CSR Works for MOLANA AZAD Primary School, Kandla	Shri M L Bellani, Trustee, DPT, Shri Kandla Port Education Society, New Kandla	7.00 Lakhs
3	Grant financial contribution for facility of Army Cantonment for 50 nos. air coolers at Kutch Border Area	Shri Vinod L Chavda, MP	15 Lakhs
4	40% of the estimated cost of providing drainage lines at Tuna and Vandi villages under Swachh Bharat Abhiyan.	Shri Sarpanch, Tuna Village & Vandi village & Shri M L Bellani, Trustee, DPT	<b>Rs. 39.80 Lakhs</b> <i>Approx. estimated Cost Rs.99.50 Lakhs, of which 40% to be contributed by DPT.</i>
5	CSR works for S.H.N. Academy English School (managed by Indian Inst. Of Sindhology – Bharati Sindhu Vidyapeeth), Adipur	Director, S.H.N Academy English School	<b>40 Lakhs</b>
6	Construction of internal roads at Bhaktinagar Society, Kidana	Smt Maltiben Maheshwari, MLA	<b>15 Lakh</b>
	<b>TOTAL</b>		<b>155.10</b>

**Table 7.3f: CSR Works Approved for 2018-19**

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
1	CSR work to Donate 100 Nos of Computers to Daughters of Martyred Soldiers in the country under the "BETI BACHAO BETI PADHAO" program by Atharva Foundation, Mumbai	Chairman, Atharva Foundation, Mumbai	<b>24.00</b>
2	CSR work to Donate ONE (40 Seater) School Bus for Deaf Children Students for the Institute of Mata Lachmi Rotary Society, Adipur	Mata Lachmi Rotary Society, Adipur	<b>18.00</b>
3	CSR work to Providing One R.O Plant with Cooler at PanchyatPrathmikSala, Gadpadar Village for the ANARDE Foundation, Kandla&Gandhidham Center.	Dist. Rural Development Officer, Annarde Foundation-Kandla & Gandhidham	<b>1.50</b>
4	CSR work for Providing Drainage Line at MeghparBorichi village, AnjarTaluka	Shri Vasanbhai Ahir, MLA, Gujarat Govt	<b>25.00</b>
5	CSR work for Construction of Health Centre at Kidana Village	Shri Vinod L Chavda, MP	<b>13.00</b>
6	CSR work to provide 4 Nos. of Big Dust Bin for MithiRoharJuth Gram Panchayat.	Shri Sarapanch, Mithi RoharJuth Gram Panchayat	<b>3.40</b>

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
7	CSR work for Renovation & construction of shed at CharanSamaj, Gandhidham –Adipur.	Shri Vinod L Chavda, MP	10.00
8	CSR Work for Renovation/Repairing of Ceiling of School Building at A. P Vidhyalay, Kandla.	Smt Maltiben K. Maheshwary, MP, Gandhidham.	10.00
9	CSR work for Construction of Over Head Tank & Providing 10 Nos of Computers (for students) of NavjivanViklangSevashray, Bhachau, Kutch	Shri Jitendra Joshi, Founder Secretary, Shri Navjivan Viklang Sevashray, Bhachau, Kutch	9.50
10	CSR work to Provide Books & Tuition fees for Educational facilities to weaker section children of ValmikiSamaj, Kutch.	Shri Manohar Jala, Chairman of "National Commission of Safai Karamcharis"	2.00
11	CSR work to provide Water Purifier & Cooler for the ST. Joseph's Hospital, Gandhidham	Smt. Maltiben K Mahewari, MLA, Gandhidham	1.50
12	CSR work for Construction of Second Floor (Phase – I) for Training Centre of "GarbhSanskran Kendra" "Samarth Bharat Abhiyan" of Kutch Kalyan Sangh, Gandhidham	Shri Vinod L Chavda, MP, Kutch	37.00
<b>TOTAL</b>			<b>154.90</b>

**Table 7.3g: CSR works approved for the year 2019-20 (approval from Ministry of Shipping still awaited)**

Sl. No.	Name of Work	Proposal Received from / / Name of Organization / N.G.O	Cost (Rs. In lakhs)
1	CSR activities for Providing Drainage line at Nani Nagalpar village.	Sarpanch of Village:-Nani Nagalpar, Taluk: Anjar.	3.00
2	CSR activities for Development of ANGANWADI Building at School no- 12 at Ward no 3 & 6 at Anjar.	Shri Vasanhbai Ahir, MLA	7.00
3	CSR activities for Improving the facilities of Garden at Sapna Nagar(NU-4)& (NU-10 B), Gandhidham.	Shri K P Maheshwari, Resident Sapnanagar, Gandhidham	18.00
4	CSR activities for Providing of Plastic Shredding Machine to Mirror Charitable Trust, Gandhidham.	Mirror Charitable Trust, Gandhidham	4.75
5	CSR activities for development of School premises of Shri Guru Nanak Edu. Society, Gim.	Shri Guru Nanak Education Society, Gandhidham.	30.00
6	CSR activities for the improvement of the facilities at St. Joseph Hospital & Shantisadan at Gandhidham	St. Joseph Hospital Trust, Gandhidham	20.00
7	CSR activities for the improvement of the facilities at SVP (SardarValabhbbhai Patel ) Multipurpose Hall at Gandhidham	Request from MarwadiYuva Munch & UNION Gandhidham	500.00
8	Consideration of Expenditure for running of St Ann's High School at Vadinar of last 5 years 2014 to 2019 under CSR.	Proposal from COM, OOT Vadinar, DPT	825.00
9	CSR activities for development of school premises of Shri Adipur Group Kanya Sala no-1 at Adipur	Principal, Shri Adipur Group KanyaSala, Adipur	6.50
10	CSR activities for development of school premises of Shri Jagjivan Nagar Panchyat Prathmiksala, Gandhidham.	Principal, Shri Jagjivan Nagar Panchyat Prathmiksala, Gandhidham.	16.50
11	CSR activities for development of school premises of Ganeshnagar Government high school, Gandhidham.	Shri Vinod L Chavda, MP, Kutch	9.00
12	CSR activities for improving greenery, increase carbon sequestration and beat Pollution at Kandla, DPT reg.	Work awarded to Forest Department, Bhuj	352.32
13	CSR activities for providing infrastructures facilities at "Bhiratna Sarmas Kanya Chhatralaya" under the Trust of Samaj Nav- Nirman at Mirjapur highway, Ta Bhuj.	SamajNav- Nirman at Mirjapur highway, Ta Bhuj.	46.50
<b>TOTAL</b>			<b>1838.57</b>

**List of CSR applications received from various NGOs , Organizations , Village Sharpanchs etc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
1	CSR activities for the development of gardening at Sector -5 , Gim	Shri Sarvodaya Co-Operative Housing Society Ltd	<b>Appx Cost – Rs 25.00 Lakhs</b>  <b>Cost for –</b> Comp wall, Benches, Plantation, walkway, other facilities  (Land is reserved for Garden development only since from 50 years)
2	CSR activities for providing various facilities in SHRI GANESHNAGAR GOVT HIGHSCHOOL, GANDHIDHAM	Principal of School	<b>Appx cost –Rs 20.00 Lakhs</b>  (Two times CSR works carried out at school by DPT)
3	CSR activities for the VadhiyarVankarSamajvaadi, NaviSunderpuriGim	SmtMaltiben K Maheswari, MLA	<b>Appx Cost Rs 6.00 Lakhs</b>  Cost for Const. of Comp Wall
4	CSR activities for Construction work of Cabin at Oslo Area- Gim	SmtMaltiben& Shri VinadChavda	Cost not mentioned.
5	CSR activities & Land requirement forAkhil Kutch SamastaMeghvanshiGurjarmeghwal Charitable Trust ,Gim.	Shri Akhil Kutch SamastaMeghvanshiGurjarmeghwal Charitable Trust. Shri Dharmendra R Gohil	Cost Not mentioned.  (demand of Land for development of SAMAJ VADI in Gandhidham)
6	CSR Activities for providing Water supply pipe line, Play ground and sports equipment, electric facilities, drinking water facilities for poor people & Fishermen at VANDI Village.	Shri R RKhambhra, PRO , Collector Office, Bhuj.	<b>Appx Cost Rs 51.00 Lakhs</b>  (Last year also applied by village Sarpanch ) &  Recommended by Shri VASANBHAI AHIR, MLA, Shri V L Chavda, MP)
7	CSR activities for the Tuna village,	Sarpanch, Tuna village	<b>Appx Cost Rs. 25 Lakhs</b> <b>Cost for :-</b>

**List of CSR applications received from various NGOs , Organizations , Village Sharpnachs etc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
	Ta -Gim		2 No Fab shed 20'x20'x1250= 10 Lakh 2 Nos of Agnawadi =10 Lakh Fab shed for school=5 Lakh
8	CSR activities for the Global Vision India Foundation, Gim	Global vision India Foundation, G'dham	Requirement of Land –OR- Old building at Gandhidham for foundation of welfare activities.
9	CSR activities for the UNITED ORPHANAGE FOR THE DISABLED, TAMIL NADU	UNITED ORPHANAGE FOR THE DISABLED, TAMIL NADU	<b>Cost Rs 25,000.00</b>  (Winter sweaters for children)
10	CSR activities for the Garden Development on already bounded area with Compound wall near Plot no 448 Sector-1/A, Gandhidham.	Residents, near Plot no 448, Sector-1/A, Gim.	<b>AppxCost Rs 20.00 Lakhs</b>  (Requirement to provide benches, drinking water facility, plantation, lightings & walkways in side bounded area)
11	CSR activities for donation of Land for the Shri SUNDARPUI Govt Primary School, Gim	SmtMalti ben Maheshwari, MLA	(request for Land Requirement)
12	CSR activities for Extension of Adarsh Primary School building, Adipur	GandhidhamMatri Mandal, English Medium School, Adipur	<b>Appx Cost Rs. 40.00 Lakhs</b> (Construction for 4 Rooms extension)  (Trust registered under Societies Registration Act XXI -1860, Reg No F-42 dtd 23.9.1965. Land belong to Trust)
13	CSR Activities for providing HD projector for KANYA MAHA VIDYALAYA, Adipur	Principal, KANYA MAHA VIDYALAYA, Adipur	<b>Cost Rs 1.50 Lakhs</b>  (School Managed by G'dhamMaitry Mandal, Adipur)

**List of CSR applications received from various NGOs , Organizations , Village Sharpnchs etc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
14	CSR activities for DONATION various Medical Equipment for the Hospital of Gandhidham Jain SevaSamiti, Adipur	Gandhidham Jain SevaSamiti, Adipur	<b>Cost for :-</b> 1) Fresenius Haemodialysis Machine Rs 38.00 Lakh 2) Maltislice Helical CT Scanner- Rs 52.00 Lakhs 3) Others Rs 54.00 Lakhs <b>(Total Appx Cost Rs 144 Lakhs)</b>
15	CSR activities for SHRI VIDI JUTH GRAM PANCHAYAT, Vidi, Anjar	Sarpanch, Vidi Gram	<b>Appx Cost Rs 30.00 Lakhs</b>  Cost for- Drainage , Garbage vehicle, and Cattle shed  (Already applied earlier at Sr-5/12)
16	CSR activities for SOS CHILDREN'S VILLAGES INDIA, Madhapar, Bhuj	Director, SOS Children's Village of India-Bhuj	<b>Appx Cost Rs 31.00 Lakhs</b>  (request for Financial support towards parentless and abandoned Children Education support located at Bhuj ) & support to women working in SOS.
17	Gujarat Biodiversity Board, Gandhinagar invites to involved National & Global endeavour of conservation of biodiversity by creating financial partnership with GBB under CSR programme of expenditure to be incurred 187 Lakh.	GUJARAT BIODIVERSITY BOARD, GANDHINAGAR	<b>Requirement- Financial Support from DPT for AppxRs 1.88 Cr.</b>  (Cost for various meetings, collection of primary data from villagers , processing of documentation, printing , TA DA of Technical support & Miscexp for 150 Peoples Biodiversity Register (PBR).



**List of CSR applications received from various NGOs , Organizations , Village Sharpnachs etc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
18	CSR activities for providing furniture & Home appliances for ROJAVANAM TRUST at Madurai.	Shri Arul Kannan, Director	<b>Appx Cost Rs 30 Lakhs</b>  (seeking help to provide facilities to Aged & Homeless people living in Trust and Purchasing of New Ambulance)
19	CSR activities for providing Dialysis Machine for treatment of Kidney patients at "ST JOSEPH'S HOSPITAL TRUST" at Gandhidham.	Sr. Franciline, Administrator of Hospital.	<b>Appx Cost Rs 31.36 Lakhs</b>  (Cost of 5 Nos of Dialysis Machines for treatment of kidney patients)
20	CSR activities for providing facilities in Girls Hostel of Gasturba Gandhi BalikaVidhyalay, Gandhidham.	Shri Vinod L Chavda, MP	<b>Appx cost Rs 30 Lakhs.</b>  (Cost of Comp Wall, Entrance gate, Girls toilets etc)
21	CSR works for providing Oxygen Generator Plant and 45 KV Silent Generator for COVID HOSPITAL at Swami LilashahKutia, Adipur.	Secretary, BHARAT VIKAS PARISHAD, Gandhidham	<b>Appx Cost Rs 80.00 Lakhs</b>  (Facilities for 100 Beds of COVID patient which it to be extend upto 240 Beds)
22	CSR works for providing Two Numbers of Oxygen Concentrator and others medical equipment for the Trust ,Antarjal, Gim.	President SHRI SARV JEEV KALYAN TRUST, ANTARJAL, Gandhidham	<b>Appx Cost Rs21.50 Lakhs</b>  (Facilities to be provided for the treatment of CORONA PATIENTS at their trust.)
23	CSR works for providing Fabricated Shed , Construction of Compound Wall and Land levelling for the Cattle of <b>GauSevaSamiti-Tappar</b> at Gram-Tappar, Ta Anjar.	Shri Vinod Chavda, MP & Presedent , GauSevaSamiti, village Tappar, Ta-Anjar	<b>Appx Cost Rs84 Lakhs</b>  (Facilities to be provided for Cattle shelters at Village.) (Land belongs to Gram-panchayat)
24	CSR works for Construction of Auditorium Hall at RSETI (Rural Self Employment Training Institute) at	Shri Vinod Chavda, MP & Director of RSETI, Bhuj	<b>Cost not mentioned.</b>  (Facilities to be provided

**List of CSR applications received from various NGOs , Organizations , Village Sharpnchs etc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
	Bhujodi-Bhuj.		for the people needs Self-employment activities.)
25	CSR works for Providing of Furniture for the School "SHRI GALPADAR PANCHAYAT PRATHMIC KUMAR GROUP SALA " atGalpadar Village Ta Gim.	Principal, SHRI GALPADAR PANCHAYAT PRATHMIC KUMAR GROUP SALA " atGalpadar Village Ta Gim.	<b>Cost not mentioned.</b>  (Facilities to be provided for the Students of Workers & poor village people who study in the school.)
26	Construction of Shed, hall and Gate for the DADA Bhagwandas Charitable Trust, Adipur. (Sr no -4)	Shri Vinod Chavda, MP & DADA BHAGWANDAS CharitableTrust, Gandhidham	<u>As per CSR Guideline-</u> ➤ Promoting gender equality and empowering women ➤ Eradicating extreme hunger and poverty (Considered shed and hall )  Fab Shelter Shed - 30'x100' x 1250=37.00 Lakh & RCC Hall – 20'x100'x1500=30.00 Lakh  <b>(Appx Cost Rs67.00 Lakhs)</b> Land authority belongs to Trust given by GDA and NOC given by SRC.Doc submitted.
27	CSR work for reconstruction of the Internal Roads of the Sector-9B-C and Sector-10 area in Gandhidham.	President, Shri TejaKangad, The Gandhidham Chamber of Commerce and Industry, Gandhidham.	Cost not mentioned.

**List of CSR applications received from various NGOs , Organizations , Village Sharpanchsetc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
	<b><u>CSR Applications kept pending in last year Agenda:-</u></b>		
27	CSR Activities for providing Water supply pipe line, Play ground and sports equipment, electric facilities, drinking water facilities for poor people & Fishermen at VANDI Village. (Sr no-3)	Sarpanch ,Village-VANDI , Ta- Anjar  (Recommd. By Shri VASANBHAI AHIR, MLA, Shri V L Chavda, MP)	<u>As per CSR Guideline-</u> ➤ Env Sustainability ➤ Eradicating extreme hunger and poverty  (to be Consider for health Center ,Drainage line, Water sump etc activities) <b>(Appx Cost - 51.00 Lakhs )</b>  (Land authorization of Gram Panchayat)
28	Construction of Shed, hall and Gate for the DADA Bhagwandas Charitable Trust, Adipur. (Sr no -4)	DADA BHAGWANDAS CharitableTrust, Gandhidham  (Recommd. By Shri V L Chavda, MP)	<u>As per CSR Guideline-</u> ➤ Promoting gender equality and empowering women ➤ Eradicating extreme hunger and poverty (Considered shed and hall )  Fab Shed - 30'x100' x 1250=37.00 Lakh & RCC Hall – 20'x100'x1500=30.00 Lakh  <b>(Appx Cost Rs 67.00 Lakhs)</b> Land authority belongs to Trust given by GDA and NOC given by SRC. Doc submitted.
29	10 Nos of Computers required for ShirMaheswarinagar Panchayat Girls Primary School, Gandhidham& Boys Group School, Gandhidham. (Sr no-8)	Maheswarinagar Panchayat Primary Kanya Sala, Gandhidham  (Contact no 9913903686)	<b>AppxRs 5.00 Lakhs</b>  <u>As per CSR Guideline-</u> ➤ Promotion of Education (to be consider for 20 Computers)

**List of CSR applications received from various NGOs , Organizations , Village Sharpnchsetc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
			Visited the site. Land belongs to MahewariMeghwadSamaj given by SRC for school purpose, doc are awaited.
30	Construction of Shed and Roof at JeparMatiyadev, shamsanbhumi at Kidana village & Maheswari Community Hall at JuniSundarpuri, Gandhidham. (Sr no-10)	Shri VINOD CHAVDA, MP	<b>AppxRs 15.00 Lakhs</b>  (Land authorization not mentioned)
31	Drainage, road, Dust bins, & shed for Cattle shelters at VIDI Village, Ta –Anjar. (Sr no- 12)	Village- VIDI, Ta: Anjar	<b>AppxRs 30.00 Lakhs</b>  <u>As per CSR Guideline-</u> ➤ Env Sustainability ➤ Eradicating extreme hunger and poverty (Consider for Garbage vehicle & Drainage Cost)
32	Education, Women empowerment and Primary health care services at Kutch area. (Sr no-13)	Light of Life Trust, <b>Mumbai.</b>	Cost not mentioned.
33	Request for Help Divyang persons to employment by providing machineries. (Sr no-14)	Kutch DivyangSangthan, Gandhidham.	Cost not mentioned
34	Construction of 2 <sup>nd</sup> Floor of Shri MaheswariMeghwadSamaj, Gandhidham.  (Sr no-20)	Shri MaheswariMeghwadSamaj, Gandhidham	<b>AppxRs. 15.00 Lakhs</b>  (Visited the site and Land ownership documents awaited) (Name plate of DPT fixed at the Asset)

**List of CSR applications received from various NGOs , Organizations , Village Sharpanchsetc for the FY 2021-22 .**

Sr.No	Name of Scheme	Proposal Received from / Name of Organization / N.G.O	Brief Details
35	Installation of Mini Science Center at Anjar and Gandhidham. (Sr no-21)	STEM Learning Pvt Ltd, Mumbai.	Cost not mentioned.
36	CSR work for Shri Rampar Gram Panchayat. ➤ Wall Plastering for Cattles -7 Lakhs ➤ Shed for Cattel's-15 Lakhs  (Sr no-25)	Shri Sarpanch, Rampar Village.	<b>AppxRs 22.00 Lakhs</b>  (Land authorization of Gram Panchayat and under taking submitted by applicant)
37	CSR activities for the 45,000 Patients over the period of 3 years by "SMILE FOUNDATION", Mumbai.  1. Concept for Nutrition covering 3 years 2. Concept for Mobile Health Unit reaching beneficiaries for 3 years 3. Concept for Vocational Training with NGO (Sr no-29)	Proposal from "SMILE FOUNDATION " Mumbai.	Appx Cost- <b>Rs 539 Lakhs</b> for 3 years
38	Development of Park in Public utility plot in between Block "C" & "D" of Sapna Nagar (NU-4) , Gandhidham (Sr no -31)	Shri RAVI MAHESHWARI, DPT	Land belongs to DPT earmarked for recreational purpose.  (Total Cost – <b>Rs88.75 Lakhs</b> )
39	CSR works for NariJanshsktiVikas Foundation at Gandhidham near Shakti Nagar.  (Sr no-33)	NariJanshsktiVikas Foundation, Ahmedabad	➤ Promoting gender equality and empowering women ➤ Env Sustainability ➤ Under promotion of education  (Consider for Computers with printers, Sewing machine & RO plant <b>Cost Rs 48 Lakhs</b> )

# **Annexure -III**



**Second year Post-Monsoon Report  
October 2022-January 2023**

**Regular Monitoring of Marine Ecology in and  
around the Deendayal Port Trust and  
Continuous Monitoring Programme**



**Submitted to**  
**Deendayal Port Authority**  
Administrative Office Building  
Post Box No. 50, Gandhidham (Kachchh)  
Gujarat-370201



**Submitted by**  
**GUJARAT INSTITUTE OF DESERT ECOLOGY**  
P.B. No. 83, Mundra Road, Opp. Changleshwar Temple  
Bhuj-Kachchh, Gujarat-370001

**March 2023**

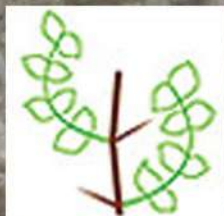


**Second year Post-Monsoon Report  
October 2022-January 2023**

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around the Deendayal Port Trust and  
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P.B. No. 83, Mundra Road, Opp. Changleshwar Temple  
Bhuj-Kachchh, Gujarat-370001

**March 2023**



**Project Coordinator**  
**Dr. V. Vijay Kumar, Director**

**Principal Investigator**

<b>Dr. Durga Prasad Behera</b>	Project Scientist	Phytoplankton & Zooplankton, Physico-chemical parameters, Marine Fisheries, Intertidal and Subtidal benthos
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<b>Dr. Dhara Dixit</b>	Project Scientist	Halophytes, Sediment

**Team members**

<b>Mr. Dayesh Parmar</b>	Project officer	GIS & Remote sensing
<b>Ms. Pallavi V. Joshi</b>	Junior Research Fellow	Phytoplankton and Zooplankton, Water & Sediment

Post-monsoon (October2022 to January 2023)

S. No	Components of the Study	Remarks
1	MoEF & CC sanction letter and details	(i). EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/12/16 Dev. Of 7 integrated facilities – specific condition no. xviii. (ii). EC & CRZ clearance granted by the MoEF &CC, GoI dated 18/2/2020 Dev. Remaining 3 integrated facilities – specific condition no. xxiii. (iii). EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 -specific condition no. xv. (iv). EC & CRZ clearance granted by the MoEF &CC, GoI dated 20/11/20 – Creation of waterfront facilities (OJ 8 to 11- Para VIII Marine Ecology, specific condition iv.
2	Deendayal Port letter sanctioning the project	DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/11 date 03.05.2021
3	Duration of the project	Three years-from 24.05.2021 to 23.05.2024
4	Period of the survey carried	Second Year Post-Monsoon season (October 2022 to January 2023)
5	Survey area within the port limit	All major and minor creek systems from Tuna to Surajbari and Vira coastal area.
6	Number of sampling locations	Fifteen sampling locations in and around the DPA port jurisdiction
7	<b>Components of the report</b>	
7a	Mangroves	The overall average density was 3011 trees/ha of <i>A. marina</i> during Post-monsoon 2022-2023. Among the 12 sampling sites, the mean plant density was maximum at Tuna creek (4371/ ha), followed by Jangi creek (3210/ Ha). Considering the sampling sites individually the highest tree density was reported at S12 in the Tuna creek area (6515/Ha). The lowest average tree density of individual sites was reported in S-5 (1491 trees/ Ha) sampling site located at Phang creek. In terms of creeks, the lowest average density was recorded at Kharo creek in which only one sampling site is located S-7 (2291/ha.
7b	Mudflats	The highest TOC value (0.87%) was recorded at station S-6 followed by S-10 site. The lowest TOC value was reported at S-1. It is observed that TOC values varied significantly among the sampling stations, which means that organic carbon depends on the living life forms and the type of life forms in the mudflats.

## Snapshot

<b>7c</b>	Zooplankton	The zooplankton identified from the 15 stations falls under 10 phyla and 45 genera which are described 15 groups. The phylum Arthropoda was the predominant represented with 30 genera, including copepods, crabs, shrimps and their larvae. The highest percentage was due to the calanoid copepods (40.4%) followed by Decapoda (16.4%) and Gastropoda (6.4%).
<b>7d</b>	Phytoplankton	The generic number recorded during the monsoon period ranged from 22 to 26 at the sampling stations with remarkable variations concerning the composition. The maximum number (26 genera) was observed at S-3 & S-9, and the minimum from S-8 represented 22 genera. The percentage composition of the various groups varied from 1 % to 61 %, of which the centrales and pennales are the dominant, constituting 61% and 38%, respectively.
<b>7e</b>	Intertidal Fauna	The intertidal fauna and the species diversity of the invertebrates showed the maximum for phylum Mollusca (8 species) followed by Arthropoda (6 species). The phylum Chordata was represented by one species. The overall percentage composition of the four groups of intertidal fauna at the 15 sites revealed the Arthropoda (31.6%), Mollusca (42.1%), Nematoda, Nemertea and Chordata ( each 5.3%).
<b>7f</b>	Sub-tidal Macrobenthos	The DPA port environment revealed that Mollusca (13 species) and Annelida (6 species) were the major constituents, followed by Arthropoda (2 species) and Cnidaria (1 species). The phylum Mollusca constituted the maximum (59%) share of the subtidal Fauna, followed by Annelida (27%), least number of percentage was contributed by Cnidaria (5%).
<b>7g</b>	Seaweeds	No seaweed is reported in the DPA area.
<b>7h</b>	Seagrass	No seagrass is reported in the DPA area.
<b>7i</b>	Marine reptiles	One species of reptile was recorded from the DPA area.
<b>7j</b>	Marine mammals	Two species of marine mammal was recorded from the DPA area.
<b>7k</b>	Halophytes	Four halophytes were recorded along the selected Deendayal Port Authority sites during the Monsoon sampling; among the halophyte species recorded, <i>Salicornia brachiata</i> alone was found in the 3 sampling locations. The percentage of <i>Salicornia brachiata</i> was found to be the highest at stations S-11 (100%) and the lowest at S-3.
<b>7l</b>	Avifauna	A total of 79 species belonging to 9 orders, 32 families and 59 genera were recorded from the coastal area of Deendayal Port Authority during the Monsoon season study.

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# **1. Introduction**

Deendayal Port is located at the inner end of Gulf of Kachchh on the Kandla creek (22°59'4.93N and longitude 70°13'22.59 E) in the Kachchh district of Gujarat state, operated by Deendayal Port Authority (DPA). Being the India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private participation. Since its formation in the 1950s, the Deendayal Port provides the maritime trade requirements of states such as Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana and Gujarat. Because of its proximity to the Gulf countries, large quantities of crude petroleum are imported through this port. About 35% of the country's total export takes place through the ports of Gujarat in which the Deendayal port has a considerable contribution. Assortments of liquid and dry cargo are being handled at DPA Port. The dry cargo includes fertilizers, iron and steel, food grains, metal products, ores, cement, coal, machinery, sugar, wooden logs, etc. The liquid cargo includes edible oil, crude oil and other petroleum products. Cargo handling has increased from 117.5 MMT to 127 MMT during 2021-2022. Presently, the Port has total 1-16 dry cargo berths for handling dry cargo, 6 oil jetties, and one barge jetty at Bunder basin, dry bulk terminal at Tuna Tekra, barge jetty at Tuna and two SPMs at Vadinar for handling oil. Regular expansion or developmental activities such as the addition of jetties, allied SIPC and ship bunkering facilities are underway in order to cope with the increasing demand for cargo handling during the recent times.

A developmental initiative of this magnitude is going on since past 7 decades, which will have its own environmental repercussions. Being located at the inner end of Gulf of Kachchh, Deendayal Port Authority encompasses a number of fragile marine ecosystems that includes a vast expanse of mangroves, mudflats, creek systems and associated biota. Deendayal Port is a natural harbour located on the eastern bank of North-South trending Kandla creek at an aerial distance of 90 km from the mouth of Gulf of Kachchh. The Port's location is marked by a network of major and minor mangrove lined creek systems with a vast extent of mudflats. Coastal belt in and around the port has an irregular and dissected configuration. Due to its location at the inner end of the Gulf, the tidal amplitude is elevated, experiencing 6.66 m during mean high-water spring (MHWS) and 0.78 m during mean low water spring (MLWS) with MSL of 3.88 m. Commensurate with the increasing tidal amplitude, vast intertidal expanse is present in and around the port environment. Thus, the occurrence of mudflats on the intertidal zone enables mangrove formation to an extensive area. Contrary to the southern coast of Gulf of Kachchh, the coral formations, seaweed and

seagrass beds are absent in the northern coast due to high turbulence induced suspended sediment load in the water column, a factor again induced due to the conical Gulf geomorphology and surging tides towards its inner end.

### **1.1. Rationale of the present study**

The ongoing developmental activities at Deendayal Port Authority has been intended for the following.

- i. The development of 3 remaining integrated facilities (Stage 1) within the existing Port at Kandla which includes development of a container terminal at Tuna off Tekra on BOT base T shaped jetty, construction of port craft jetty and shifting of SNA section of Deendayal port and railway line from NH-8A to Tuna port.
- ii. EC & CRZ clearance granted by the MoEF &CC, GoI dated 18/2/2020 Dev. Remaining 3 integrated facilities – specific condition no. xxiii.
- iii. EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 -specific condition no. xv.
- iv. EC & CRZ clearance granted by the MoEF &CC, GoI dated 20/11/20 – Creation of water front facilities (OJ 8 to 11- Para VIII Marine Ecology,specific condition iv).

As per the environmental clearance requirements to these developmental initiatives, by MoEF & CC, among other conditions, has specified to conduct the continuous monitoring of the coastal environment on various aspects covering the three the seasons. The regular monitoring shall include physico-chemical parameters coupled with biological indices such as mangroves, seagrasses, macrophytes and plankton on a periodic basis during the construction and operation phase of the project. Besides, the monitoring study also includes assessment of Mudflats, Fisheries, and Intertidal fauna including the macrobenthos as components of the management plan. The regular marine ecology monitoring includes Micro, Macro and Mega floral and fauna components of marine biodiversity of the major intertidal ecosystems, the water and sediment characteristics. In accord with MoEF&CC directive, DPA has consigned the project on ‘Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme” to Gujarat Institute of Desert Ecology (GUIDE), Bhuj during May, 2021. Further, Deendayal Port authorities has entrusted Gujarat Institute of Desert Ecology (GUIDE) to continue the study for another three years, i.e., 2021 – 2024. The study covers all the seasons as specified by the specific condition of the Ministry of Environment, Forest and Climate Change

(MoEF&CC). The present study is designed considering the scope of the work given in the EC conditions.

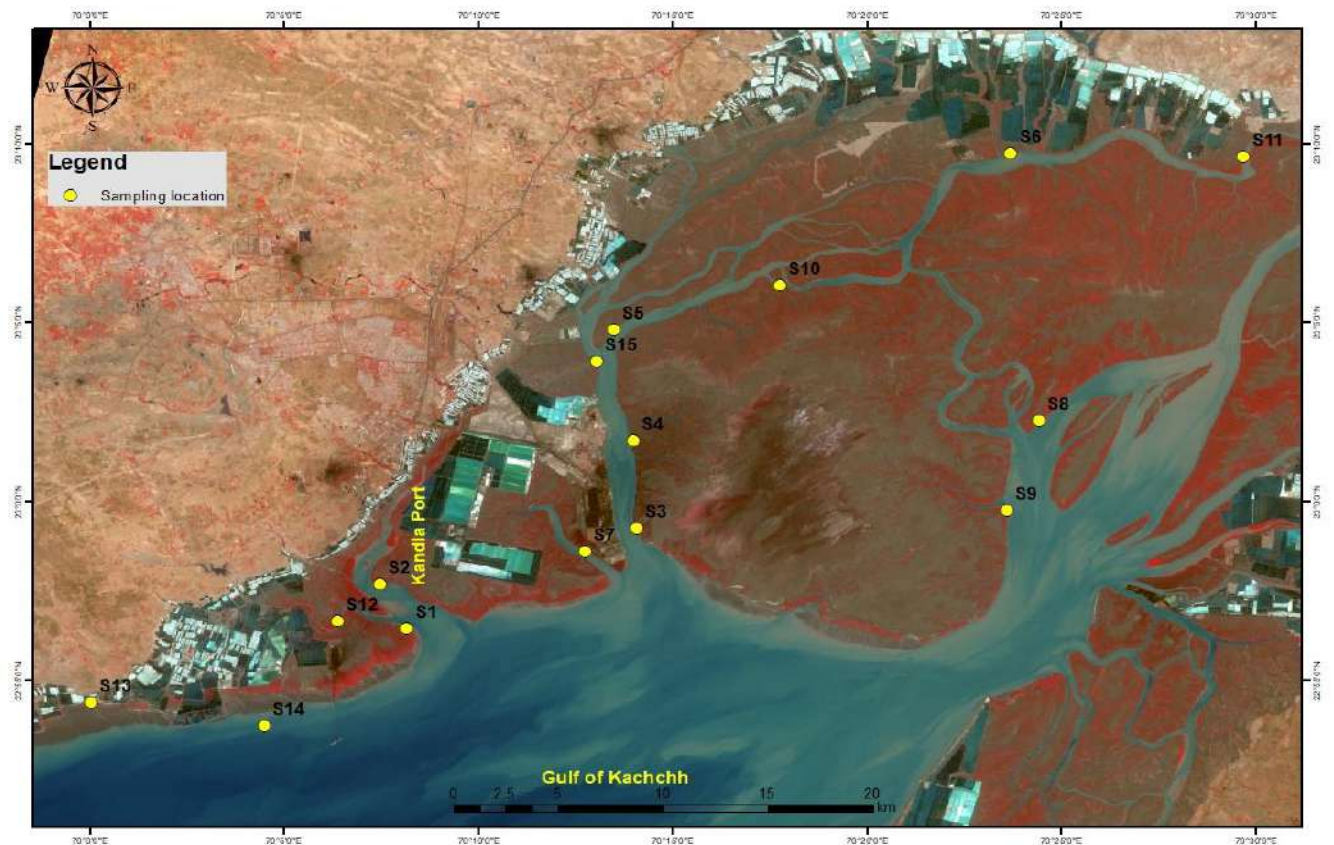
## **1.2. Scope of work**

The scope of the present investigation includes physico-chemical and marine biological components as mentioned in the specific conditions of MoEF&CC, EC & CRZ clearance dated 19.12.2016,18.2.2020,19.2.2022 and 20.11.2020 with specific conditions xviii, xxiii, xv & iv respectively. A detailed holistic approach to different components of the study such as marine physico-chemical parameters of water and sediment and marine biodiversity within the Deendayal Port area will be carried out. Based on the results obtained during the project period, a detailed management plan will be drawn at the end of the project period. The biological and physico-chemical variables will be investigated during the present study on a seasonal basis i.e., monsoon, post monsoon and pre-monsoon as follows.

- ✓ Physico-chemical characteristics of water and sediment
- ✓ Detailed assessment of mangrove vegetation structure including density, diversity, height, canopy, and other vegetation characteristics.
- ✓ GIS and RS studies to assess different ecological sensitive land use and land cover categories within the Port area such as the extent of dense and sparse mangroves, mudflats, creek systems, and other land cover categories within the port limits.
- ✓ Quantitative and qualitative assessment of the intertidal fauna, composition, distribution, diversity, density, and other characteristics.
- ✓ Data collection on the species composition, distribution, diversity and density of sub-tidal benthic fauna.
- ✓ Estimation of primary productivity at the selected sampling sites located in around the DPA area.
- ✓ Investigation of the species composition, distribution, density, and diversity of phytoplankton and zooplankton.
- ✓ Recording the occurrence, diversity and distribution of halophytes, seagrasses, seaweeds and other coastal flora. Investigations on the Avifaunal density, diversity, composition, habitat, threatened and endangered species and characters. Fishery Resources – Species composition, diversity, Catch Per Unit Effort (CPUE) and other socio-economic information.

### 1.2.1. Study Area

The coastal belt in and around Deendayal Port Authority jurisdiction is characterized by a network of creek systems and mudflats which are covered by sparse halophytic vegetation like scrubby to dense mangroves, creeks and salt-encrusted landmass which form the major land components. The surrounding environment in 10 km radius from the port includes built-up areas, salt pans, human habitations and port related structures on the west and north creek system, mangrove formations and mudflats in the east and south. The nearest major habitation is Gandhidham town located about 12 km away on the western part with population of 2,48,705 (as per 2011 census).



**Figure 1: Map showing the sampling locations 2021-2024**

## 2. Sampling of water and sediment samples

Sampling was carried out for the coastal water (surface) and sediment to determine physical and chemical characteristics from the prefixed sampling sites. The biological parameters (benthic and pelagic fauna, flora and productivity) were also estimated (Table.1).

**Table 1: Physico-chemical and biological parameters analysed**

<b>Parameters</b>	
<b>Water</b>	<b>Mangrove &amp; Other Flora</b>
• pH	<b>Mangrove</b>
• Temperature	• Vegetation structure, density
• Salinity (ppt)	• Diversity
• Petroleum Hydrocarbons-PHC	• Height
• Dissolved oxygen	• Canopy and other vegetation characteristics
• Total Suspended Solids (TSS)	
• Total Dissolved solids (TDS)	<b>Halophytes:</b>
<b>Nutrients</b>	• Percentage of distribution
Nitrate (NO <sub>3</sub> )	• Diversity
• Nitrite (NO <sub>2</sub> )	
• Total Nitrogen	<b>Seagrass and Seaweed</b>
• <b>Sediment</b>	• Occurrence, distribution, and diversity.
• Texture	<b>Intertidal fauna</b>
• Total organic carbon (TOC)	• Composition, distribution, diversity, density and other characteristics.
• <b>Biological Parameters</b>	<b>Avifauna</b>
Phytoplankton- Genera, abundance, diversity and biomass	• Density, diversity, composition, habitat,
• Productivity-Chlorophyll a	• Threatened and endangered species and characters
• Zooplankton – Species, abundance, diversity	
• Macrobenthos - genera, abundance, diversity	
• Fishery Resources	
• Common fishes available	
• composition, diversity	
• Catch Per Unit Effort (CPUE)	

The water samples were collected from each pre-designated site in pre-cleaned polyethylene bottles. Prior to sampling, the bottles were rinsed with sample water to be collected and stored in an ice box for transportation to laboratory and refrigerated at 4°C till further analysis. The analysis of the water quality parameters was carried out by following standard methods (APHA, 2017). All extracting reagents were prepared using metal-free, AnalaR grade chemicals (Qualigens Fine Chemicals Division of Glaxo SmithKline Pharmaceuticals Limited, Mumbai) and double distilled water prepared from quartz double distillation assembly.

## **2.1. Methodology**

### **Physico-chemical Parameters**

#### **pH and Temperature**

A Thermo fisher pH / EC / Temperature meter was used for pH and temperature measurements. The instrument was calibrated with standard buffers just before use.

#### **Salinity**

A suitable volume of the sample was titrated against Silver nitrate (20 g/l) with Potassium chromate as an indicator. The chlorinity was estimated, and from that, salinity values were derived using a formula (Strickland and Parsons,1972).

#### **Total Suspended Solids (TSS)**

About 100 ml of the water sample was filtered through pre-weighed filter paper and placed in the Hot air oven at a specified temperature as per the protocol for 1 hour. The filter paper was allowed to cool in a desiccator to obtain a constant weight by repeating the drying and desiccation steps.

#### **Total Dissolved Solids (TDS)**

The water samples were subjected for gravimetric procedure for confirmation of the readings obtained from the hand -held meter. About 100 ml of the water sample was taken in a beaker and filtered which was then dried totally in a Hot Air Oven (105°C). The TDS values were calculated using the difference in the initial and final weight of the container.



### **Turbidity**

The sample tube (Nephelometric cuvette) was filled with distilled water and placed in the sample holder. The lid of the sample compartment was closed. By adjusting the 'SET ZERO' knob, the meter reading was adjusted to read zero. The sample tube with distilled water was removed, the 40 NTU standard solutions were filled in the tube, and the meter reading was set to read 100. Other standards were also run. The turbidity of the marine water sample was then found by filling the sample tube with the sample, and the reading was noted.

### **Dissolved Oxygen (DO)**

DO was determined by Winkler's method (Strickland and Parsons,1972).

### **Phosphate**

Acidified Molybdate reagent was added to the sample to yield a phosphomolybdate complex that is reduced with Ascorbic acid to a highly coloured blue compound, which is measured at the wavelength of 690 nm in a Spectrophotometer (Shimadzu UV 5040).

### **Total phosphorus**

Phosphorus compounds in the sample were oxidized to phosphate with alkaline Potassium per sulphate at high temperature and pressure. The resulting phosphate was analyzed and described as total phosphorous.

### **Nitrite**

Nitrite in the water sample was allowed to react with Sulphanilamide in acid solution. The resulting diazo compound was reacted with N-1-Naphthyl ethylenediamine dihydrochloride to form a highly coloured azo-dye. The light absorbance was measured at the wavelength of 543 nm in Spectrophotometer (Shimadzu UV 5040).

### **Nitrate**

The Nitrate content was determined as nitrite (as mentioned above) after its reduction by passing the sample through a column packed with amalgamated Cadmium.

### **Petroleum Hydrocarbon (PHs)**

The water sample (1liter) was extracted with hexane and the organic layer was separated, dried over anhydrous sulphate and reduced to 10 ml at 30°C under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with Saudi Arabian crude residue as a standard. The residue was obtained by evaporating lighter fractions of the crude oil at 120°C.

### **Sediment characteristics**

Sediment samples were collected from the prefixed stations by using a Van Veen grab having a mouth area of 0.04m<sup>2</sup> or by a non-metallic plastic spatula. Sediment analysis was carried out using standard methodologies. In each location (grid), sediment samples were collected from three different spots and pooled together to make a composite sample, representative of a particular site. The collected samples were air dried and used for further analysis.

### **Sediment Texture**

For texture analysis, specified unit of sediment sample was sieved through sieves of different mesh size as per Unified Soil Classification System (USCS). Cumulative weight retained in each sieve was calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves (USDA,1951). The percentage of the various fractions was calculated from the weight retained and the total weight of the sample. The cumulative percentage was calculated by sequentially subtracting percent retained from the 100%.

### **Total Organic carbon**

Percentage of organic carbon in the dry sediment was determined by oxidizing the organic matter in the sample by Chromic acid and estimating the excess Chromic acid by titrating against Ferrous ammonium sulphate with Ferroin as an indicator (Walkley and Black, 1934).

## **2.3. Biological Characteristics of water and Sediment**

### **Primary productivity**

Phytoplankton possess the plant pigment chlorophyll 'a' which is responsible for synthesizing the energy for metabolic activities of phytoplankton through the process of photosynthesis in which CO<sub>2</sub> is used and O<sub>2</sub> is released. It is an essential component to understand the consequences of pollutants on the photosynthetic efficiency of phytoplankton in the system. To estimate this, a

known volume of water (500 ml) was filtered through a 0.45 µm Millipore Glass filter paper and the pigments retained on the filter paper were extracted in 90% Acetone. For the estimation of chlorophyll 'a' and pheophytin pigments the fluorescence of the Acetone extract was measured using Fluorometer before and after treatment with dilute acid (0.1N HCL) (Strickland and Parsons,1972).

### **Phytoplankton**

Phytoplankton samples were collected from prefixed 15 sampling sites from the coastal water in and around DPA location using standard plankton net with a mesh size of 25µm and a mouth area of 0.1256 m<sup>2</sup> (20 cm radius). The net fitted with a flow meter (Hydrobios) was towed from a motorized boat moving at a speed of 2 nautical miles/hr. Plankton adhering to the net was concentrated in the net bucket by splashing seawater transferred to a pre-cleaned and rinsed container and preserved with 5% neutralized formaldehyde and appropriately labelled indicating the details of the collection, and stored for further analysis. The Quantitative analysis of phytoplankton (cell count) was carried out using a Sedgewick-Rafter counting chamber. The density (No/l) was calculated using the formula:  $N = n \times v/V$  (Where, N is the total No/liter, n is the average number of cells in 1 ml, v is the volume of concentrate; V is the total volume of water filtered. The identification was done by following the standard literature of Desikachary, (1987), Santhanam et.al. (2019) and Kamboj et.al. (2018).

### **Zooplankton**

Zooplankton samples were collected using a standard zooplankton net made of bolting silk having 50µm with mouth area of 0.25 m<sup>2</sup> fitted with a flow meter. The net was towed from a boat for 5 minutes with a constant boat speed of 2 nautical miles/hr. The initial and final reading in the flow meter was noted down and the plankton concentrate collected in the bucket was transferred to appropriately labeled container and preserved with 5% neutralized formaldehyde. One ml of the zooplankton concentrate was added to a Sedgwick counting chamber and observed under a compound microscope and identified by following standard literature. The group/taxa were identified using standard identification keys and their number was recorded. Random cells in the counting chamber were taken for consideration and the number of zooplankton was noted down along with their binomial name. This process was repeated for five times with 1 ml sample and the average value was considered for the final calculation. For greater accuracy, the final density values were counter-checked and compared with the data collected by the settlement method.

Univariate measures such as Shannon-Wiener diversity index ( $H'$ ), Margalef's species richness ( $d$ ), and Pielou's evenness ( $J'$ ), Simpson's dominance ( $D$ ) was determined using PAST software.

### **Intertidal Fauna**

Intertidal faunal assemblages were studied for their density, abundance and frequency of occurrence during Post-monsoon 2022 at the pre-fixed 15 sampling locations within the DPA jurisdiction. Sample collection and assessment of intertidal communities were done in the intertidal zone during the low tide period. At each site, 1 x1 m<sup>2</sup> quadrates were placed randomly and all visible macrofaunal organisms encountered inside the quadrate were identified, counted and recorded. At each site, along the transects which run perpendicular to the waterfront, three to six replicate quadrate samples were assessed for the variability in macro-faunal population structure and the density was averaged for the entire intertidal belt. Organisms, which could not be identified in the field, were preserved in 5% formaldehyde, brought to the laboratory and identified using standard identification keys (Abott, 1954; Vine, 1986; Oliver, 1992; Rao, 2003; 2017; Psomadakis *et al.*, 2015; Apte, 2012; 2014; Naderloo 2017; Ravinesh *et al.* 2021; Edward *et al.*, 2022). Average data at each site were used to calculate the mean density (No/m<sup>2</sup>).

### **Subtidal macro benthic Fauna**

The sampling methods and procedures were designed in such a way to obtain specimens in the best possible condition as to maximize the usefulness of the data obtained. For studying the benthic organisms, triplicate samples were collected at each station using Van Veen grab, which covered an area of 0.04m<sup>2</sup>. The wet sediment was passed through a sieve of mesh size 0.5 mm for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal dye for ease of spotting at the time of sorting. The number of organisms in each grab sample was expressed as No. /m<sup>2</sup>. All the species were sorted, enumerated and identified by following the available literature. The works of Day (1967), Hartman (1968, 1969), Rouse and Pleijel (2001), Robin *et al.*, (2003), Amr (2021), were referred for polychaetes; Crane (1975), Holthuis (1993), Naderloo (2017). Xavier *et al.*, (2020) for crustaceans; Subba Rao (1989, 2003, 2017), Apte (2012, 2014), Ramakrishna and Dey (2007), Ravinesh *et al.* (2021) and Edward *et al.*, (2022) for molluscs. Statistical analyses such as diversity indices and quadrat richness were calculated using Paleontological Statistics Software Package for Education and Data (PAST) version 3.2.1 (Hammer *et al.*, 2001).





**Plate 1: Estimation of intertidal fauna by the quadrate method**





**Plate 2: Collection of Plankton and macrobenthos in subtidal habitat**

## **2.4. Mudflats**

Mudflats are ecologically and socio-economically vital ecosystems that bring benefits to human populations around the globe. These soft-sediment intertidal habitats, with >10% silt and clay (Dyer 1979), sustain global fisheries through the establishment of food and habitat (including important nursery habitats), support resident and migratory populations of birds, provide coastal defenses, and have aesthetic value. Mudflats are intimately linked by physical processes and dependent on coastal habitats, and they commonly appear in the natural sequence of habitats between subtidal channels and vegetated salt marshes. In some coastal areas, which may be several kilometress wide and commonly form the largest part of the intertidal area. Mudflats are characterized by high biological productivity and abundance of organisms but low in species diversity with few rare species. The mudflat biota reflectsthe prevailing physical conditions of the region. Intertidal mudflats can be separated into three distinct zones such as the lower tidal, middle and upper mudflats. The lower mudflats lie between mean low water neap and mean low water spring tide levels, and are often subjected to strong tidal currents. The middle mudflats are located between mean low water neaps and mean high water springs. The upper mudflats lie between the mean high-water neap and mean high water springs. The upper mudflats are the least inundated part and are only submerged at high water by spring tides (Klein, 1985). Salt marsh vegetation may colonize as far seaward as mean high water neaps. Mudflats will often continue below the level of low water spring tides and form sub-tidal mudflats (McCann, 1980). The upper parts of mudflats are generally characterized by coarse clays, the middle parts by silts, and the lower region by sandy mud (Dyer *et al.*, 2000). The intertidal mudflats are prominent sub-environments that occurred on the margin of the estuaries and low relief sheltered coastal environments. The fine-grained sediments of intertidal mudflats (70%-90%) are derived from terrestrial and marine regions (Lesuere *et.al.*,2003). Estuarine mudflats are potential sites for deposition of organic matter derived from terrigenous, marine, atmospheric and anthropogenic sources and are mainly associated with fine grained particles (Wang *et.al.*, 2006).

### **Sampling locations**

The Sediment samples were collected from 15 sampling locations by using sediment corer. From each site triplicate samples were collected from up to 100 cm depth with four intervals (0-25cm, 25-50cm, 50-75cm & 75-100cm) and made into composite sample for analysis. The samples were packed in zip lock bags, stored in icebox and shifted to the laboratory for subsequent analysis.





**Plate 3: Sediment sample collection at mangrove and mudflat areas**

**Total Organic Carbon**

The organic carbon content of the mudflats was estimated to assess the biological productivity of the sediment. Soil Organic Carbon (SOC) was estimated following the method of Walkley and Black (1934). In this method, organic matter (humus) in the soil gets oxidized by Chromic acid (Potassium dichromate plus concentrated H<sub>2</sub>SO<sub>4</sub>) by utilizing the heat evolved with the addition of H<sub>2</sub>SO<sub>4</sub>. The unreacted dichromate is determined by back titration with Ferrous ammonium sulphate (redox titration). Organic carbon was determined by following the below given formula:



$$\text{Oxidizable organic carbon (\%)} = \frac{10 (B - T)}{B} \times 0.003 \times \frac{100}{\text{wt. of soil}}$$

Where B = volume (mL) of Ferrous ammonium sulfate required for blank titration. T = volume of Ferrous ammonium sulfate needed for soil sample. Wt. =weight of soil (g).

### **Estimation of Bulk Density (BD)**

The soil under field condition exists as a three-phase system viz. solid (soil particles), liquid (water) and gas (mostly air). The soil organic matter contained in a unit volume of the soil sample is called its bulk density. The amount of bulk density depends on the texture, structure and organic matter status of the soil. High organic matter content lowers the bulk density, whereas compaction increases the bulk density. To determine the bulk density of the sediment samples collected during the present study, the oven-dry weight of a known sediment volume was considered, and mass per unit volume was calculated (Maiti, 2012).

### **2.5. Mangrove assessment**

Mangroves are widely distributed on the Deendayal Port Authority jurisdiction along the Kandla coast. The 15 mangrove sites selected at the different creeks belong to Deendayal Port Authority jurisdiction and all these stations are supposed to be sufficient to represent the mangroves status in Kandla. The mangrove stations in this study were named Tuna, Jangi, Kandla, Phan and Navlakhi based on the nearest location to the respective creek system. The Point Centered Quadrate Method (PCQM) was used for the collection of data of mangrove vegetation structure. The data included measurements of density of plants, height variations, canopy and basal area of mangrove trees as per the method of Cintron and Novelli (1984). For this method, a transect of a maximum of 200 m was applied mostly perpendicular or occasionally parallel to the creek. The sampling points considered at an interval of every 10 m and the vegetation structure of the that area were recorded. As the orientation of the transect line was already fixed, it was easy for movements within the station area for data recording. The distance between trees from the center of the sampling point for nearest 4 trees of four different directions, height of trees from the ground level, canopy length and canopy width were measured to determine the canopy cover in this study. The equipments utilized in the field were handy, and easy to use such as ranging rods, pipes and for measurement of girth at root collar above the ground (GRC), a measuring tape was used. The plants with a height <50 cm was considered as regeneration class and >50 cm but <100 cm was

considered as recruitment class. Along the transects, sub-plots of 1×1 m<sup>2</sup> for regeneration and 2×2 m<sup>2</sup> were laid randomly for recruitment class of the mangrove sites.



**Plate 4: Assessment of mangrove density, height, canopy cover and girth**



## **2.6. Halophytes**

To quantify and document the halophytes at Deendayal Port Authority region, quadrature method was followed. At each sampling location quadrates of various sizes have been laid during every seasonal sampling. For recording the plant density at each transect, a quadrature 1 x 1m<sup>2</sup> has been laid within the site each tree quadrates were used randomly (Misra,1968; Bonham, 1989). Four quadrates each for shrubs and herbs were laid in side each tree quadrature to assess the halophytes and the percentage cover in the study area. To enrich the species inventory, areas falling outside the quadrates were also explored and the observed species were recorded and photographed and identified using standard keys. Specimens of the various species were collected to know more information on habitat and for the preparation of herbarium.



**Plate 5: Assessment and percentage cover of halophytes**

## **2.7. Marine Fishery**

Fishery resources and the diversity were assessed from the selected sampling sites. Finfish and shellfish samples were collected using a gill net with a 10 mm mesh size. The net was operated onto the water from a canoe or by a person standing in waist deep water during the high tide using a cast net. For effective sampling, points were fixed at distances within the 15 offshore sites for deploying fishing nets to calculate the Catch per Unit effort estimated per hour. The collected specimens were segregated into groups, weighed and preserved in 10% neutralized formalin solution. Finfishes were identified following Fischer and Bianchi (1984), Masuda *et al.* (1984), de Bruin *et al.* (1995) and Mohsin and Ambiak (1996). Relevant secondary information pertaining to fishery resources of Deendayal Port creek systems were gathered through technical reports, the District Fisheries department, Government gazette and other research publications.



**Plate 6: Collection of fisheries information from DPA environment**



## **2.8. Avifauna**

The Avifauna population was determined along DPA mangrove strands for which the area was demarcated into fifteen major stations. In each station, creeks of varying lengths from 2 to 5 km are available. These creeks were surveyed by using boat and adopting “line transect” method. A total of fifteen boat transect (one in each site) survey was conducted in the Post-monsoon October 2022 to January 2023). Survey was done in both terrestrial habitats like Mangrove plantations adjoining the mudflats, waste land, and aquatic habitats, like creek area, rivers and wetland.

### **Boat Surveys**

Mangrove bird diversity was calculated by using Boat Survey method. Birds were observed from an observation post on board the boat which has given the greatest angle of clear view. Birds within a 100 meter transect on one side of the boat were counted in 10-minute blocks of time (Briggs *et al.* 1985; van Franeker, 1994). Detection of birds was done with a binocular (10 x 40) and counts were made: (1) continuously of all stationary birds (swimming, sitting on mangrove, or actively feeding) within the transect limits and (2) in a snap-shot fashion for all flying birds within the transect limits. The speed of the boat determines the forward limit of the snapshot area within a range of 100 meters. Longer or shorter forward distances were avoided by adapting the frequency of the snapshot counts. Birds that following and circling the boat were omitted from both snapshot and continuous counts. If birds arrive and then follow the boat, they were included in the count only if their first sighting falls within a normal snapshot or continuous count of the transect area. For each bird observation species, number of individuals and activity at the time of sighting, were recorded. Species richness and diversity index were calculated for different mangrove patches (i.e. fifteen station) of the study station in the Deendayal port Authority.

## **2.9. Data analysis**

Data collected in- situ and through laboratory analysis of samples were subjected to descriptive statistical analysis (PAST and Primer 7.0) for the mean, range and distribution of different variables from the selected 15 study stations.

### **3. Results**

#### **3.1. Water quality assessment**

The data on the mean water quality parameters measured at the time of sampling of the biological components from the 15 study sites during post-monsoon are presented in Table1.

##### **Temperature (°C) and pH**

The water temperature at the sampling sites ranged from 9°C to 28°C with average of 19°C. The maximum temperature of seawater was reported at S-6 and the minimum at S-9 in Kandla (Navlaki ) creek. The pH of creek water ranged from 7.1 to 8.1 with average of 7.9. The highest pH was reported at sites S-2 and S-5 and the lowest pH 7.1 was noticed at S-11 in Janghi creek. The overall observation along the port environment revealed that the temperature fluctuation might be due to the low atmospheric temperature(winter) in the month of December and the pH range showed minor fluctuations among the sampling locations.

##### **Salinity (ppt)**

The salinity of Deendayal Port authority ranged from 12 ppt to 43 ppt with the average value of 39 ppt. The minimum salinity was observed at S-10 and maximum at S-9. The hypersaline condition of creek system during post-monsoon season might be due release of brine water from salt pan in to this creek system.

##### **Dissolved oxygen (DO)**

The dissolved oxygen in the coastal waters of Deendayal port authority area ranged from 3.9 mg/L to 7.7 mg/L with the average of 6.8 mg/L. The highest dissolved oxygen concentration was observed at S-6 and the lowest was observed at S-5. The concentration of dissolved oxygen varies mainly due to the rate of photosynthesis and respiration by plants and animals in water. Generally, the coastal waters are having high level of dissolved oxygen due to the dissolution from the atmosphere through diffusion process on the surface layer (CCME,1999).

##### **Suspended Solids (TSS)**

The total suspended solids (TSS) concentration at the 15 sampling sites ranged from 140 mg/L to 640 mg/L with the average of 209 mg/L. The highest TSS values was reported at S-8 in the Navlaki creek. The minimum TSS value was recorded at S-12 which was 140 mg/L.

### **Total Dissolved solids (TDS)**

The total dissolved solids (TDS) in the water consist of inorganic salts and dissolved materials which mostly comprises of anions and cations in creek water system. The TDS of the samples varied from 32,200mg/L to 45,700 mg/L with an average of 39,500 mg/L. The maximum value was reported at S-2 which may be due to replenishment dissolved solids due to the gulf current system and movement s of cargo in the navigation channel of Kandla creek system.

### **Turbidity**

The turbidity of the water samples from the study sites ranged between 46 NTU and 342 NTU with the average of 190 NTU. The lowest value was reported at S-15 and the highest value at S-6 followed by S-9.

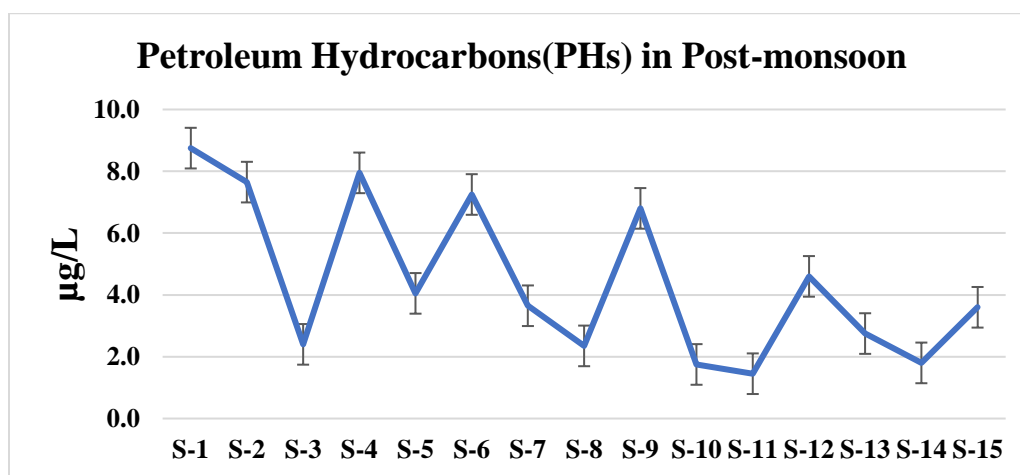
### **Water nutrients (Nitrate, Nitrite and Total Phosphorus)**

The nutrients influence growth, metabolic actions and reproduction of biotic components in the aquatic environment. The distribution of nutrients mainly depends upon tidal conditions, types of season and fresh water influx from land. The nitrate concentration ranged from 0.003 mg/L to 0.140 mg/L with an average of 0.060 mg/L. The highest nitrate concentration was observed at station S-9 and the lowest at station S-1. Very miniature variation was noticed concentration of nitrate among the study station. Likewise, nitrite values varied between 0.007 mg/L to 0.021 mg/L. The highest concentration was observed at station S-1 and lowest concentration was observed at station S-9. The Total phosphorus values among the study station ranged from 0.67 mg/L to 2.02 mg/L with in average of 1.26 mg/L. The highest phosphorus concentration was observed at station S-3 near oil jetty of Kandla creek and the lowest concentration was observed at S-12 inTuna creek. Highest concentration might be due to leaching of phosphatic fertilizers while handling of cargo port area.

### **Petroleum Hydrocarbons (PHs)**

Petroleum Hydrocarbons (PHs) represent the most commercially utilized fossil fuels (Adelaja, 2015). Reports have indicated that their consumption is projected to rise exponentially from 85 million barrels in 2016 to 106.6 million barrels by 2030 (Igunnu et. al, 2014). They are used as raw materials in many industries and primary energy sources. However, they also represent one of the prioritized and widespread contaminants posing serious threats to the ecology owing to their stability and robustness (Cozzarelli et. al, 2014; Pablo et. al, 2020; Uddin et. al, 2021).

PHs comprise the polycyclic aromatic hydrocarbons (PAHs), alkanes, paraffin, cycloalkanes, organic pollutants, and non-hydrocarbon components like phenol, sulfur compounds, thiol, metalloporphyrin, heterocyclic nitrogen, naphthenic acid, and asphaltene. The introduction of the PHs immediately alters the composition of that particular ecological niche/ecosystem, subsequently reducing the overall functionality and inducing weathering. This weathering of the PHs triggers a series of influences which may be either chemical (auto-oxidation/photo-oxidation), physical (dispersion), physiochemical (sorption, dissolution, evaporation), or biological (microbial and plant catabolism of hydrocarbons) (Truskewycz et. al, 2019). Marine organisms get affected by the presence of the PHs. The bioaccumulation of lethal PHs in the aquatic food chain persists for many years and in turn influences the primary producers, primary consumers, and secondary consumers. About 90% of the PHs discharge can be associated with anthropogenic activities (oil spills) in both, the terrestrial as well as marine environments. It has been reported that around 8.8 million metric tonnes of oil are annually discharged into the aquatic environment (Dadrassnia and Agamuthu, 2013). In the current study, the presence of PHs in water samples collected along all the 15 sampling sites were detected and estimated. The PHs ranged from 1.45 µg/L to 7.65 µg/L. The PHs detected from the individual sites have been represented in (Fig.....). The highest concentration of the PHs was detected at S-1 site ( Tuna creek) while the lowest was noted for S-11 (Janghi creek). A moderate level of the PH content was noted down at site S-2 (7.65 µg/L) and S-6 (7.25 µg/L) followed by S-9 (6.8 µg/L) and the rest of the sites.



**Figure 2: Petroleum hydrocarbons in water (µg/L) during Post-monsoon 2022-2023**



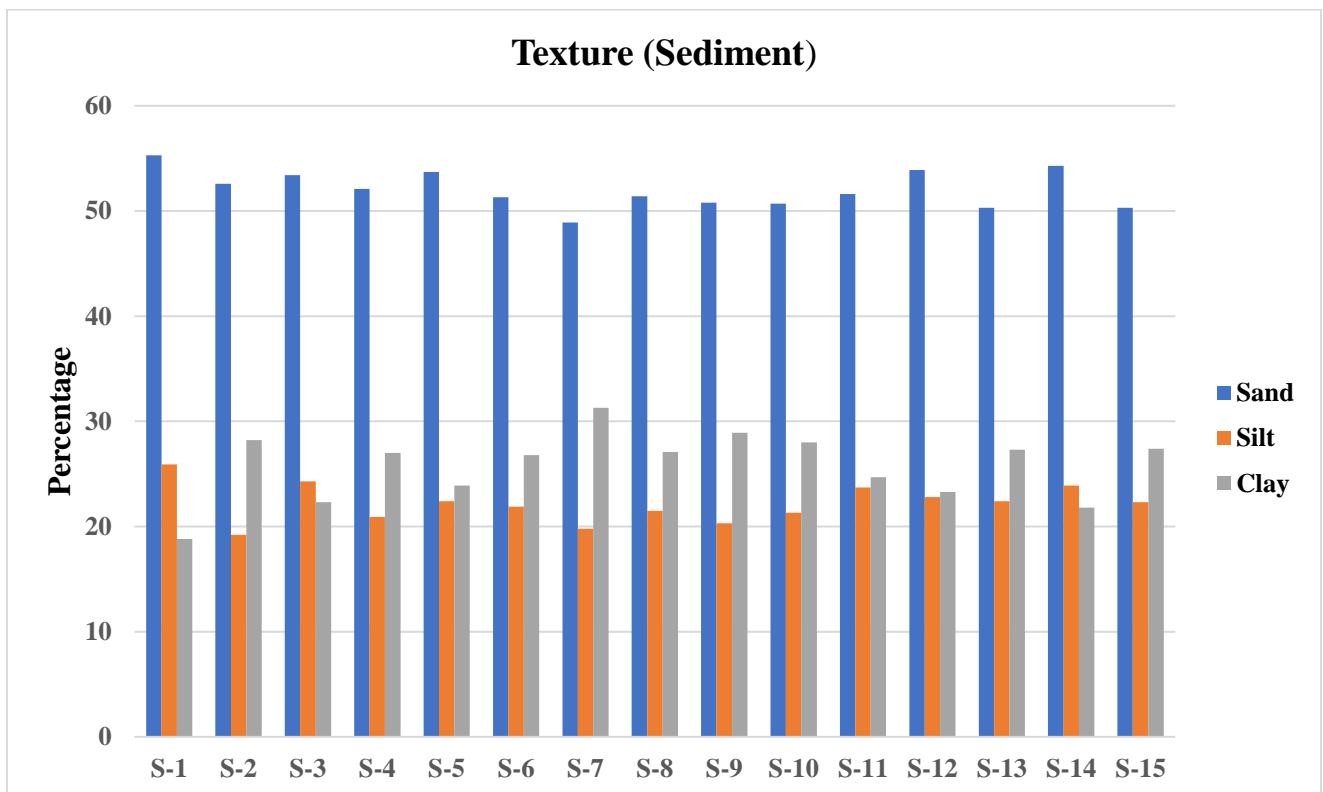
**Table 2: Physico-chemical characteristics of coastal waters during Post-monsoon 2022-2023**

Parameters	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
Temp (°C) (Air)	24	24	21	21	32	30	20	14	12	29	23	23	19	18	26
Temp (°C) (Water)	20	20	21	20	24	28	17	10	9	20	16	17	16	19	24
pH	7.8	8.1	8	7.9	8.1	7.9	7.9	8	7.8	7.8	7.1	8	8	7.9	8
Salinity (ppt)	39	38	39	41	41	41	42	41	43	12	39	40	43	41	40
Dissolved oxygen (mg/L)	7	7	7	7	4	8	8	6	7	7	6	7	7	7	7
Total Suspended Solids (TSS) (mg/L)	207	163	199	181	160	219	165	640	232	148	175	140	192	158	154
Total Dissolved solids (TDS) (mg/L)	40000	41200	39300	39200	39700	40000	39600	45700	35100	39300	41500	40600	38100	32200	41000
Turbidity (NTU)	265	235	218	139	73	132	209	249	342	273	228	227	167	49	46
Nitrate (NO <sub>3</sub> ) (mg/L)	0.003	0.034	0.136	0.059	0.015	0.026	0.066	0.111	0.140	0.034	0.074	0.029	0.131	0.029	0.018
Nitrite (NO <sub>2</sub> ) (mg/L)	0.012	0.017	0.008	0.014	0.021	0.015	0.015	0.011	0.007	0.015	0.014	0.017	0.016	0.007	0.007
Total Phosphorus (mg/L)	1.83	0.87	2.02	1.54	1.06	1.83	0.96	0.87	1.35	0.77	1.25	0.67	0.87	1.35	1.73
PHs (µg/L)	8.75	7.65	2.4	7.95	4.05	7.25	3.65	2.35	6.8	1.75	1.45	4.6	2.75	1.8	3.6
Chlorophyll a (mg/L)	0.58	0.49	0.14	0.25	0.32	0.80	1.00	0.64	0.22	1.14	0.34	0.65	0.16	0.28	0.83

### 3.2. Sediment

#### Sediment texture

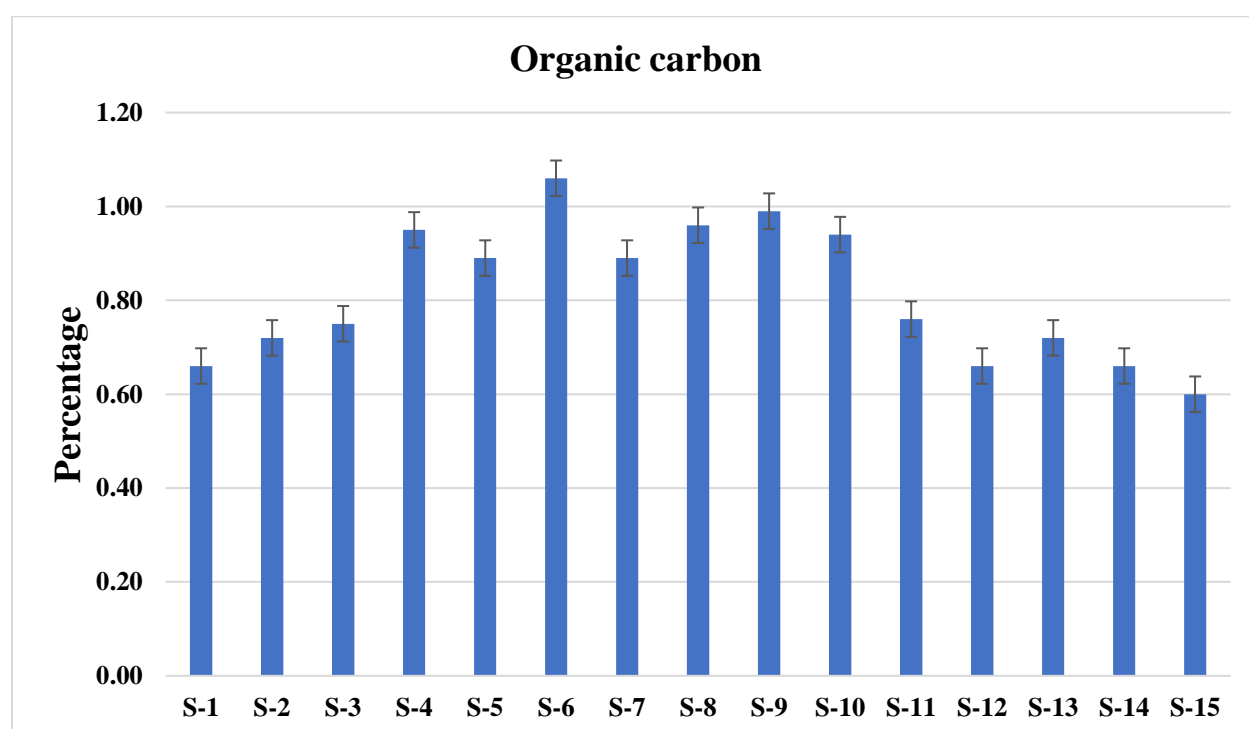
The percentage composition of the soil particles in the sediment analyzed from the 15 sampling sites are presented in Fig.3. There were noticeable variations in the soil fractions, (Texture) sand, silt and clay, among the stations. In the present study the highest percentage of clay was reported at S-7 followed by S-2. The highest percentage of sand was observed at S-11 followed by S-15 station. As per the observations, the percentage of silt content was less compared to clay and sand in many sampling sites except S-15. The nature of soil texture was characterized by the proportion of clay, sand and silt fractions. The Soil texture (Percentage) revealed the dominance of sandy-clay type in all the stations with less variations among them. This consistently high clay-loam value may be attributed to the sifting activity of sediment transport system. The absence of perennial flow of freshwater into the coast along with lack of wave induced sand transport from open sea are the possible reasons for this uniform pattern of soil texture.



**Figure 3: Textural characteristic of sediment at DPA in Post-monsoon 2022-2023**

### **Total Organic Carbon (TOC)**

In the present study, the total organic carbon content in the sediment varied from 0.60% to 1.06% (Fig.4). The highest value-of TOC were reported at S-6 followed by S-9. The lowest TOC value was recorded at S-15. The distribution of total organic carbon closely followed the distribution of sediment type i.e., sediment low in clay content contained relatively low organic carbon.



**Figure 4: Total Organic Carbon content (%) in DPA during Post-monsoon 2022-2023**



### 3.3. Biological characteristics of water and sediment

#### Primary productivity

Chlorophyll 'a' the photosynthetic pigment which can be used as a representation for phytoplankton productivity and thus is an vital water quality parameter. Generally, the primary production of the water column is assessed from Chlorophyll 'a' concentration. It is well known that half of the global primary production being mediated by the activity of microscopic phytoplankton.

In the present study, Chlorophyll 'a' concentration fluctuated from 0.14 mg/L to 1.14 mg/L with average of 0.52 mg/L. The highest concentration 1.14 mg/L was reported at S-10 (Fig.5) followed by S-7 (1.00) . The photosynthetic pigment chlorophyll a which is a measure of the population density of phytoplankton during the Post-monsoon period showed wide range of variations among the sites. The Chlorophyll 'a' content was very low at S-3.

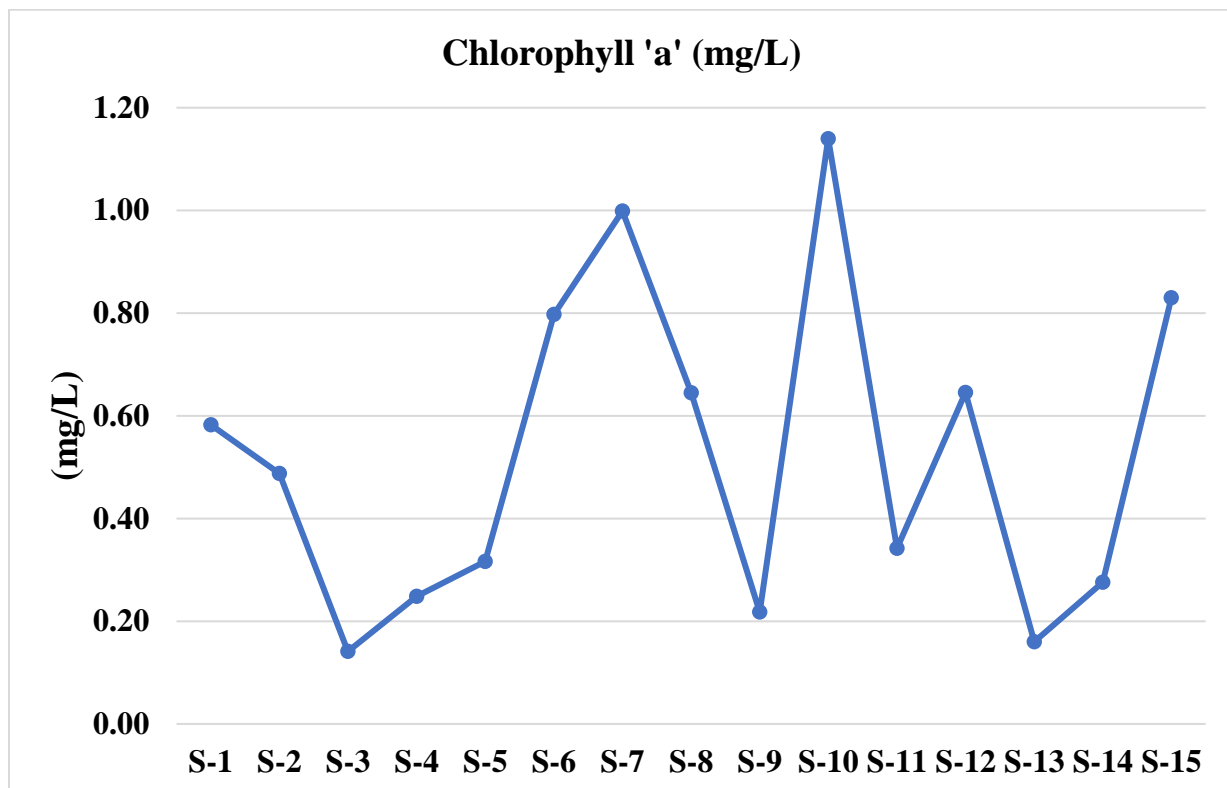


Figure 5: Chlorophyll 'a' concentration at the study stations in Post-monsoon 2022-2023

### **3.4. Phytoplankton**

Phytoplankton are free-floating, photosynthetic, aquatic microorganisms, which are distributed either actively by their locomotory organs (flagella) or passively by water currents. Most of the phytoplankton survive on the open surface waters of lakes, rivers and oceans. The phytoplankton community is mainly represented by algal representatives including both prokaryotes and eukaryotic genera. Plankton populations are mostly represented by members of Cyanobacteria, Chlorophyta, Dinophyta, Euglenophyta, Haptophyta, Chrysophyta, Cryptophyta, and Bacillariophyta. Planktonic representative taxa are absent in other algal divisions like Phaeophyta and Rhodophyta.

#### **Generic Status**

There were four groups of phytoplankton occurred during Post-monsoon along the DPA, Kandla coast and its peripheral creek system which include Diatom (Pennales, Centrales), Dinophyceae and Cyanophyceae. The number of genera recorded during the Post-monsoon period varied between was 22 to 26 at the 15 sampling stations. The maximum number genera (26) was observed at S-3,S-9 and S-12 and the minimum from S-8 representing 22 genera. As far as generic status is concerned the centrales diatom contributed a greater number of genera (16) followed by Pennales (9) (Fig.6 & Table 3). Among the diatoms of phytoplankton, the genera *Coscinodiscus* ,and *Thalassionema* were primarily dominated at all the study stations. The genera representing of the groups Dinophyceae and Cyanophyceae encountered in minimum numbers.

#### **Percentage composition of phytoplankton**

The cumulative percentage composition of the five groups of phytoplankton from all the study sites is presented in Fig.7. The percentage composition varied from 1 % to 61 % of which the pennales and centrales are the dominant constituting 38% and 61% respectively. The diatoms pennales and centrales together formed 99% of the phytoplankton population by number of genera as well as number of individuals while the rest 1% is constituted by Dinophyceae during the Post-monsoon 2022-2023.

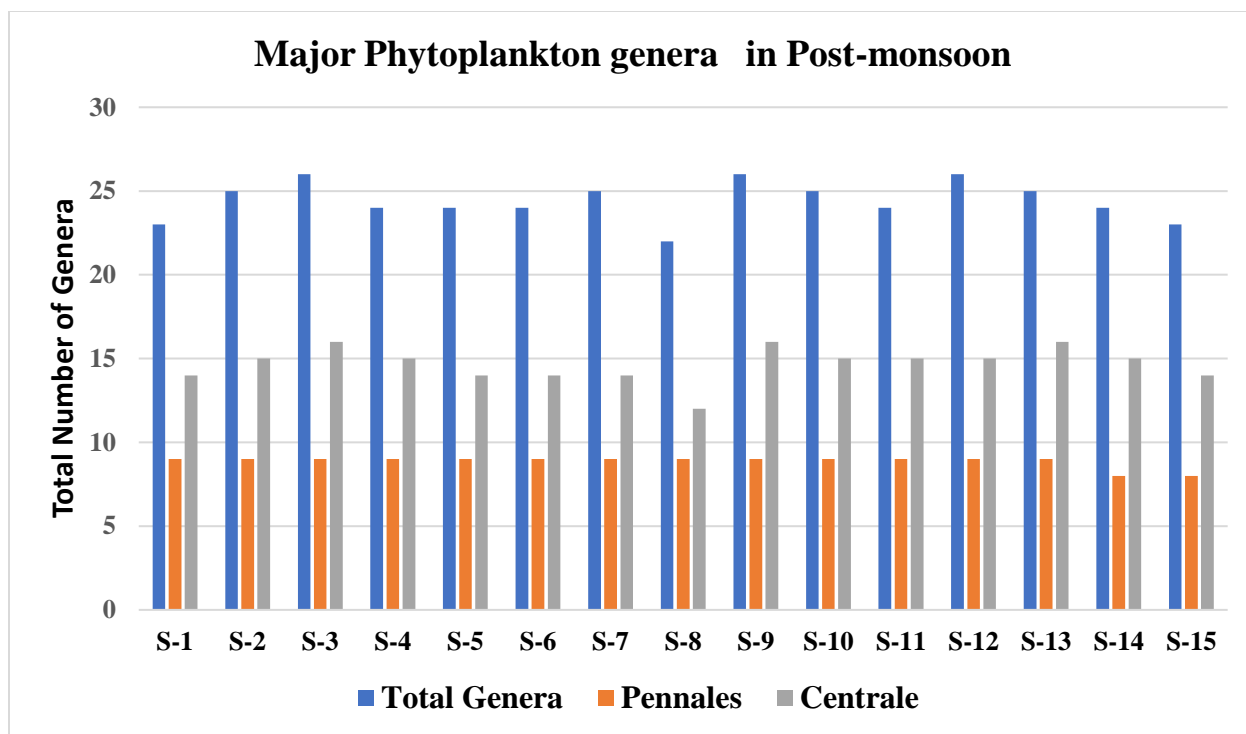


Figure 6: Number of Phytoplankton genera in Post-monsoon 2022-2023

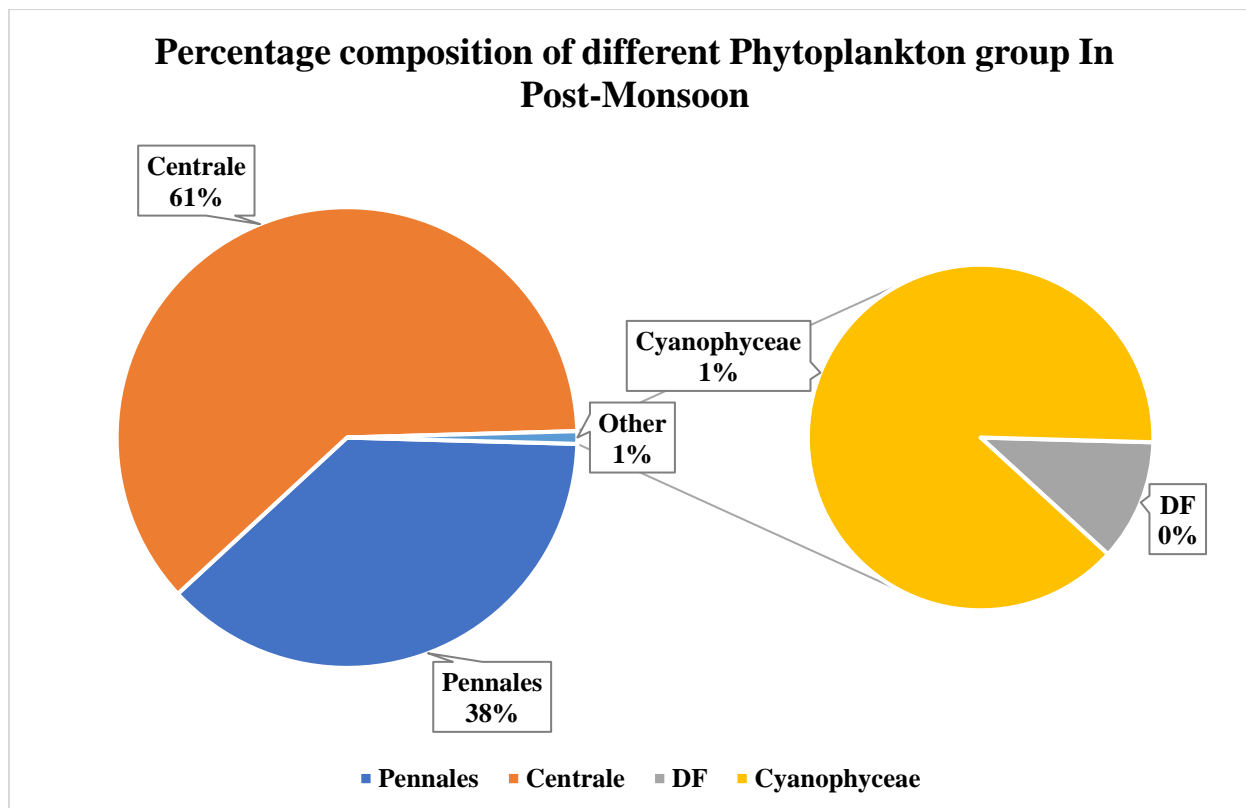
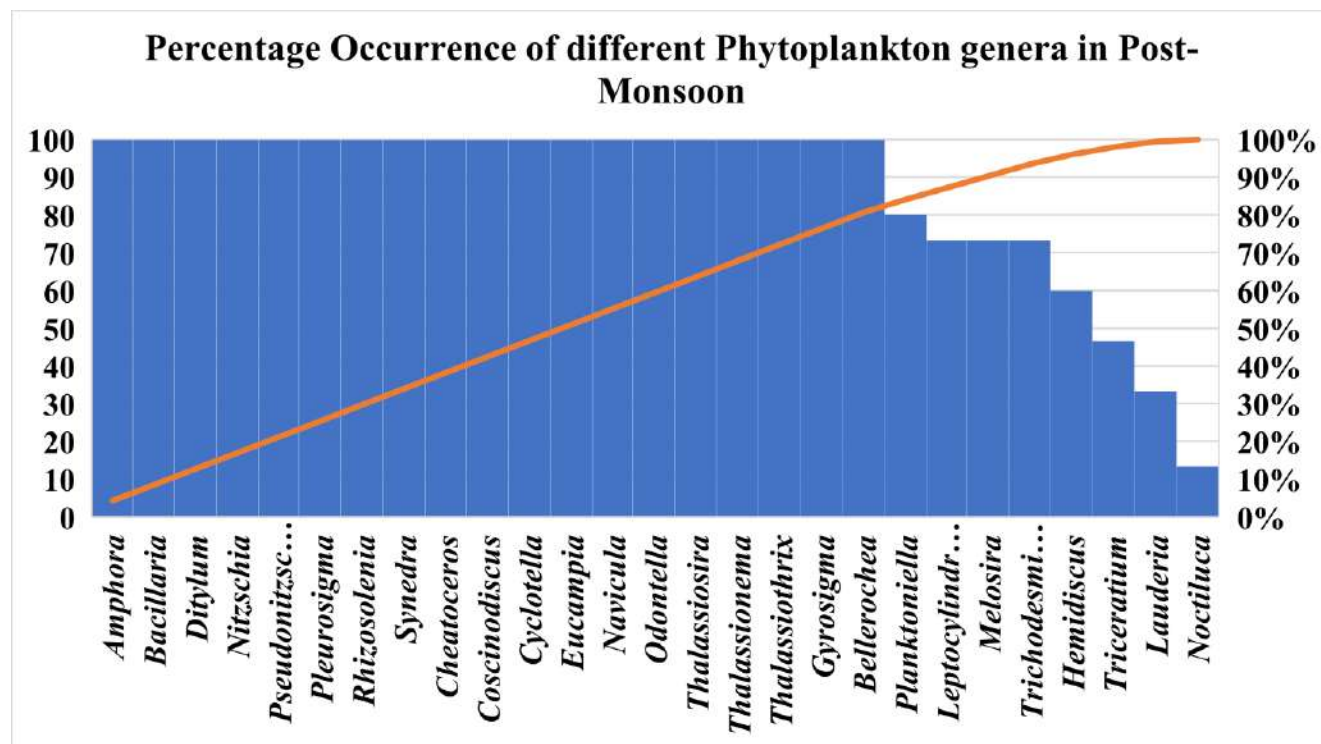


Figure 7: Percentage composition of phytoplankton groups in Post-monsoon 2022-2023

### Percentage of occurrence

The percentage occurrence denotes the number of representations by a genus among the sites sampled. The percentage occurrence of different phytoplankton genera varied from 13% to 100% with an average of 87%. Nineteen phytoplankton genera have the highest percentage of occurrence (100%) (fig 8) followed by Planktoniella (80%) occurrence during the Post-monsoon season 2022-2023.

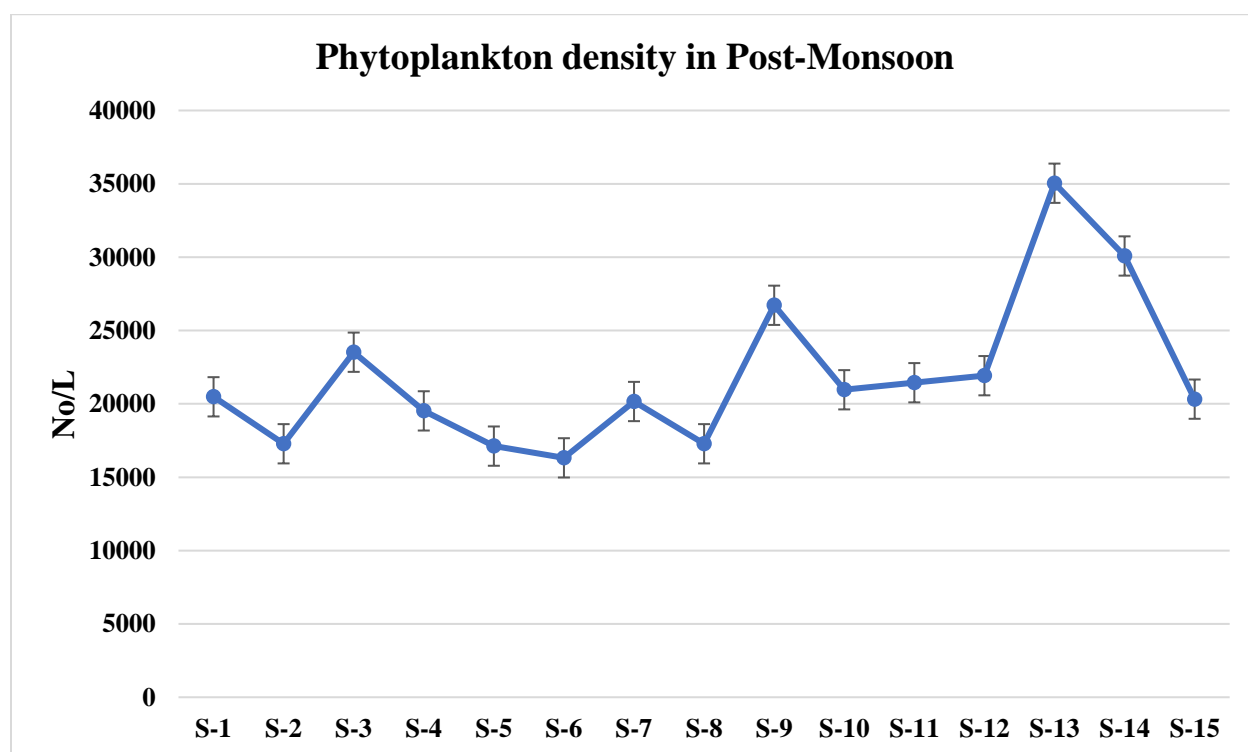


**Figure 8: Percentage occurrence of phytoplankton genera in Post-monsoon 2022-2023**

### Phytoplankton density and diversity

The density signifies the abundance of plankton which is measured as cell/ individual/L. The phytoplankton density varied from 16,320 No/L to 35,040 No/L with the average 21,887 No/L. The highest phytoplankton density was observed at station S-13 (35,040 No/L) followed by S-14 (30,080 No/L), whereas the lowest 16,320 No/L at S-6(fig.9). Diversity indices have become part of standard methodology in the ecological studies particularly, impact analysis and biodiversity monitoring of the environments (PEET,1974). Biodiversity indices reflects the biological variability which can be used for comparison with space and time. Various species diversity

indices respond differently to different environmental factors and behavioral patterns of biotic communities. Among the different stations, the number of phytoplankton taxa varied from 22 to 26 (Table-4). During Post-monsoon the Margalef and Menhinik richness indices were maximum at stations S-12 & S-6 (2.50 & 0.19 respectively). The Shannon diversity index was maximum 3.04 (S-9) and minimum 2.81 at S-7. The Simpson index clearly reflects the species dominance (genera) at S-9 (0.95) and the low value (0.92) was noticed at S-17.

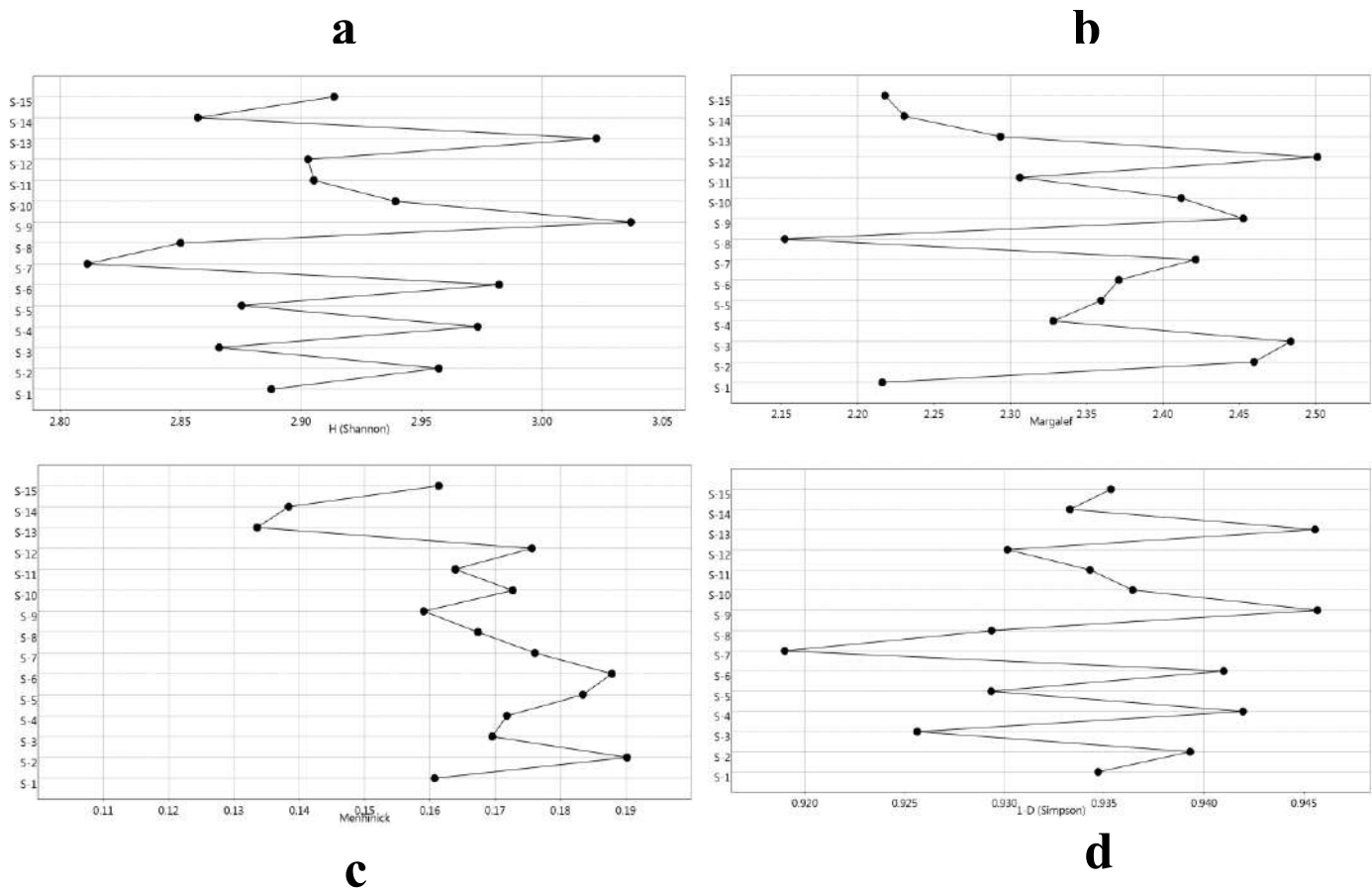


**Figure 9: Phytoplankton density in Post-monsoon 2022-2023**

As per Shannon Wiener's rules for the aquatic environment i.e., both soil and water are classified as very good when  $H'$  value is greater than four ( $>4$ ), whereas the good quality represents the  $H'$  value with a range of 4-3, similarly moderate-quality ( $H'$  value 3-2), poor quality ( $H'$  value 2-1) and very poor-quality  $H'$  value significantly less than one ( $<1$ ). Presently Deendayal Port Authority and its periphery environment has been influenced by contaminants deposited from industries and the cargo movements. Accordingly, species diversity decreases at sites with poor water quality. As deduced from the Shannon diversity index values between 2.81 to 3.04 representing the poor quality of environmental status dominated by the few genera such as *Coscinodiscus* and *Thalassionema*. A community dominated by relatively few species indicates



environmental stress (Plafkin *et al.*, 1989). According to Staub *et. al* (1970) species diversity index value between 3.0 to 4.5 represents slightly polluted and the lightly polluted environment, the index value characterizes 2.0-3.0, similarly, moderately polluted environment shows index value of 1.0-2.0 and finally, the heavily polluted environment index value is 0.0-1.0. While considering the overall index values it is inferred that the study sites can be included under the category of lightly polluted (Fig.10).



**Figure 10: Different diversity indices of Phytoplankton**

**a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index**

Table 3: Phytoplankton density, percentage composition and occurrence during Post-monsoon 2022-2023 in DPA

Grpou	Genera	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	PC	PO
Pennales	<i>Amphora</i>	320	160	320	320	640	800	160	480	1120	800	320	1280	320	160	1440	2.6	100
	<i>Bacillaria</i>	960	960	640	320	160	480	640	960	1120	800	480	640	1440	800	1280	3.6	100
	<i>Dirylum</i>	960	1280	1760	1440	800	320	640	960	2240	960	2080	1760	2240	1760	640	6.0	100
	<i>Nitzschia</i>	1760	1440	800	320	640	960	2240	960	2080	1760	1440	1280	2240	1600	1120	6.3	100
	<i>Pseudonitzschia</i>	480	640	320	800	640	480	1120	800	320	160	640	160	160	160	320	2.2	100
	<i>Pleurosigma</i>	320	320	640	160	160	320	160	480	1120	640	160	320	960	1280	640	2.3	100
	<i>Rhizosolenia</i>	640	960	960	1280	800	480	640	160	800	640	640	800	1440	1600	480	3.8	100
	<i>Synedra</i>	1760	1440	1120	1280	2240	1280	1120	1920	1600	1440	960	1760	2720	2400	1760	7.6	100
	<i>Navicula</i>	1120	640	640	1280	800	640	320	480	1440	160	1120	480	1760	0	0	3.3	87
Centrales	<i>Cheatoceros</i>	1600	1440	2720	2080	1760	1600	3360	960	1280	2720	2560	1760	3200	3040	1600	9.7	100
	<i>Coscinodiscus</i>	1760	1600	3360	960	1280	1600	1440	2720	2080	1760	1600	3360	2400	3040	2720	9.7	100
	<i>Cyclotella</i>	160	160	160	480	320	160	320	160	480	480	640	320	800	1440	960	2.1	100
	<i>Eucampia</i>	480	320	320	320	160	160	640	320	800	480	160	320	320	160	800	1.8	100
	<i>Lauderia</i>	160	160	0	0	0	0	0	0	160	0	160	0	0	0	0	0.2	33
	<i>Leptocylindricus</i>	480	160	160	160	320	320	0	0	160	160	0	320	1280	640	320	1.4	73
	<i>Melosira</i>	160	320	320	160	160	320	0	0	160	320	160	0	320	0	160	0.8	73
	<i>Odontella</i>	1120	1440	1760	1440	800	480	640	960	2400	960	2400	1760	2400	3040	800	6.8	100
	<i>Planktoniella</i>	0	0	160	640	320	480	640	800	0	320	640	480	800	160	320	1.8	80
	<i>Triceratium</i>	0	0	160	320	0	0	160	0	320	0	0	160	480	160	0	0.5	47
	<i>Thalassiosira</i>	160	320	800	1120	160	1280	800	960	1120	320	640	160	1120	960	320	3.1	100
	<i>Hemidiscus</i>	0	160	160	0	0	0	160	0	160	160	160	320	320	160	0	0.5	60
	<i>Thalassionema</i>	2560	640	2880	800	2240	480	2720	640	1120	1600	960	1600	2400	2720	1760	7.7	100
	<i>Thalassiothrix</i>	960	1120	800	1120	480	1280	640	1120	960	1440	640	800	1440	1120	800	4.5	100
	<i>Gyrosigma</i>	640	480	1120	960	640	320	160	640	800	1280	1120	960	1440	1120	640	3.8	100
	<i>Bellerochea</i>	800	320	640	480	640	1120	800	160	1120	960	640	320	1280	1120	800	3.4	100
DF	Noctiluca	0	0	0	0	0	0	160	0	0	0	0	160	0	0	0	0.1	13
Cyanophyceae	Trichodesmium	0	160	160	0	160	320	160	160	320	480	0	160	0	160	320	0.8	73

*Deendayal Port Authority 2<sup>nd</sup> Year Post-Monsoon (October2022-January2023)*

Total Density	20480	17280	23520	19520	17120	16320	20160	17280	26720	20960	21440	21920	35040	30080	20320	
Total Genera	23	25	26	24	24	24	25	22	26	25	24	26	25	24	23	

**PC: Percentage of composition**

**PO: Percentage of Occurrence**



### 3.5. Zooplankton

Zooplankton are highly sensitive to changes caused by physical and chemical factors in aquatic ecosystems and their distribution deliver information regarding the productivity and pollution of the particular area (Gajbhiye and Desai, 1981). Zooplankton are distributed in a wide range of habitats extending from the neuston to benthos and play vital roles influencing fisheries, oceanography and climate (Terdalkar and Pai, 2001). It has various significant roles in the estuarine ecosystem and connecting link between nutrient cycling and phytoplankton, primary production and many commercial fisheries in estuaries and coastal waters and form a chief food for a variety of pelagic consumers including coelenterates, ctenophores, fish larva forage fish and some benthic organisms such as sponges and molluscs (Day *et al.*, 1989).

#### Phylum, group and generic status

The zooplankton identified from the 15 stations falls under 10 phyla and 45 genera belonging to the 15 groups (Table 5). The phylum Arthropoda was the predominant, represented with 30 genera including copepods, crabs, shrimps and their larva. The phylum Arthropoda dominated in the samples with major groups Calanoida, Harpacticoida, Cyclopoida, (Copepoda) Decapoda, Branchiopoda, Thecostraca, Onychopoda, and the larval forms of crustaceans. There were 19 genera of copepods of Phylum Arthropoda occurred in the samples. Among the copepods 12 genera, of the Calanoida ranked first in terms of generic representation, *Acartia*, *Acrocalanus*, *Aetideus*, *Nannocalanus*, *Temora* and *Calanus* while the other 2 groups, Harpacticoida, Cyclopoida were poor in generic status. (figure-11). Besides this 11 genera belonging to Foraminifera (*Tintinnopsis*, *Codonellopsis*), Chaetognatha, Nematoda, Polychaeta, Branchiopoda, Thecostraca, Cnidaria and fish were also present in the samples.

#### Percentage composition

The overall percentage of the various groups of zooplankton varied from 5.4% to 40.4%. The highest percentage was due to the calanoid copepods (40.4%) followed by Decapoda (16.4%) and Gastropoda (6.4%). The group which contributed the least was *Appendicularia* (5.4%) (Fig.12). The minor group of 11 genera constituted 25.8% of population in which contributed by fish larvae, Globigerina and Branchiopoda (Table 4). Among the zooplankton groups calanoid group was the predominant zooplankton at all sites

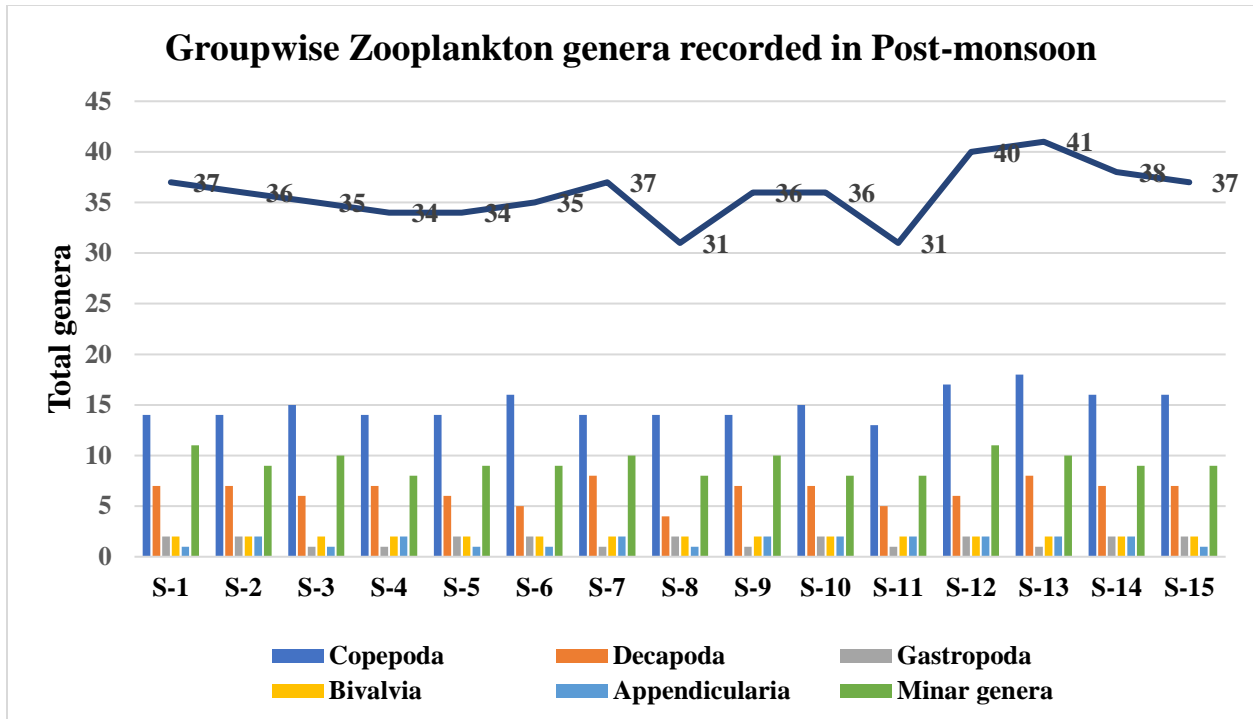


Figure 11: Phylum and generic status of zooplankton during Post-monsoon 2022-2023

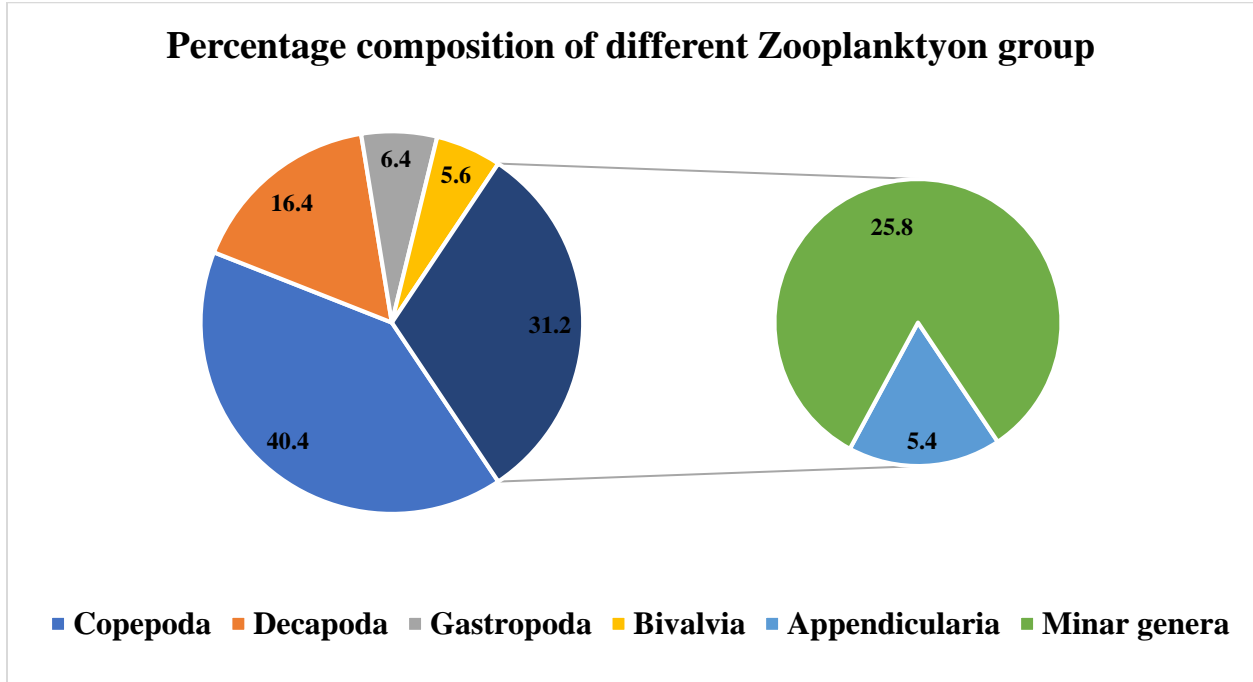


Figure 12: Percentage composition of zooplankton groups during Post-monsoon 2022-2023

### Percentage occurrence of zooplankton

The percentage occurrence of zooplankton communities varied from 37% to 100 % (.Figure 13). There were 7 zooplankton genera that exhibited 100% of occurrence (Fig.12) followed by *Branchiopoda Thecostraca* (90%) occurrence. from the study sites (Table4).

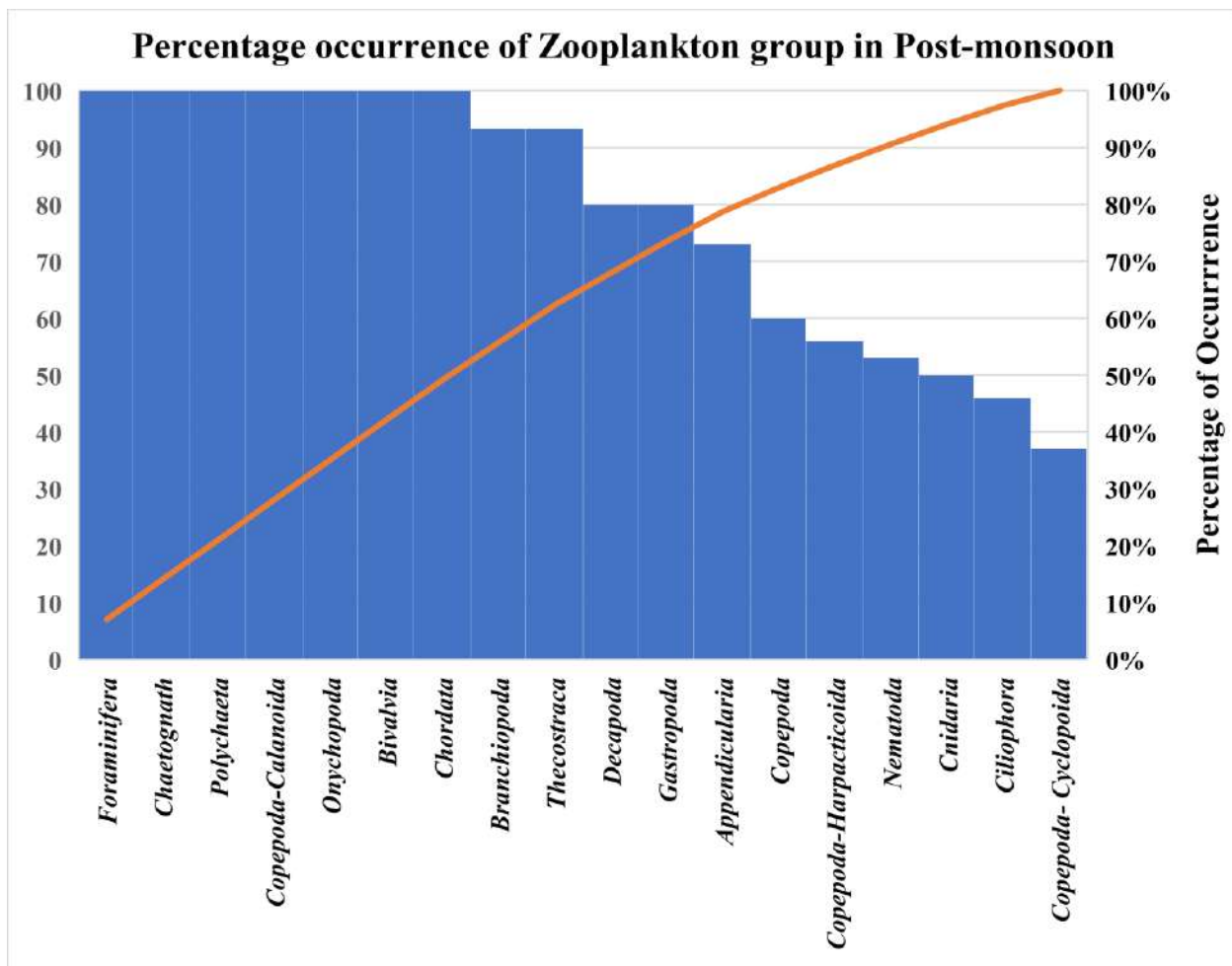


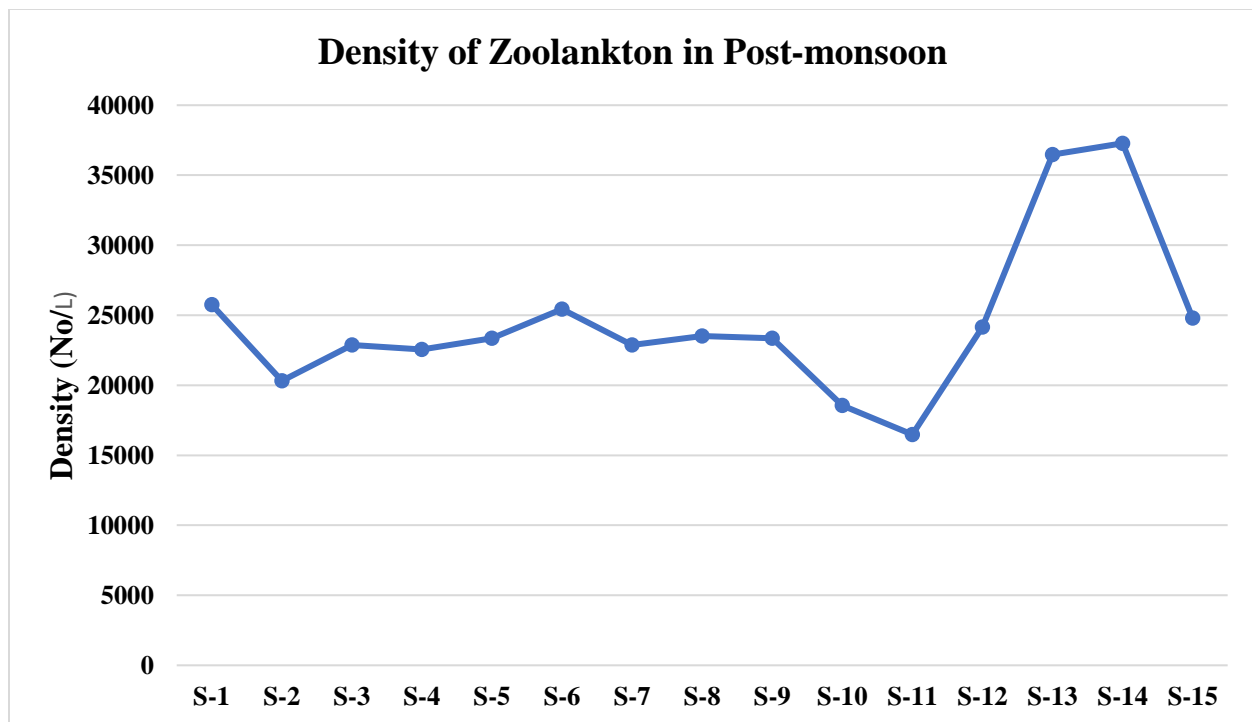
Figure 13: Percentage occurrence of Zooplankton groups during Post-monsoon 2022-2023

### Density of zooplankton

Zooplankton population density values during the Post-monsoon 2022 at the 15 sampling sites ranged from 16,840 No/L to 37,280 No/L with an overall average of 24,523 No/ L (Table 5). Station-wise, the highest density of 37,280 No/ L was recorded in S-14 and lowest density was reported at S-1 (16,480 No/ L) (Figure 14).

### Diversity Index

The Shannon diversity index of the zooplankton ranged between 3.05 to 3.34. Similarly, Margalef and Menhinick species richness index also varied from 2.98 to 3.77, and 0.19 to 0.26 respectively representing the suspended load environment (Figure 15).



**Figure 14: Zooplankton Density in the different stations during Post-monsoon 2022-2023**

Table 4: Zooplankton generic status during Post-monsoon 2022-2023 in Deendayal Port Authority area

Phylum	Groups	Genera/ name	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15	PC	PO
Protozoa	Foraminifera	<i>Globigerina</i>	2400	320	1120	2880	160	3680	1920	800	480	640	960	160	1440	480	1760	5.2	100
Colenterate	Cnidaria	<i>Obelia</i>	160	0	320	0	160	0	0	160	160	0	0	0	160	0	0	0.3	47
		<i>Physalia</i>	0	0	160	0	0	160	160	0	160	0	0	320	160	0	160	0.3	53
Ciliophora		<i>Tintinnopsis</i>	160	0	0	0	0	0	160	0	0	0	0	160	0	0	0	0.1	20
		<i>Codonellopsis</i>	320	160	320	0	160	320	160	0	0	160	160	320	320	160	0	0.7	73
	Chaetognath	<i>Sagitta</i>	480	320	640	160	160	800	1760	1120	1440	640	800	480	1120	480	320	2.9	100
Annelida	Nematoda	<i>Nematode worm</i>	480	160	0	160	0	0	160	0	320	0	0	160	0	160	160	0.5	53
	Polychaeta	<i>Polychaete larvae</i>	480	2880	640	480	1120	160	320	640	160	640	320	800	480	1120	1760	3.3	100
Arthropoda	Copepoda Calanoida	<i>Acartia</i>	1440	960	800	800	320	1120	800	1600	1760	1280	480	0	800	2720	480	4.2	100
		<i>Acrocalanus</i>	1760	1280	2560	480	2720	960	960	1440	1600	1440	960	800	2720	2080	1760	6.4	
		<i>Aetideus</i>	640	320	480	1280	800	960	1120	1600	320	480	640	1760	1440	800	480	3.6	
		<i>Calanopia</i>	640	320	160	160	1120	480	800	1120	160	320	480	1120	800	480	640	2.4	
		<i>Calanus</i>	800	800	320	1120	800	1600	1760	1280	480	0	800	2720	480	1440	1120	4.2	
		<i>Centropages</i>	320	160	320	320	160	160	480	800	160	160	320	640	1600	2080	1120	2.4	
		<i>Eucalanus</i>	640	320	160	160	1120	480	800	1120	160	320	480	1120	800	480	640	2.4	
		<i>Labidocera</i>	320	320	160	160	320	480	160	800	640	320	320	160	160	640	160	1.4	
		<i>Nannocalanus</i>	320	1120	800	1600	1760	1280	480	0	800	2720	480	640	800	960	1120	4.0	
		<i>Paracalanus</i>	480	320	160	160	160	320	160	320	320	640	480	480	320	160	320	1.3	
		<i>Pseudodiaptomus</i>	480	480	160	320	320	160	480	480	160	320	320	160	320	160	160	1.2	
		<i>Temora</i>	640	320	480	1280	800	960	1120	1600	320	480	640	1760	2880	1440	480	4.1	
		<i>Tomopteris</i>	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0.0	
	Copepoda Harpacticoida	<i>Corycaeus</i>	0	0	160	0	0	160	0	320	0	160	0	160	0	0	160	0.3	40
		<i>Clytemnestra</i>	320	160	320	0	160	160	0	0	0	160	0	160	320	160	0	0.5	60
		<i>Euterpina</i>	160	0	160	320	0	320	0	320	480	160	0	160	640	320	160	0.9	73
		<i>Microsetella</i>	0	0	0	160	0	320	0	160	0	160	0	160	160	320	160	0.4	53
	Copepoda- Cyclopoida	<i>Oithona</i>	0	160	0	0	0	0	160	0	160	0	320	0	160	0	0	0.3	33
		<i>Oncaea</i>	0	0	0	0	160	0	160	0	0	0	0	160	160	320	160	0.3	40

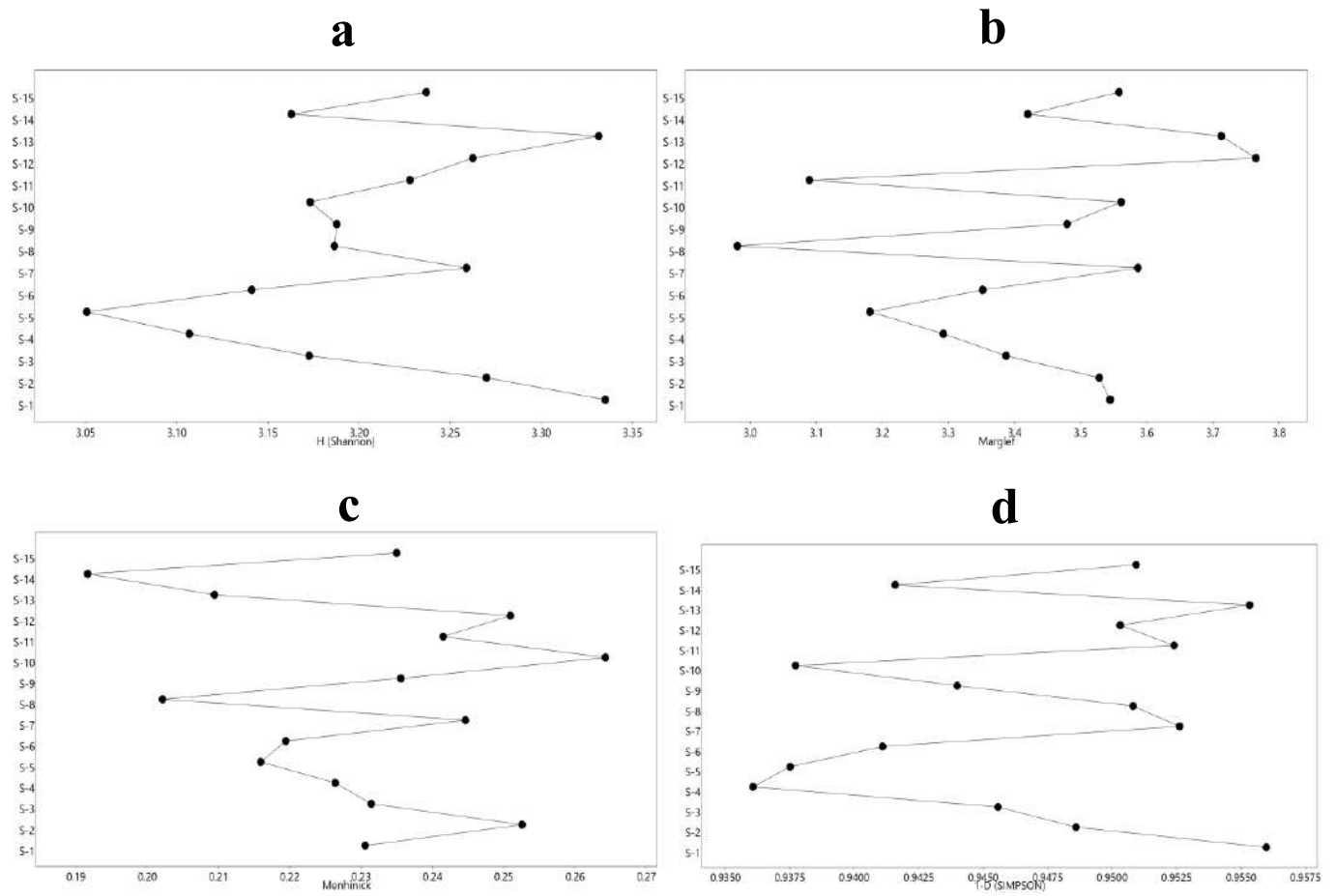


**Deendayal Port Authority 2<sup>nd</sup> Year Post-Monsoon (October2022-January2023)**

	<b>Decapoda</b>	<i>Caridean larvae</i>	640	320	160	480	640	800	160	320	1120	320	640	160	640	320	800	2.0	100
		<i>Euphausia</i>	1600	320	1440	320	640	1920	640	320	3360	2400	1920	1760	1280	5600	2240	7.0	100
		<i>Lucifer</i>	160	640	0	640	320	0	160	0	160	320	160	0	160	160	1600	1.2	73
		<i>Megalopa larva</i>	160	0	160	0	0	160	160	0	160	0	0	160	320	160	0	0.4	53
		<i>Mysis</i>	480	320	1440	320	160	160	160	0	160	320	0	160	160	160	160	1.1	87
		<i>Nauplius larvae</i>	960	320	640	480	160	0	800	320	160	160	640	160	1440	640	320	2.0	93
		<i>Phyllosoma larva</i>	0	160	0	320	0	0	160	0	0	160	0	0	160	0	160	0.3	40
		<i>Zoea larvae</i>	1120	800	320	640	160	480	160	320	1120	800	160	800	960	320	640	2.4	100
	<b>Branchiopoda</b>	<i>Cladocera</i>	480	1280	1600	480	2400	160	0	640	1120	320	160	960	1440	800	1120	3.5	93
	<b>Thecostraca</b>	<i>Cirriped nauplius</i>	640	320	160	160	0	320	640	800	320	160	480	160	1120	800	160	1.7	93
<b>Mollusca</b>	<b>Gastropoda</b>	<i>Creseis</i>	160	160	0	0	160	320	0	160	0	320	0	160	0	320	480	0.6	60
		<i>Gastropod larvae</i>	1920	640	320	3360	2400	1920	1600	320	1440	320	640	1280	2080	1760	1280	5.8	100
	<b>Bivalvia</b>	<i>Bivalve larvae</i>	1280	480	1440	960	320	320	1120	640	800	320	160	640	640	1760	160	3.0	100
		<i>Veliger Larva</i>	320	960	640	160	640	160	320	320	1120	320	160	960	1760	1440	160	2.6	100
	<b>Chordata</b>	<i>fish larvae</i>	160	1280	1760	640	800	2080	1440	1120	800	320	1120	1280	3360	2880	1760	5.7	1000
<b>Appendicularia</b>		<i>Oikopleura</i>	1440	640	2080	800	1920	1120	960	2400	640	160	800	640	1920	2400	320	5.0	100
		<i>Copelata</i>	0	160	0	160	0	0	160	0	320	480	160	160	0	0	0	0.4	47
<b>Total Density</b>			25760	20320	22880	22560	23360	25440	22880	23520	23360	18560	16480	24160	36480	37280	24800		
Total genera			37	36	35	34	33	35	37	31	36	36	31	39	40	37	37		

**PC: Percentage of composition**

**PO: Percentage of Occurrence**



**Figure 15: Diversity indices of Zooplankton**

**a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index**

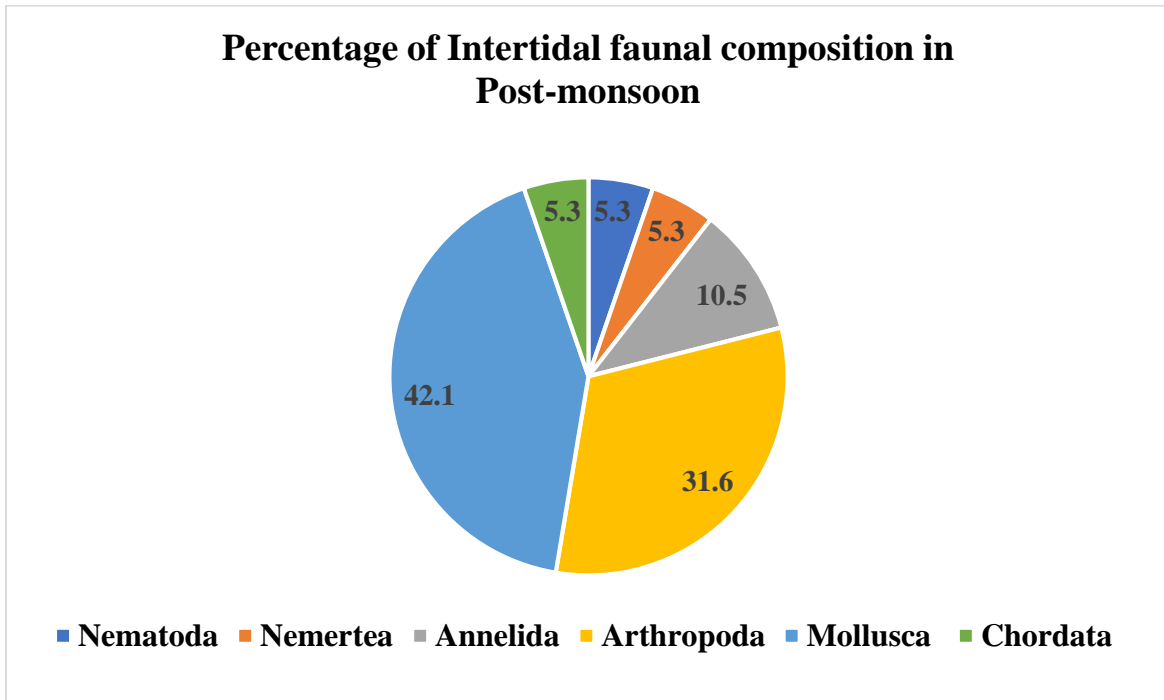
### 3.6. Intertidal Fauna

The intertidal zone is the area above the water level at low tide and submerged at high tide. Intertidal habitats are found along the margins of the sea and include rocky shores, mudflats, salt marshes, and estuaries. The intertidal diversity was documented during Post-monsoon at the prefixed 15 sampling locations within the DPA jurisdiction. All the macroinvertebrates and vertebrate samples were collected from the sampling stations during the low tide. At each site, 1x 1 m<sup>2</sup> quadrat was placed randomly, and all visible macro-faunal organisms encountered inside the quadrat were identified, counted and recorded. At each site along the transects that run perpendicular to the waterfront, three to six replicate quadrat samples were assessed for the variability in macro-faunal population structure (Davidson *et al.*, 2004; Ravinesh and Biju Kumar, 2013). The density of the different faunal groups was averaged for the entire intertidal belt. Organisms, which could not be identified in the field, were preserved in 5% formaldehyde, brought to the laboratory and identified using standard identification keys (Abott, 1954; Vine, 1986; Oliver, 1992; Rao, 2003; 2017; Psomadakis *et al.*, 2015; Apte, 2012; 2014; Naderloo 2017; Ravinesh *et al.*, 2021; Edward *et al.*, 2022). The invertebrates' taxonomic composition, relative abundance, species richness and diversity were determined (Zar, 1984) to describe the mangrove environment's overall biodiversity at DPA premises. Statistical analyses such as diversity indices and richness were calculated using Paleontological Statistics Software Package for Education and Data (PAST) version 3.2.1 (Hammer *et al.*, 2001).

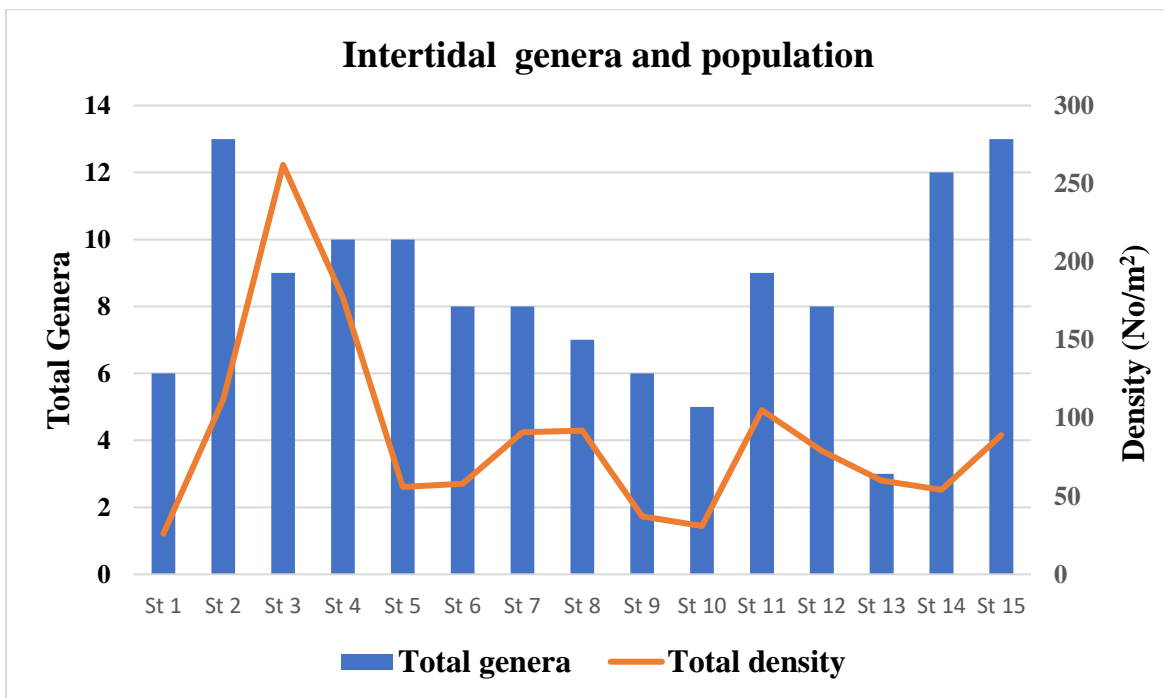
#### Intertidal Fauna

##### Composition of intertidal Fauna

The intertidal ecological survey has been conducted at the prefixed 15 locations within the vicinity of the Deendayal Port Authority. The species diversity of the invertebrate phyla showed the maximum for phylum Mollusca (8 species) which is followed by Arthropoda (6 species), Annelida (1 species), Nematoda (1 species) and Nemertea (1 species). The phylum Chordata (1) was represented by a single species. The percentage composition of the phyla represented in the samples varied from 5.3% to 42.1%. Among the fauna the highest percentage was contributed by Mollusca (42.1%) followed by Arthropoda (31.6%) and least percentage was due to Nematoda, Nemertea and Chordata (each 5.3%) in the study area during post monsoon (Table 5 & Fig.16).



**Figure 16: Intertidal Faunal composition (percentage) during post-monsoon 2022-2023**



**Figure 17 Intertidal genera and population density in Post-monsoon 2022-2023**

### Intertidal genera and total Population density in (No/m<sup>2</sup>)

The population density of intertidal fauna recorded during the post monsoon survey are presented in Fig17. The total genera of intertidal fauna varied from 3 to 13 at the different sampling sites and the average being 8 genera. Highest number of genera was recorded in station S-15 & S-2 followed by S-14,S4 and S-5 (10 each). Least number of genera (3) was recorded at the station S-13. Similarly the density of intertidal fauna varied from 26 No/m<sup>2</sup> to 262 No/m<sup>2</sup> with average variation of 89 No/m<sup>2</sup>. The highest population density was recorded at S-3 and lowest population density was recorded at S-1

### Percentage composition of species

The percentage composition of intertidal species presented in Fig 18. The overall percentage composition of the four groups of intertidal Fauna at the 15 stations varied from 0.1% to 33.6%. The highest percentage was contributed by the species *Pirenella cingulata* (33.6%) followed by *Optediceros breviculum* (13.5%) and *Amphibalanus amphitrite* (10.9% and the lowest percentage was represented by *Metaplex indica* (0.1%).

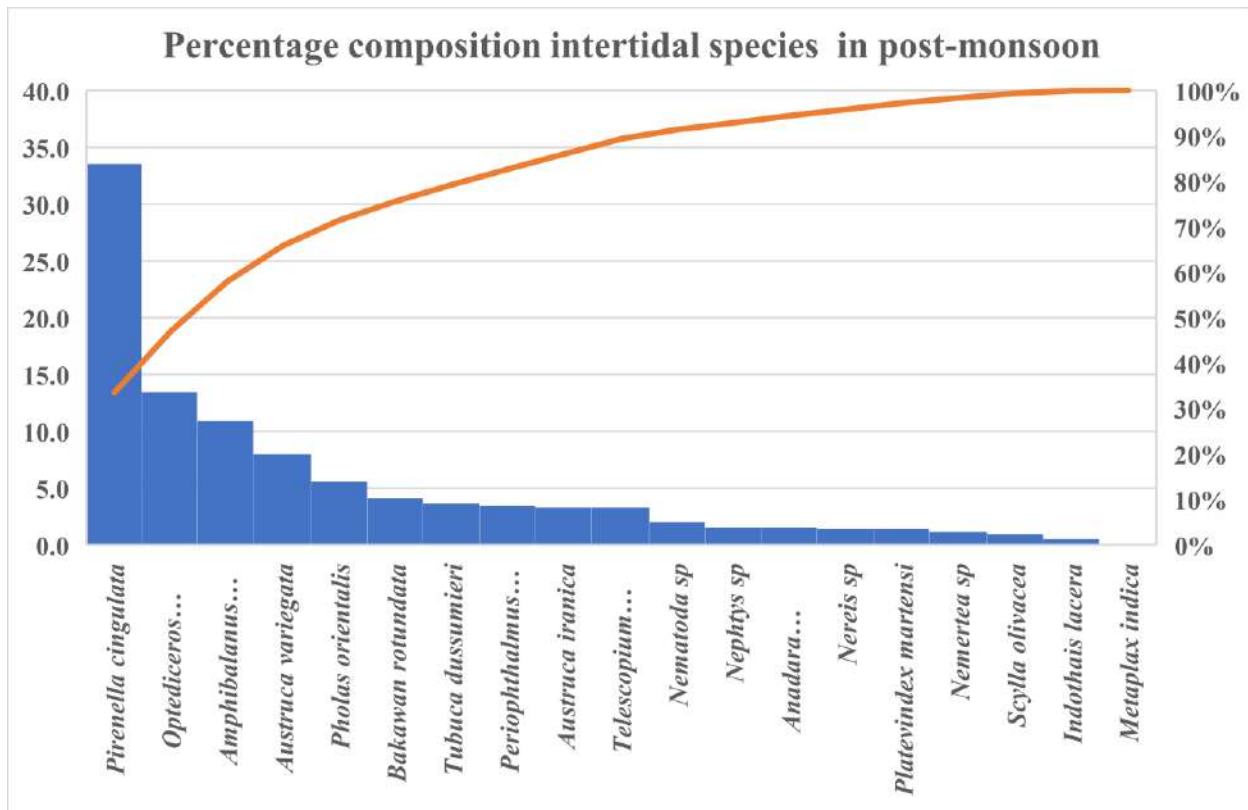
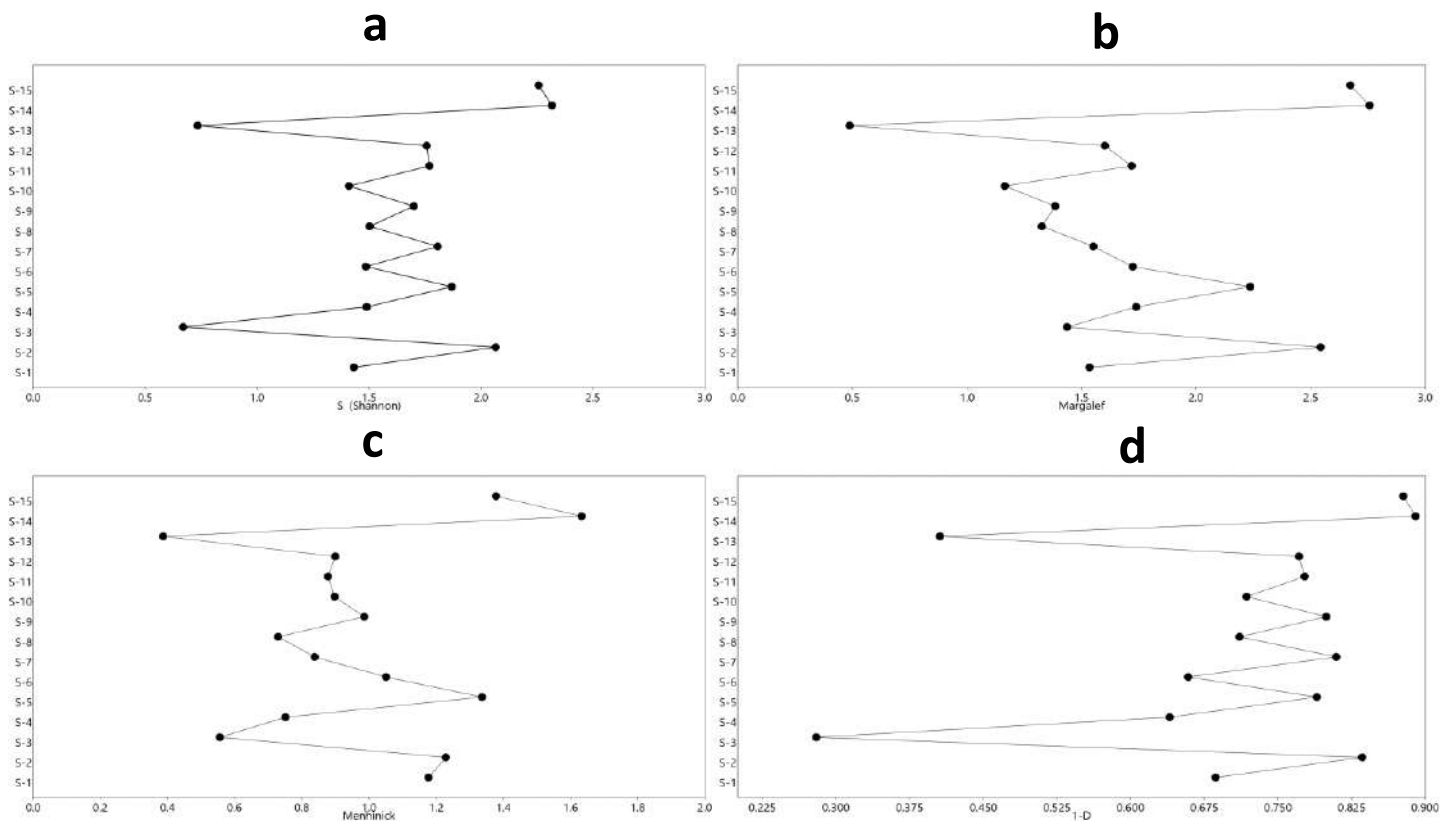


Figure 18: Percentage composition of Intertidal species during post-monsoon 2022-2023

## Diversity indices

Figure .19 represents the various intertidal diversity indices calculated for the different fauna recorded from the 15 sites adjoining the DPA port area, Kandla. Diversity indices were calculated for the subtidal fauna in which the Shannon diversity ( $H'$ ) values varied from 0.67 (S-3) to 2.32 (S-14). The Simpson\_1-D varied from 0.28 (S -3) to 0.89 (S-14). The menhinick index varied from 0.39 to 1.63, with the maximum in S-14 and the minimum at S-13. The Margalef index ranged from 0.49 to 2.76, the maximum at S-15 and the minimum at S-13.



**Figure 19: Diversity indices of Intertidal fauna during post-monsoon 2022-2023**

**a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index**

Table 5: Intertidal faunal distribution along Deendayal Port Authority area during Post-monsoon 2022-2023

Phylum	Species	S-1	S-2	S-3	St 4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	St 12	S- 13	S-14	S- 15	PC	PO
<b>Nemertea</b>	<i>Nemertea</i> sp	0	0	1	2	0	1	0	0	0	2	0	3	0	3	3	1.1	47
<b>Nematoda</b>	<i>Nematoda</i> sp	0	13	0	0	3	1	0	2	0	5	0	0	0	1	2	2.0	47
<b>Annelida</b>	<i>Nereis</i> sp	3	0	0	3	2	0	0	6	0	0	0	4	0	0	1	1.4	40
	<i>Nephtys</i> sp	0	4	3	0	0	4	0	0	3	0	3	0	0	3	0	1.5	40
<b>Arthropoda</b>	<i>Scylla olivacea</i>	0	1	0	0	4	0	2	0	0	0	3	0	0	3	0	1.0	33
	<i>Austruca variegata</i>	0	10	4	7	1	0	11	21	5	8	11	9	0	3	16	8.0	80
	<i>Austruca iranica</i>	0	32	0	0	0	0	0	0	0	3	0	7	0	1	1	3.3	33
	<i>Metaplax indica</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	7
	<i>Amphibalanus amphitrite</i>	0	23	0	31	21	0	0	42	0	0	0	14	0	0	14	10.9	40
	<i>Tubuca dussumieri</i>	0	1	2	7	11	0	0	13	0	0	0	6	0	0	9	3.7	47
<b>Mollusca</b>	<i>Pirenella cingulata</i>	0	0	221	100	0	6	26	3	5	0	34	0	45	6	0	33.6	60
	<i>Telescopium telescopium</i>	2	0	3	5	0	0	11	0	6	0	7	0	7	0	3	3.3	53
	<i>Indothais lacera</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0.5	13
	<i>Bakawan rotundata</i>	2	3	2	0	3	3	22	0	0	0	8	0	0	9	3	4.1	60
	<i>Platevindex martensi</i>	0	0	3	0	3	0	2	0	0	0	4	0	0	4	3	1.4	40
	<i>Optediceros breviculum</i>	13	11	23	11	1	32	0	0	12	0	32	32	0	0	12	13.5	67
	<i>Anadara inaequalis</i>	0	2	0	4	0	5	0	5	0	0	0	4	0	0	0	1.5	33
	<i>Pholas orientalis</i>	5	9	0	0	7	0	12	0	0	13	0	0	8	7	13	5.6	47
<b>Chordata</b>	<i>Periophthalmus waltoni</i>	0	2	0	7	0	6	5	0	6	0	3	0	0	8	9	3.5	53
<b>Density /m2</b>		<b>26</b>	<b>112</b>	<b>262</b>	<b>177</b>	<b>56</b>	<b>58</b>	<b>91</b>	<b>92</b>	<b>37</b>	<b>31</b>	<b>105</b>	<b>79</b>	<b>60</b>	<b>54</b>	<b>89</b>		
<b>Total genera</b>		<b>6</b>	<b>13</b>	<b>9</b>	<b>10</b>	<b>10</b>	<b>8</b>	<b>8</b>	<b>7</b>	<b>6</b>	<b>5</b>	<b>9</b>	<b>8</b>	<b>3</b>	<b>12</b>	<b>13</b>		

### **3.7. Subtidal Fauna (Macrobenthos)**

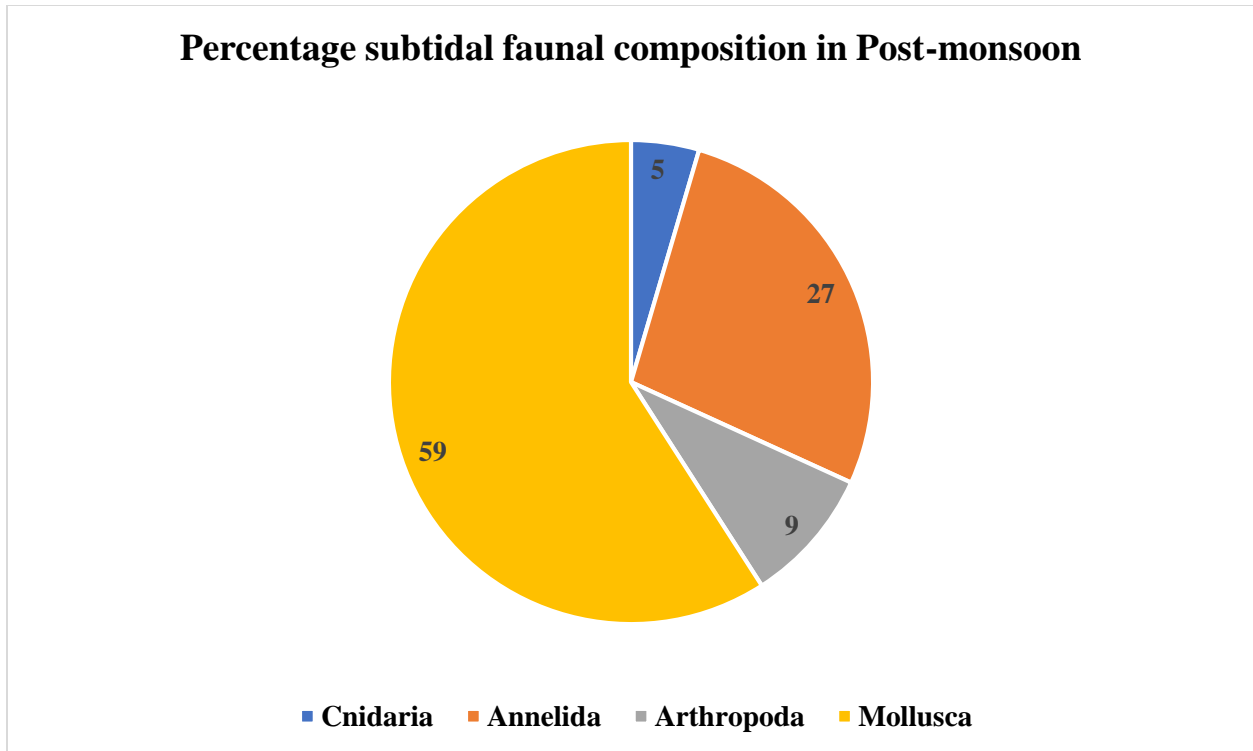
Subtidal ecosystems are permanently submerged due to tidal influence, whereas intertidal ecosystems are found between the high tide and low tide, experiencing fluctuating influences of land and sea. Macrobenthos are an important component of estuarine and marine ecosystems. At large scales, food may be the prime limiting factor for benthic biomass. Depending on the system's characteristics, grazing by benthic suspension feeders may be the most important factor determining system dynamics. The sampling methods and procedures were designed in such a way as to obtain specimens in the best possible condition to maximize the usefulness of the data obtained. For studying the benthic organisms, triplicate samples were collected at each station using Van Veen grab, which covered an area of 0.04m<sup>2</sup>. The wet sediment was passed through a sieve of mesh size 0.5 mm for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal dye for the ease of spotting at the time of sorting (Ravinesh and Biju Kumar, 2022). The number of organisms in each grab sample was expressed as No /m<sup>2</sup>. All the species were sorted, enumerated and identified by following available literature. The works of Day (1967), Hartman (1968, 1969), Rouse and Pleijel (2001), Robin et al., (2003), Amr (2021), were referred for polychaetes; Crane (1975), Holthuis (1993), Naderloo (2017). Xavier *et al.*, (2020) for crustaceans; Subba Rao (1989, 2003, 2017), Apte (2012,2014), Ramakrishna and Dey (2007), Ravinesh *et al.* (2021) and Edward *et al.*, (2022). for molluscs. Statistical analyses such as diversity indices and quadrat richness were calculated using Paleontological Statistics Software Package for Education and Data (PAST) version 3.2.1 (Hammer *et al.*, 2001).

#### **Subtidal macrobenthos**

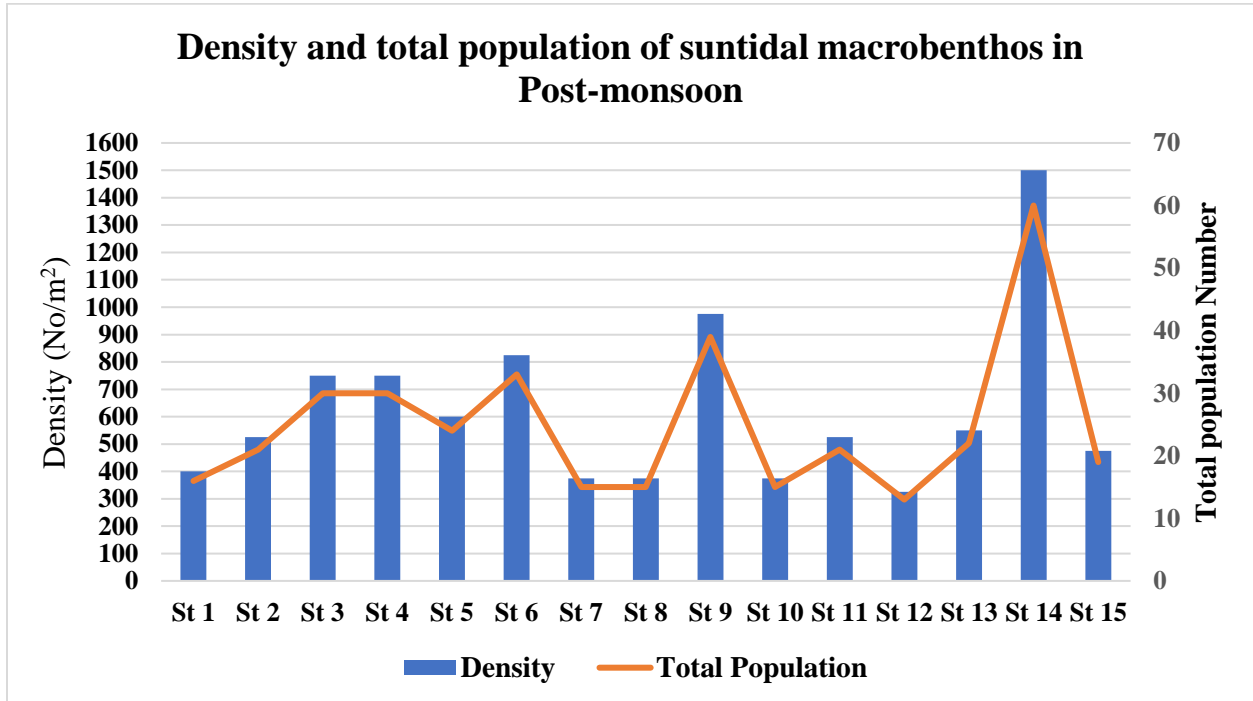
##### **Phylum composition of subtidal Fauna**

The subtidal macrofauna survey was conducted at 15 locations within the vicinity of the Deendayal Port Authority. The species diversity calculated was maximum for phylum Mollusca (13 species) which is followed by Annelida (6species) and Arthropoda (2 species),The Cnidaria was represented by a single species (Table.6). The fanatic composition varied from 5% to 59%. Among the fauna the highest percentage of contribution was contributed by Mollusca (59%) followed by Annelida (27%) and least number of percentage was contributed by Cnidaria (5%) ( Fig 20. )





**Figure 20. Phylum composition of subtidal macrobenthos during Post-monsoon 2022-2023**



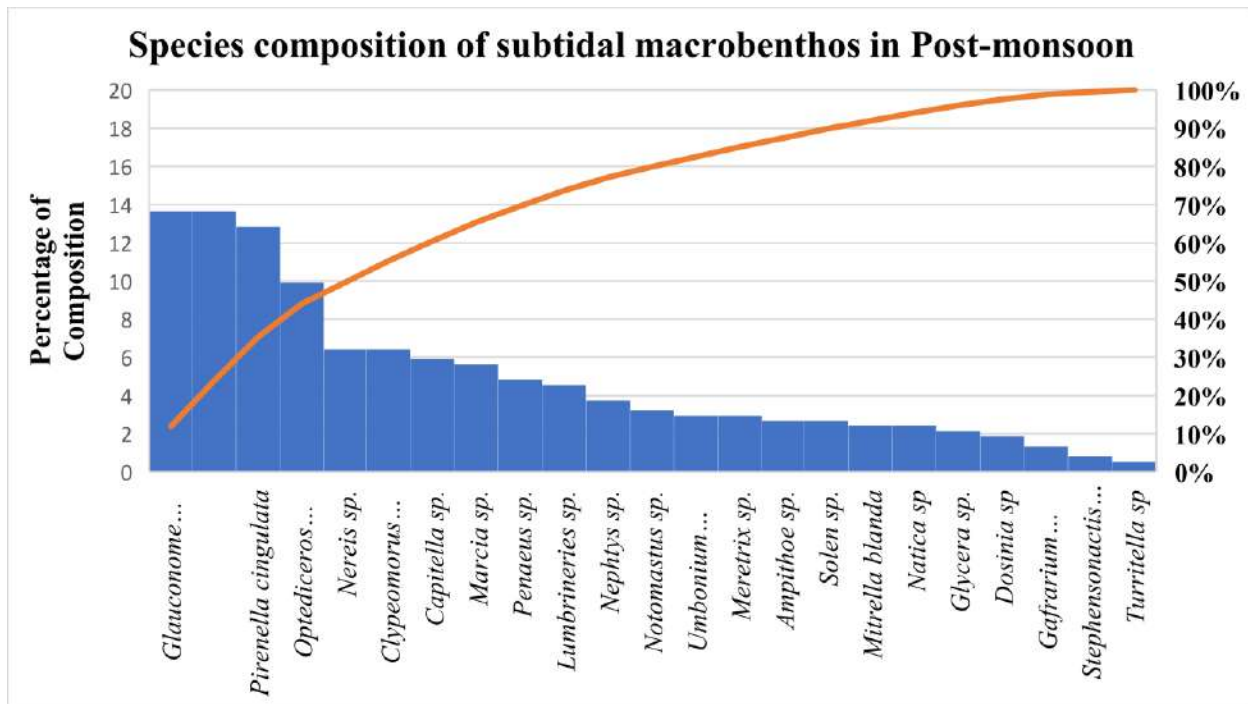
**Figure 21: Total genera and population density macrobenthos during Post-monsoon 2022-2023**

### Total genera & population density (No/m<sup>2</sup>)

The number of intertidal fauna population collected from the intertidal zone and its density are presented in Fig 21. The total genera of subtidal fauna varied from 6 to 116 with average of 9 number. Highest number of genera was recorded in station S-14 (16) and lowest number of genera was recorded along the station S-7 (3 No). Similarly the total population of subtidal fauna varied from 13-60 number with average variation of 25 number. Highest number of population was recorded at S-14 (60 no) and lowest was recorded at S-12 (13 no). Likewise the subtidal macrobenthos population density varied from 325 No/m<sup>2</sup> to 1500 No/m<sup>2</sup> with average 622 No/m<sup>2</sup>. The highest population density was recorded at S-14 (1500 No/ m<sup>2</sup>) followed by S-9 (975 No/ m<sup>2</sup>) and the lowest density was recorded at S-12 throughout the study period.

### Percentage composition of species

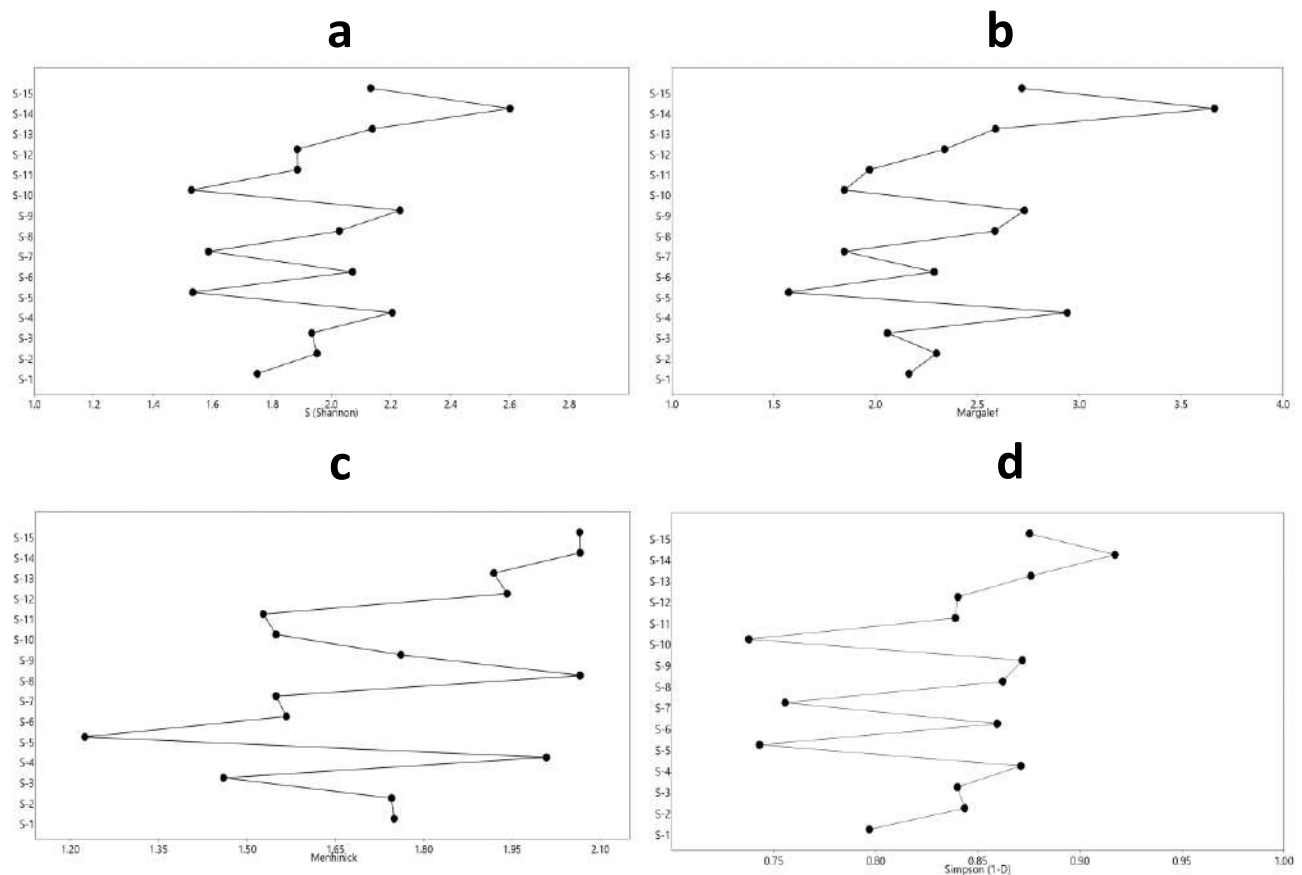
The overall percentage composition of the four groups of subtidal genera/species at the 15 stations varied between 0.5% to 14% with an average of 4.5% (Fig.22). The highest percentage of species composition was contributed *Glaucanome angulata* (13.7%) followed by *Pirenella cingulata* (12.9%) and *Clypeomorus bifasciata* (6.4%) and *Nereis sp.* (6.4%) while the least was (0.5%) represented by *Turritella sp.*



**Figure 22. Percentage composition of Subtidal Macrobenthic species in Post-monsoon 2022-2023**

## Diversity indices

Figure 23 represents the various intertidal diversity indices calculated for the different fauna recorded from the 15 sites adjoining the DPA port area, Kandla. Diversity indices were calculated for the subtidal fauna in which the Shannon diversity ( $H'$ ) values varied from 1.53 (S-10) to 2.60 (S-14). The Simpson\_1-D varied from 0.74 (S -5) to 0.92 (S-14). The menhinick index varied from 1.23 to 2.07, with the maximum in S-14& S-15 and the minimum at S-5. The Margalef index ranged from 1.57 to 3.66, the maximum at S-14and the minimum at S-5.



**Figure 23: Diversity indices of Subtidal fauna during Post-monsoon 2022-2023**

**a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index**

Table 6: Macro-benthic faunal distribution during Post-monsoon 2022 -2023in Deendayal Port Area

Phylum	Genera/Species	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11	St 12	St 13	St 14	St 15	PC
<b>Cnidaria</b>	<i>Stephensonactis</i> sp.	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0.8
<b>Annelida</b>	<i>Capitella</i> sp.	0	3	0	0	3	0	0	0	5	4	3	1	0	3	0	5.9
	<i>Glycera</i> sp.	0	1	0	0	0	0	2	0	2	0	0	0	3	0	0	2.1
	<i>Lumbrineria</i> sp.	1	0	4	3	0	0	1	0	0	2	0	2	2	0	2	4.6
	<i>Nephtys</i> sp.	2	0	2	1	0	3	0	2	3	0	0	0	0	1	0	3.8
	<i>Nereis</i> sp.	0	3	1	1	0	4	0	0	3	1	4	0	4	0	3	6.4
	<i>Notomastus</i> sp.	2	0	0	2	0	3	0	0	2	0	0	0	3	0	0	3.2
<b>Arthropoda</b>	<i>Ampithoe</i> sp.	0	0	0	0	2	0	0	1	3	0	0	2	0	2	0	2.7
	<i>Penaeus</i> sp.	0	2	0	0	1	4	0	0	3	0	2	0	2	1	3	4.8
<b>Mollusca</b>	<i>Umbonium vestiarium</i>	1	0	0	2	0	3	0	1	0	1	0	0	0	3	0	2.9
	<i>Mitrella blanda</i>	0	0	0	0	0	0	0	0	0	0	2	0	0	7	0	2.4
	<i>Clypeomorus bifasciata</i>	0	0	0	0	0	0	0	2	10	0	2	3	0	6	1	6.4
	<i>Natica</i> sp	0	0	0	1	0	0	0	0	0	0	0	0	1	7	0	2.4
	<i>Optedicerus breviculum</i>	4	5	6	4	2	2	3	2	1	0	0	0	0	5	3	9.9
	<i>Pirenella cingulata</i>	5	0	5	6	7	5	1	2	3	1	5	2	3	1	2	12.9
	<i>Turritella</i> sp	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.5
	<i>Marcia</i> sp.	0	0	3	2	0	1	2	3	0	0	0	1	2	5	2	5.6
	<i>Glaucanome angulata</i>	0	2	7	6	9	8	6	2	0	6	3	2	0	0	0	13.7
	<i>Dosinia</i> sp	0	0	2	2	0	0	0	0	0	0	0	0	0	3	0	1.9
	<i>Gafrarium divaricatum</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	1.3
	<i>Meretrix</i> sp.	0	4	0	0	0	0	0	0	0	0	0	0	0	6	1	2.9
	<i>Solen</i> sp.	0	0	0	0	0	0	0	0	4	0	0	0	0	6	0	2.7
Density No/m <sup>2</sup>		400	525	750	750	600	825	375	375	975	375	525	325	550	1500	475	
Total Population		16	21	30	30	24	33	15	15	39	15	21	13	22	60	19	
Total genera		7	8	8	11	6	9	6	8	11	6	7	7	9	16	9	

### 3.8. Seaweeds

Along the Gujarat coast which is represented by 1600 km coastline, harbors 198 species of which 109 species from 62 genera belonging to Rhodophyta, 54 species of 23 genera to Chlorophyta, and 35 species from 16 genera to Ochrophyta (Jha *et.al.*,2009). According to Mantri *et.al.* (2020) there are 13 potential sites for the occurrence of seaweed density and diversity. The survey conducted by CSIR-CSMCRI (Jha *et.al.*, 2009) confirmed the presence of industrially important taxa, namely, *Gelidiella acerosa*, *Gelidium micropterum*, *G. pusillum*, *Ahnfeltia plicata*, *Gracilaria dura*, *G. debilis*, *Gracilariopsis longissima* (formerly *G. verrucosa*), *Hypnea musciformis*, *Meristotheca papulosa*, *Porphyra sp*, *Asparagopsis taxiformis* (Rhodophyta), *Sargassum tenerrimum*, *S. plagiophyllum*, *S. swartzii*, *Turbinaria ornata* (Ochrophyta), *Ulva prolifera* (formerly *Enteromorpha prolifera*), *Ulva compressa* (formerly *Enteromorpha compressa*), and *Ulva flexuosa* (formerly *Enteromorpha tubulosa*) (Chlorophyta) from the coastal waters of Gujarat. In the present study, an attempt was made to describe the occurrence, diversity and other ecological features of seaweeds within Deendayal Port jurisdiction. It was found that except for some drifted species *Enteromorpha* and *Chaetomorpha* at S-13 and S-14 of Vira coast (Plate-6) no natural seaweed beds are seen in the different locations within DPA environment.

Seaweeds grow in the rocky intertidal and sub tidal habitats that offer a hard substratum for attachment. Low turbidity level in the water column with high nutrient content is a major habitat requirement that enables photosynthesis. Total dissolved solids (TDS) load in the Deendayal Port area creek waters ranged from 32200 to 45700 mg/L and suspended solids value between 140-640 mg/L restricts the photosynthetic activity of seaweeds which are highly sensitive to light. Hence, seaweed formations are absent in the creek systems of the Deendayal Port coastal environment.

### 3.9. Seagrass

Similar to seaweeds, sea grasses were also absent in the creek systems of Deendayal Port area and in the adjacent coastal stretches of Kachchh due to inherent habitat conditions. Sea grasses generally thrive in shallow coastal waters and are adapted to live in submerged conditions from mid intertidal to depth as much as 50 m when light penetration is sufficient; conditions contrary to the one prevailing in Deendayal Port and the nearby creek systems explain the total absence of sea grasses.

### 3.10. Halophytes

The holophytes are the plants that are adopted in coastal estuaries and salt marshes. It is common in arid and desert milieu which often have substantial salt accumulation. Technically it is the plant which has tolerance to moderate to high salt concentration in its growth substrate. Halophytes, that survive to reproduce in environments where the salt concentrations around 200 mM NaCl or more, constitute about 1% of the world's flora. (Timothy *et al.*, 2008). Halophytes are classified based on their growth conditions as obligate halophytes, facultative halophytes, and habitat-indifferent halophytes. In the present study, four major halophytes recorded along the selected Deendayal Port Authority sites during the Post-monsoon sampling, were *Salicornia brachiata*, *Aeluropus lagopoides*, *Salvadora persica* and *Sesuvium portulacastrum*. Among the halophyte species recorded, *Salicornia brachiata* alone was found in the 8 sampling locations. (Table-7 and Plate-12). The percentage of *Salicornia brachiata* was found to be the highest at station S-9 and the lowest in S-11(100%), followed by *Salvadora persica* 20% (S-10) and *Sesuvium portulacastrum* (15% ) at S-12. The halophytes grass *Aeluropus lagopoides* reported at S-11 as 33% from Deendayal Port Authority periphery environment.

**Table 7: Percentage of Halophytes cover in the DPA during Post-monsoon 2022-2-23**

Halophytes	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11	S-12	S-13	S-14	S-15
<i>Aeluropus lagopoides</i>		0	0	0	0	0	0	0	0	0	33	0	0	0	0
<i>Salicornia brachiata</i>		0	10%	52%	81%	0	0	64%	100%	35	100%	0	0	0	66%
<i>Salvadora persica</i>		0	0	0	0	0	0	0	0	20%	0	0	0	0	0
<i>Sesuvium portulacastrum</i>		0	60%	0	0	0	0	0	0	0	0	15%	0	0	0







**a. *Salicornia brachiata* b. *Aeluropus lagopoides* c. *Salvadora persica*  
d. *Sesuvium portulacastrum***

**Plate 7: Halophyte species on the intertidal zone of Deendayal Port Authority area**

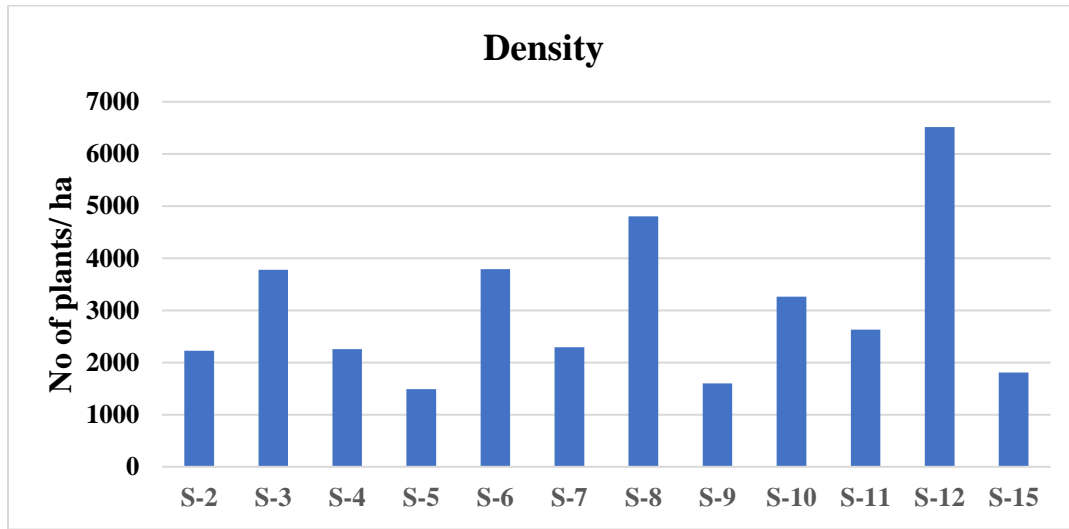


### **3.11. Mangroves**

In India, mangroves are distributed over nine states and three union territories; among those, the state of Gujarat has a longest coastline. With this, two (Gulf of Kachchh and Gulf of Khambhat) out of the three major gulfs of India are located in Gujarat. This makes Gujarat coastal area as one of the most important area in terms of ecology and environment for providing the suitable habitats for various plants and animal species living in coastal environment. Mangroves are found in intertidal areas which protect the coastal areas against various problems such as erosion caused by wind and water currents. With this, mangroves are capable to protect the coast from various natural disasters such as cyclones and tsunamis. They are also play important role as carbon sinks in coastal and intertidal zones. Gujarat shows the second largest mangrove cover of India after the state of West Bengal. This is the success of conservation and development activities had been priorities in the Gujarat for mangroves. Mangrove cover in Gujarat is distributed over a few parts such as Kachchh and Gulf of Kachchh, Saurashtra, and South Gujarat particularly Gulf of Khambhat. Gulf of Kachchh hosts one of the major mangrove formations of India spreading to an area of 980 km<sup>2</sup>. The vegetation characteristics of mangroves of Gulf of Kachchh have been thoroughly studied and documented by GUIDE.

#### **Tree Density**

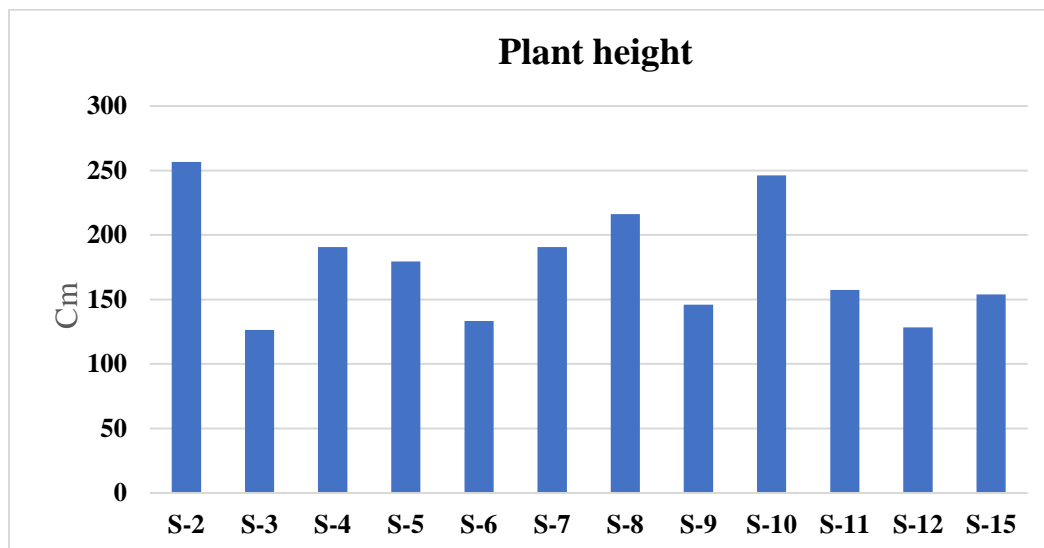
During the post-monsoon 2022-23, total 12 mangrove sites were surveyed for the recoding the plant growth parameters such as height, girth, canopy cover etc and the density of plants. Among the 12 sampling sites, the mean plant density was maximum at Tuna creek (4371/ ha), followed by Jangi creek (3210/ Ha). Considering the sampling sites individually the highest tree density was reported at S12 in the Tuna creek area (6515/Ha). The lowest average tree density of individual sites was reported in S-5 (1491 trees/ Ha) sampling site located at Phang creek. In terms of creeks, the lowest average density was recorded at Kharo creek in which only one sampling site is located S-7 (2291/ha). All these results show that inconsistency in mangroves was with respect to local geomorphology and various ecological and environmental characteristics. (Fig.24 & Table 8).



**Figure 24. Mangrove Plant density during Post-monsoon 2022-2023**

### Height

The overall mean height of the mangroves from study sites along the DPT port environment was 1.8 m during post-monsoon season of 2022 (Fig.25 ). The highest average tree height was recorded at Phang creek area (2.1 m), followed by at Tuna creek (1.9 m). In terms of individual sites, the average highest tree height was recorded at the site S-2 located at Tuna creek, followed by site S-10 located at Phang creek. The average tree heights of the various sites varied between 1.2 m and 2.6 m during the post-monsoon period.



**Figure 25. Plant height during Post-monsoon 2022-2023**

### Canopy Crown Cover

In DPA Kandla sampling area, the canopy cover of mangroves show variations in wide extends. The overall average canopy cover was reported 4.8 m<sup>2</sup> during the post-monsoon 2022. The sites S-12 at Tuna creek, S-3 at Kandla creek and S-6 at Jangi creek showed relatively lower average canopy cover compared to others. The highest average canopy cover was reported at S-2 (Tuna creek) which was ranging from 0.48 m to 22.5 m. The second largest average canopy cover was reported at S-15 site of Kandla creek which was ranging from 4 m to 8.4 m (Fig.26).

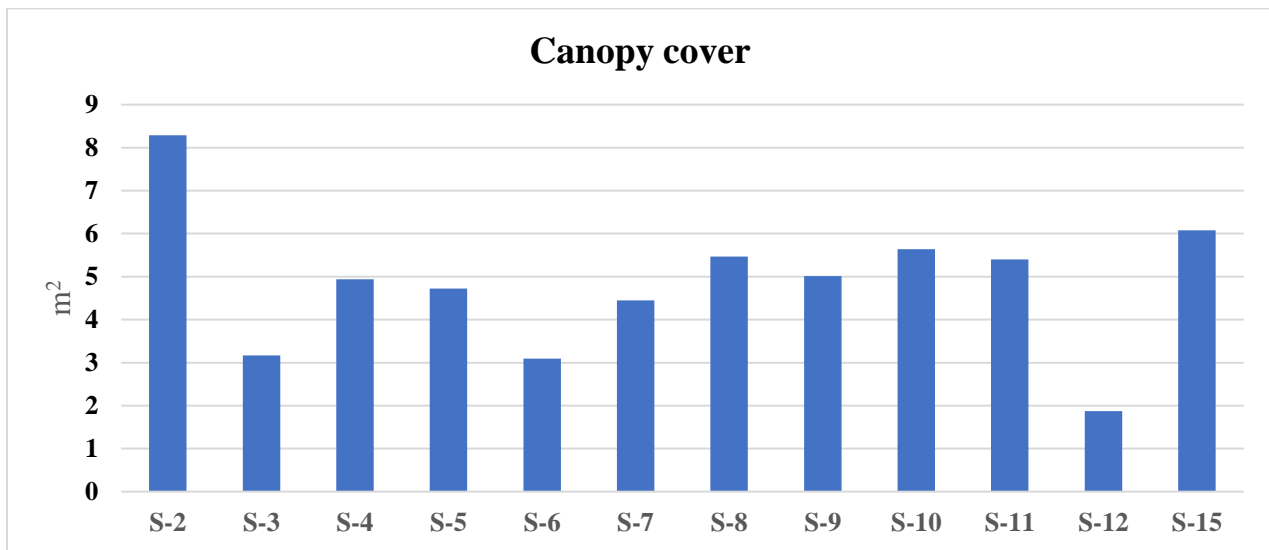
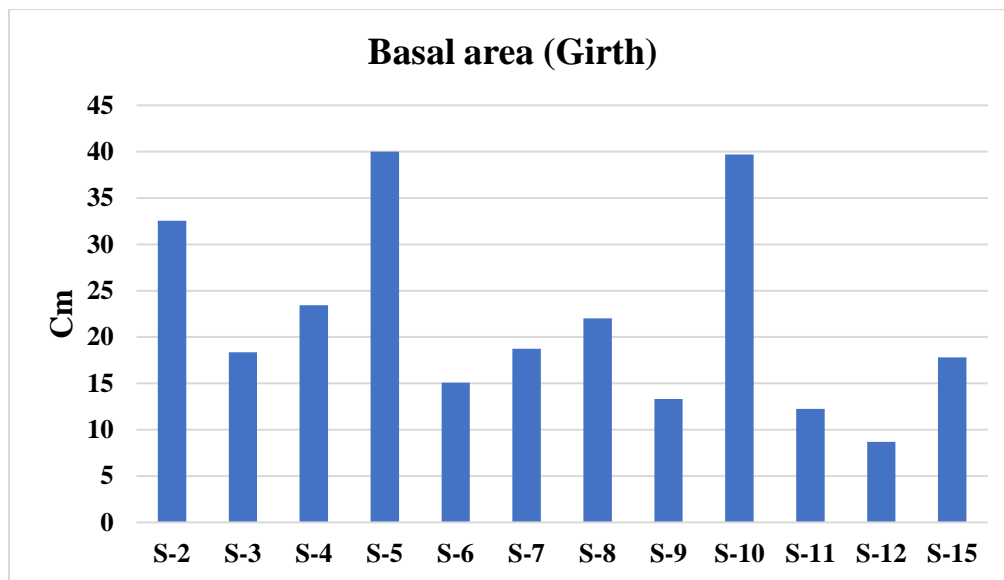


Figure 26. Mangrove canopy cover during Post-monsoon 2022-2023

### Basal area

The overall average basal girth of the mangroves of the DPA sampling sites was reported 21.7 cm. In case of individual sampling sites, the highest average basal area (40 cm) was at site S-5 followed by site S-10 (39.7 cm), located in the Phang creek. The lowest average basal girth was reported in the site S-12 (8.7 cm) of Tuna creek. The mangrove plants have multiple stems pattern which is general characteristics of a few mangrove species particularly *Avicennia marina* which is generally found in the DPA Kandla area (Fig.27).



**Figure 27. Mangrove basal area during Post-monsoon 2022-2023**

#### **Regeneration and Recruitment class**

The overall average regeneration class density was 67829 plants/ha and that of recruitment class 13483 plants/ha. The highest average regeneration class plants were recorded (141000 plants/ha) at S-8 site located in Navlakhi creek and for recruitment class, the highest average plants were recorded at site S-3 (28625 plants/ha) located in the Kandla creek during this post-monsoon season. The highest ratio for tree density to recruitment class was observed at S-3 site while the lowest ratio was observed at S-11 site. The complex hydro-edaphic conditions in the DPA Kandla premises can influence the mangrove stature and are substantiated with infrequent tidal coverage and high evapotranspiration. The availability of regeneration and recruitment class plants in the sampling sites can assure that there are plants to take position of trees in case of any harm to mature plants (Table 9).



**Plate 8: Mangrove species recorded along the Deendayal Port area**

*a. Avicenna marina b. Aegiceras corniculatum c. Ceriops tagal d. Rhizophora mucronata*

**Table 8: Density of mangroves in the DPA vicinity during Post-monsoon 2022-2023**

Sampling stations	Density (Tree/Ha)	Tree height (m)			Canopy cover (m <sup>2</sup> )			Basal Area (cm)		
		Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Tuna creek										
S2	2226.55	130.00	450.00	256.67	0.48	22.50	8.29	7.00	120.00	32.56
S12	6515.31	110.00	180.00	128.33	0.12	5.46	1.87	7.00	12.00	8.67
Mean	4370.93	120.00	315.00	192.50	0.30	13.98	5.08	7.00	66.00	20.62
Phang creek										
S5	1490.74	110.00	310.00	179.50	1.54	10.54	4.72	12.00	110.00	40.00
S10	3265.31	100.00	420.00	246.25	0.56	16.40	5.64	7.00	120.00	39.69
Mean	2378.03	105.00	365.00	212.88	1.05	13.47	5.18	9.50	115.00	39.85
Kandla creek										
S3	3780.86	105.00	210.00	126.32	0.42	15.58	3.17	7.00	80.00	18.37
S4	2256.25	110.00	380.00	190.53	0.40	12.24	4.94	7.00	80.00	23.42
S15	1810.77	110.00	230.00	154.00	3.99	8.40	6.08	10.00	40.00	17.80
Mean	2615.96	108.33	273.33	156.95	1.60	12.07	4.73	8.00	66.67	19.86
Kharo creek										
S7	2290.89	110.00	400.00	190.71	0.54	20.00	4.45	7.00	100.00	18.75
Jangi creek										
S6	3790.74	110.00	290.00	133.39	0.12	9.30	3.09	7.00	45.00	15.09
S11	2629.85	100.00	200.00	157.50	2.04	8.70	5.40	9.00	17.00	12.25
Mean	3210.30	105.00	245.00	145.45	1.08	9.00	4.25	8.00	31.00	13.67
Navlakhi creek										
S8	4805.21	110.00	400.00	216.29	0.72	21.60	5.47	7.00	80.00	22.00
S9	1600.00	105.00	200.00	146.00	2.21	9.60	5.01	9.00	18.00	13.30
Mean	3202.61	107.50	300.00	181.15	1.47	15.60	5.24	8.00	49.00	17.65
Overall average	3011.45	109.31	316.39	179.94	1.01	14.02	4.82	7.92	71.28	21.73

**Table 9: Regeneration and Recruitment class plants during Post-monsoon 2022-2023**

Station	Tree density- No/ha (1)	Regeneration density- No/ha (2)	Recruitment density- No/ha (3)	Ratio of 1:3	Ratio of 2:3
<b>Tuna creek</b>					
<b>S-2</b>	2226.55	140000	11775	1 : 5.29	11.89 : 1
<b>S-12</b>	6515.31	70000	11750	1 : 1.80	5.96 : 1
<b>Mean</b>	4370.93	105000	11763	1 : 2.69	8.93 : 1
<b>Phang creek</b>					
<b>S-5</b>	1490.74	80000	6562	1 : 4.40	12.19 : 1
<b>S-10</b>	3265.31	43000	11250	1 : 3.45	3.82 : 1
<b>Mean</b>	2378.03	61500	8906	1 : 3.75	6.91 : 1
<b>Kandla creek</b>					
<b>S-3</b>	3780.86	46500	28625	1 : 7.57	1.62 : 1
<b>S-4</b>	2256.25	84000	7000	1 : 3.10	12.00 : 1
<b>S-15</b>	1810.77	48000	8750	1 : 4.83	5.49 : 1
<b>Mean</b>	2615.96	59500	14792	1 : 5.65	4.02 : 1
<b>Kharo creek</b>					
<b>S-7</b>	2290.89	45000	22250	1 : 9.71	2.02 : 1
<b>Jangi creek</b>					
<b>S-6</b>	3790.74	54444	12500	1 : 3.30	4.36 : 1
<b>S-11</b>	2629.85	34500	4375	1 : 1.66	7.89 : 1
<b>Mean</b>	3210.30	44472	8438	1 : 2.63	5.27 : 1
<b>Navlakhi creek</b>					
<b>S-8</b>	4805.21	141000	16000	1 : 3.33	8.81 : 1
<b>S-9</b>	1600.00	42000	13500	1 : 8.44	3.11 : 1
<b>Mean</b>	3202.61	91500	14750	1 : 4.61	6.20 : 1
<b>Overall average</b>	3011.45	67828.67	13482.94	1 : 4.48	5.03 : 1



### **3.12. Marine Reptiles**

During the field surveys, one reptilian species, the saw-scaled viper *Echis carinatus sochureki* was recorded at site S-10 located in the western part of Sat Saida bet opposite to Phang creek during Post-monsoon season. This species was spotted on the ground among the mangrove trees. The literature describes the species as aggressive and strikes at a lightning speed, the observed specimen was active.



**Plate 9: Marine reptiles recorded along the Deendayal Port Authority area**



### **3.13. Marine Fishery**

Marine fish production of India during the financial year 2019-2020 was 37.27 lakhs tons (Fisheries statistics 2021). The production varied from 0.2 to 7.01 lakh tons and Gujarat state contributed the highest production (Fisheries statistics 2021). The Ichthyofauna diversity of the Gulf of Kachchh includes a total of 20 orders, 47 families and 96 species (Katira & Kardani 2017). Along the Sikka coast of Jamnagar where 112 ichthyofauna species belonging to 50 families, 12 orders, and 84 genera has been reported. Similarly, the locality of Jamnagar Marine National Park, Gulf of Kachchh reported 109 ichthyofauna species belonging to 58 families, 19 orders, and 93 genera (Brahmane et al. 2014). Apart from this, a recent study conducted by Sidat *et al.*, (2021) reported 96 species which include 20 order and 47 families. During the field observation, in the gill net catches *Mugil cephalus*, *Planiliza klunzingeri*, *Planiliza planiceps*, *Planiliza macrolepis* (Plate 9) were observed of which *Mugil cephalus* catch was the maximum during Post-monsoon season of (100 kg) followed by Lobester(30 kg) and shrimp 30 kg.from the Deendayal port periphery environment by local fishermen (Personal communication)



**Plate 10: Fishery catch along the Deendayal Port Authority in Post-monsoon 2022-2023**

### **3.14. Marine Mammals**

*Sousa plumbea* (Cuvier, 1829) is commonly referred to as the Indian Ocean humpback dolphin. During the field surveys, the Indian Ocean humpback dolphin (*Sousa plumbea*) was recorded at the site between the S-15 and S-5 in phang creek during Post-monsoon season of total 3 number . The length of the humpback dolphin is approximately 1.7 to 2m. Humpback dolphins feed mostly on small fishes, sometimes shrimps; occur mostly in small groups (mostly 12 or less); have limited nearshore movements and in most parts of their range, exhibit a fission/fusion type of social organization. The evaluation of the conservation status of a species and its subsequent listing as a Threatened species is a function of its risk of extinction, which is influenced primarily by population dynamics (population size and trends, population structure) and the key biological and environmental factors influencing those dynamics (distribution, behaviour, life history, habitat use and the effects of human activities). Besides this common dolphin also sighed in our observation.



**Plate 11. Indian Ocean humpback dolphin *Sousa plumbea***

#### **4. Mud flat**

Mudflats and mangroves establish a major ecosystem of the DPA coastal region and the significance of ecosystem services rendered by mudflat is endorsed in Coastal Regulation Zone (CRZ, 2011) as it accords special status to highly productive zone. Mudflat has an assemblage of plant-animal-geomorphological entities. DPA has been surrounded by two major ecosystems such as mangroves and mudflats which support a number of ecosystem services like nursery grounds for fish and shellfishes and breeding/feeding grounds for the birds (Spencer and Harvey, 2012). The TOC concentration is direct indicator of mudflat productivity and blue carbon sequestration.

##### **Bulk density of the sediment samples**

The data on the bulk density of the sediment samples are presented in (Fig.28). The bulk density of mangrove soil at Deendayal Port Authority coastal region in post-monsoon ranged from 1.23g/cm<sup>3</sup> to 1.52 g/cm<sup>3</sup>. The highest bulk density was recorded at S-13 and the lowest bulk density was recorded at site S-1 located at Tuna creek.

##### **Total Organic Carbon (TOC)**

The highest TOC value (0.87%) was recorded at station S-6 followed by S-10 . Lowest TOC value was reported at site S-1 (Fig.29). It is observed that TOC values varied significantly among the sampling stations which means that organic carbon is dependent on the living life forms and variations in the life forms in the mudflats. The TOC concentration is a direct indicator of mudflat productivity and blue carbon sequestration. The data on Post-monsoon samplings revealed that the different sampling sites of Deendayal Port Authority jurisdiction have considerable variations with respect to organic carbon.



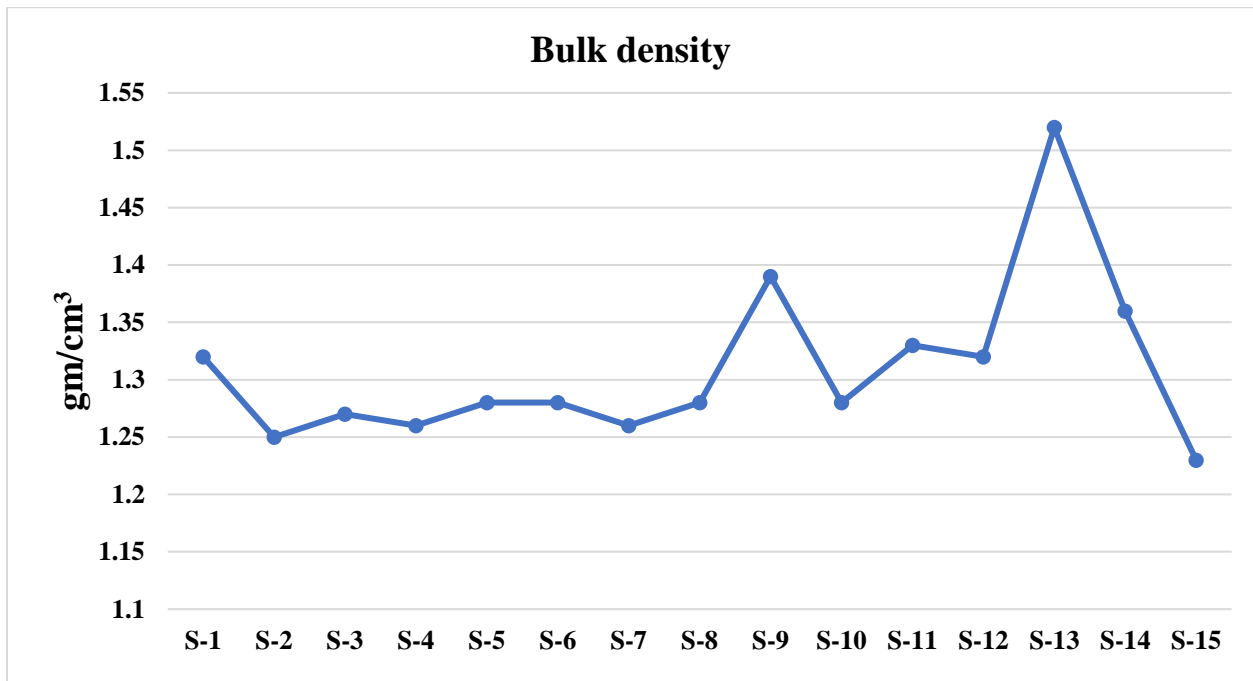


Figure 28: Bulk density of mudflat sediment during Post-monsoon 2022-2023

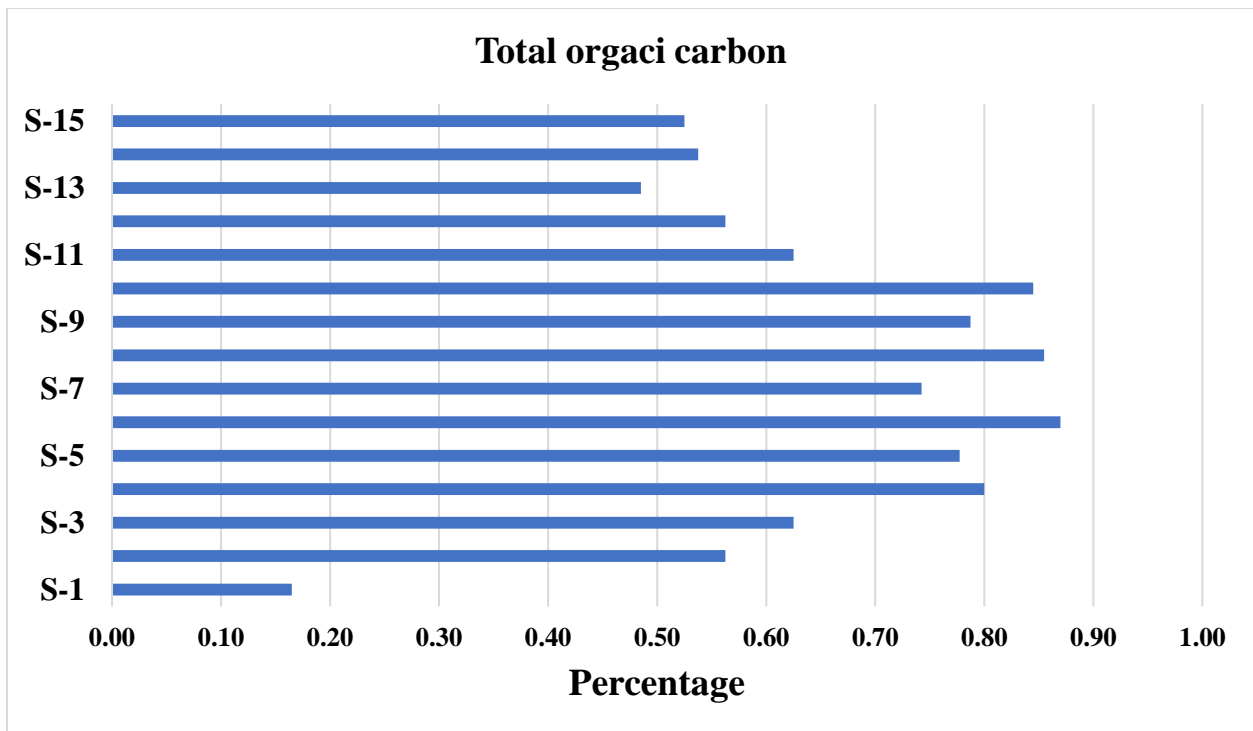


Figure 29: Percentage of Total Organic Carbon in the mudflat in Post-monsoon 2022

## **5. Avifauna**

A total of 79 species belonging to 9 orders, 32 families and 59 genera were recorded from the coastal area of Deendayal Port during this study (Annexure 1). Among these, 49 species were aquatic and 30 species were terrestrial, which included 6 species listed as Near Threatened in the IUCN 2023, Red List. Order Charadriiformes i.e. aquatic birds (including raptors and most water birds) constituted the predominant groups representing 35% of all species recorded from the study area followed by order Passeriformes (24%), Pelecaniformes (19%) and other six orders formed 22% of the recorded species. The families with a greater number of species were Scolopacidae (12 spp.), Ardeidae (8 spp.), Laridae (6 spp.), Charadriidae (5 spp.), Alcedinidae, Hirundinidae, Threskiornithidae each family having (three spp.), six families each having 2 species and eight families each having one species. From the recorded species, 26 species were migrants, 13 species were local migrants or resident migrants, 40 species were breeding resident.

Thirteen (13) kinds of feeding guilds, viz., aquatic invertebrate-feeder, piscivore, insectivore, granivore, frugivore, reptile-feeder, amphibian feeder, nectarivore, weedivore, plankton-feeder, herbivore, carrion-feeder and predatory were identified; among the bird species observed (Ali & Ripley 1987). Here, the aquatic invertebrate guild is the most frequent one with thirty six percent incidence and 31 species occurring under this shared category. Whereas, omnivore, frugivore, granivore, and plankton-feeder guilds are the least frequent with only one species observed in each. Overall mean bird species is 79 calculated from the study area. The overall Shannon diversity ( $H'$ ) is 4.04 with overall species richness index for study area is 9.80. The overall species evenness index value for study area is 0.72 with overall Equitability is 0.92. (Table 10).

### **Status, distribution and diversity of avifauna in different stations:**

Total fifteen sites were surveyed and the results shows that the maximum number of species found from the Site Site 1 (57 spp.) followed by Site 2 (55 spp.), Site 9 (46 spp.), 7 (45 spp.), and. Sites 5 have found lowest avifaunal species (31 spp.) (Fig. 30).

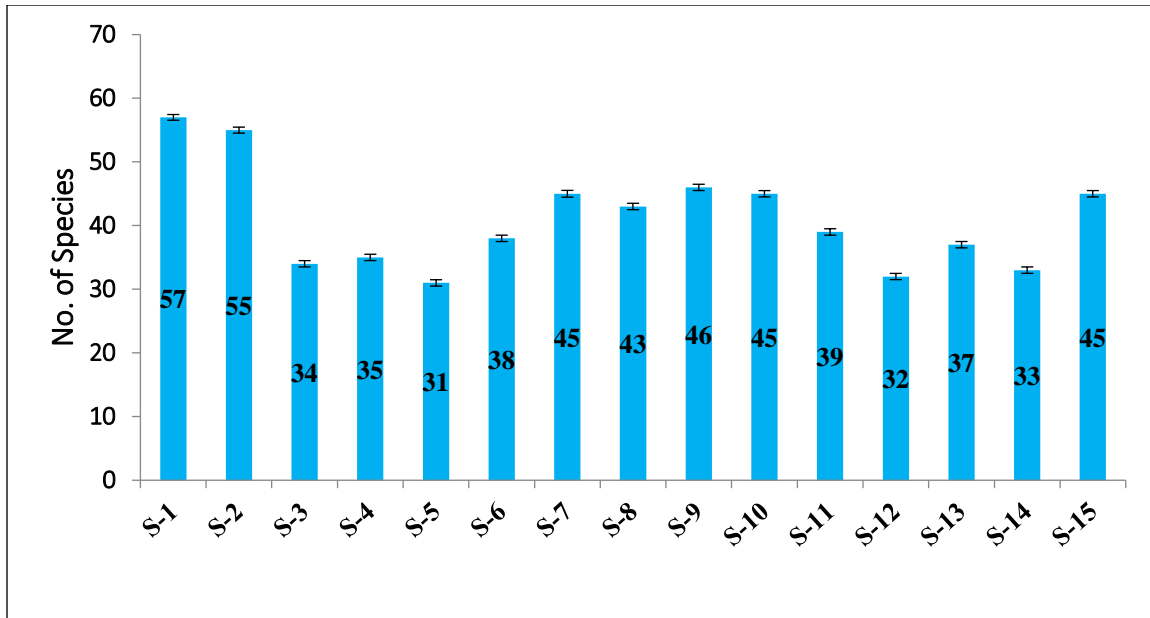


Figure 30. Number of Avian species recorded from the DPA in Post-monsoon2022-2023

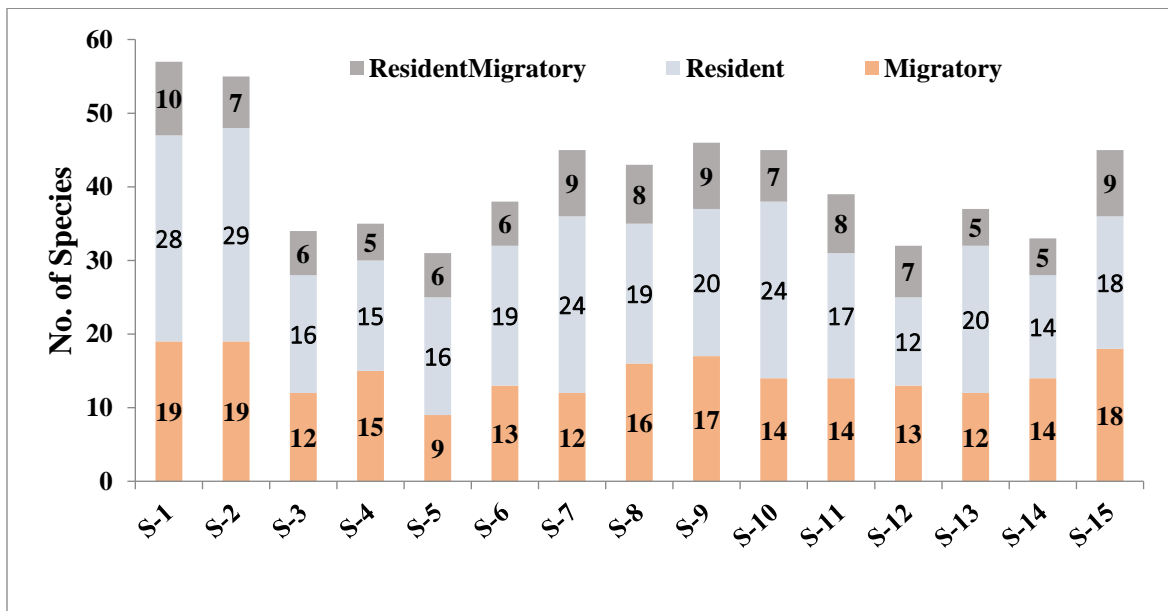
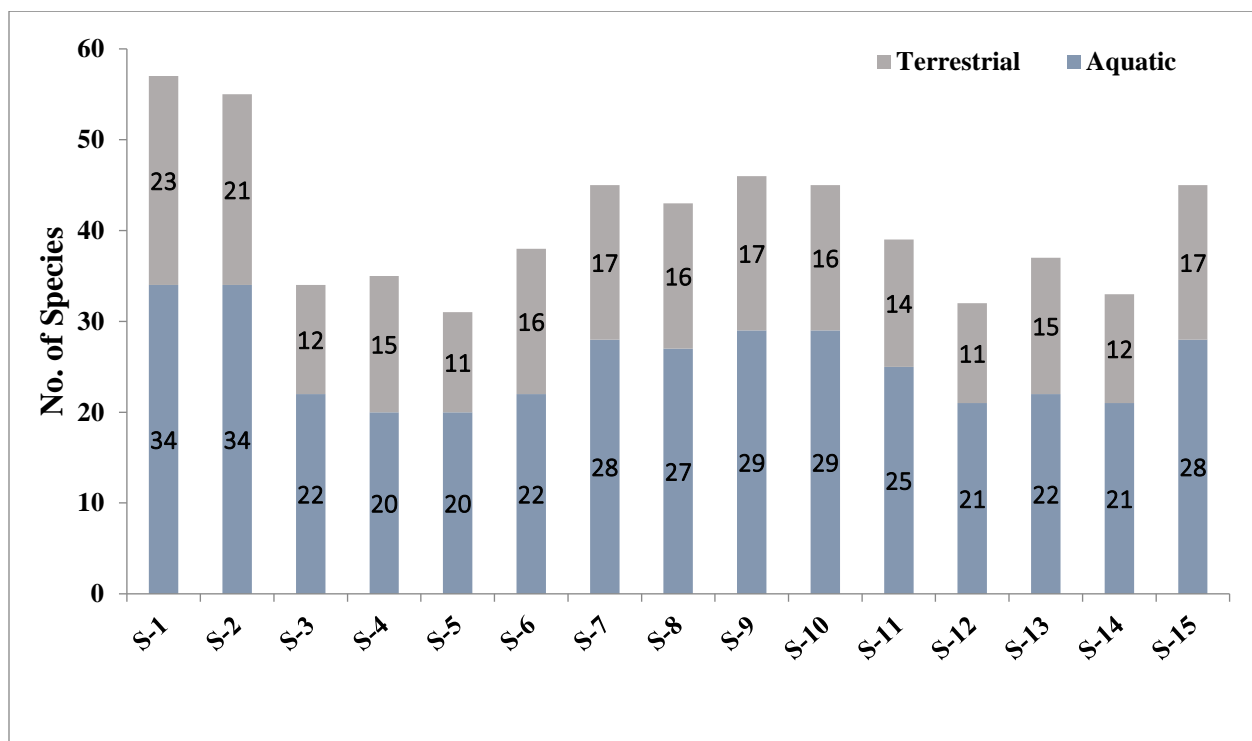


Figure 31. Behavioral status of Avian species from the DPA in Post-monsoon 2022-2023



Each site's wise migratory status was also calculated and the results shows that the maximum migratory species found from the site Site 1&2 (19 spp.) followed by Site 15 (18 spp.), Site 9 (17 spp.) and site 5 (9 spp.) (Fig. 31)..

During the survey we have surveyed both terrestrial habitat like Mangrove plantation adjoining to the Mudflats and waste land, and aquatic habitats like creek area, rivers and wetland. From the study site wise all the species categorised into two habitats i.e. terrestrial and aquatic and the results shows that the maximum terrestrial avifaunal species recorded from the site 1 (23 spp.) and site 2 (21 spp.) followed by site 7,9,15 (17 spp.) and site 6,8,10 (16 spp.). Whereas aquatic avifaunal species recorded more from Site 1 & 2 (34 spp.) followed by site 9,10 (29 spp.), site 7,15 (28 spp.) and site 8 (27 spp.)(Fig. 32)



**Figure 32. Habitat wise distribution of Bird species in Post-monsoon 2022-2023 from DPA**



During the present investigation birds with diverse food habits were observed, viz., Aquatic, Insectivores, Granivores, Piscivores, Frugivores, Omnivores and Nectarivores. All the sites have found more number of species of aquatic plant/insect feeder birds species (maximum 35 species recorded from Site 1&2) followed by Insectivores (Maximum 8 species recorded from Site 1&2), granivore (maximum 8 species recorded from Site 2) and piscivores (maximum 4 species recorded from Site 3,6,8&11) and least species found of frugivores, omnivores and nectarivores.

Data collected from point counts allows us to calculate species diversity, richness and species composition. The results shows that the maximum diversity found from the Site 1 ( $H'$  3.8) followed by Site 2 ( $H'$  3.7) and the minimum diversity recorded from site 7 ( $H'$  2.7) and Site 5 ( $H'$  2.9). The results of species richness shows that maximum species richness recorded from Site 1 (10.38 spp.) and minimum species richness recorded from Site 5 (6.11 spp.). Other diversity indices details were given in the table 10.

**Table 10. Stationwise Diversity Indices recorded from the Deendayal port Area**

<b>Diversity Indices</b>	<b>No. of Species</b>	<b>Individuals</b>	<b>Dominance_ D</b>	<b>Shannon _H</b>	<b>Evenness_ e<sup>H/S</sup></b>	<b>Margalef</b>	<b>Equitability_ J</b>
<b>S-1</b>	57	220	0.03	3.83	0.81	10.38	0.95
<b>S-2</b>	55	269	0.03	3.72	0.75	9.65	0.93
<b>S-3</b>	34	157	0.06	3.18	0.70	6.53	0.90
<b>S-4</b>	35	116	0.04	3.40	0.86	7.15	0.96
<b>S-5</b>	31	135	0.08	2.91	0.59	6.12	0.85
<b>S-6</b>	38	161	0.03	3.49	0.86	7.28	0.96
<b>S-7</b>	45	305	0.17	2.78	0.36	7.69	0.73
<b>S-8</b>	43	204	0.04	3.48	0.75	7.90	0.93
<b>S-9</b>	46	261	0.06	3.28	0.58	8.09	0.86
<b>S-10</b>	45	193	0.04	3.56	0.78	8.36	0.93
<b>S-11</b>	39	174	0.05	3.40	0.77	7.37	0.93
<b>S-12</b>	32	155	0.07	3.09	0.68	6.15	0.89
<b>S-13</b>	37	137	0.03	3.47	0.87	7.32	0.96
<b>S-14</b>	33	155	0.05	3.22	0.76	6.35	0.92
<b>S-15</b>	45	212	0.04	3.53	0.76	8.21	0.93
<b>Total</b>	<b>79</b>	<b>2854</b>	<b>0.02</b>	<b>4.05</b>	<b>0.73</b>	<b>9.80</b>	<b>0.93</b>

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# **Annexure -IV**

**Environmental Monitoring Report (EMR) prepared under “Preparing and monitoring of environmental monitoring and management plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years”**

**Monitoring period (17<sup>th</sup> April-16<sup>th</sup> May, 2023)**

**Document Ref No.: GEMI/DPA/782(2)/2023-24/18**



**Submitted to:**  
**Deendayal Port Authority (DPA), Kandla**



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**“AN ISO 9001:2015, ISO 14001:2015 AND ISO 45001:2018 Certified Institute”**



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## About this Document

Gujarat Environment Management Institute (GEMI) has been assigned with the work of “Preparing and monitoring of Environmental monitoring and Management plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years” by Deendayal Port Authority, Kandla. Under the said project the report titled “*Environment Monitoring Report (17April-16May 2023)*” is prepared.

- **Name of the Report:** *Environment Monitoring Report (April-May 2023)*
- **Date of Issue:** 21/08/2023
- **Version:** 2.0
- **Report Ref.:** GEMI/DPA/782(2)/2023-24/18

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## List of Abbreviations

<b>A</b>	Acceptable Limits as per IS: 10500:2012
<b>AAQ</b>	Ambient Air Quality
<b>AWS</b>	Automatic Weather monitoring stations
<b>BIS</b>	Bureau of Indian Standards
<b>BOD</b>	Biochemical Oxygen Demand
<b>BQL</b>	Below Quantification Limit
<b>CCA</b>	Consolidated Consent & Authorization
<b>CO</b>	Carbon Monoxide
<b>COD</b>	Chemical Oxygen Demand
<b>CPCB</b>	Central Pollution Control Board
<b>DO</b>	Dissolved Oxygen
<b>DPA</b>	Deendayal Port Authority
<b>EC</b>	Electrical Conductivity
<b>EMMP</b>	Environmental monitoring and Management Plan
<b>EMP</b>	Environment Management Plan
<b>FPS</b>	Fine Particulate Sampler
<b>FY</b>	Financial Year
<b>GEMI</b>	Gujarat Environment Management Institute
<b>IFFCO</b>	Indian Farmers Fertiliser Cooperative Limited
<b>IMD</b>	India Meteorological Department
<b>IOCL</b>	Indian Oil Corporation Limited
<b>LNG</b>	Liquefied Natural Gas
<b>MGO</b>	Marine Gas Oil
<b>MMTPA</b>	Million Metric Tonnes Per Annum
<b>MoEF</b>	Ministry of Environment & Forests
<b>MoEF&amp;CC</b>	Ministry of Environment, Forest and Climate Change
<b>NAAQS</b>	National Ambient Air Quality Standards
<b>NO<sub>x</sub></b>	Nitrogen oxides
<b>NTU</b>	Nephelometric Turbidity Unit
<b>OOT</b>	Off Shore Oil Terminal
<b>OSR</b>	Oil Spill Response
<b>P</b>	Permissible Limits as per IS: 10500:2012
<b>PAH</b>	Poly Aromatic Hydrocarbons
<b>PM</b>	Particulate Matter
<b>PTFE</b>	Polytetrafluoroethylene
<b>RCC</b>	Reinforced Concrete Cement
<b>RDS</b>	Respirable Dust Sampler
<b>SAR</b>	Sodium Adsorption Ratio
<b>SBM</b>	Single Bouy Mooring
<b>SO<sub>x</sub></b>	Sulfur oxides
<b>STP</b>	Sewage Treatment Plant
<b>TC</b>	Total Coliforms
<b>TDS</b>	Total Dissolved Solids
<b>TOC</b>	Total organic Carbon
<b>TSS</b>	Total Suspended Solids
<b>VOC</b>	Volatile Organic Compounds

# **CHAPTER 1: INTRODUCTION**

## 1.1 Introduction

Kandla Port, also known as the Deendayal Port is a seaport in Kachchh District of Gujarat state in the western India, near the city of Gandhidham. Located on the Gulf of Kachchh, it is one of major ports on the western coast. The Port is located on the Gulf of Kachchh on the north-western coast of India, 256 nautical miles southeast of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Deendayal Port's journey began in 1931 with the construction of RCC Jetty by Maharao Khengarji. Kandla was constructed in the 1950s as the chief seaport serving western India, after the independence of India. In the year 2007-08 and has retained the top position for the 14<sup>th</sup> consecutive year since then. On 31st March 2016, Deendayal Port created history by handling 100 MMT cargo in a year and became the first Major Port to achieve this milestone. It is the largest port of India by volume of cargo handled. Deendayal Port Authority, India's busiest major port in recent years, is gearing up to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 137 MMTPA (at Kandla and Vadinar) during the financial year 2022-23. The Deendayal Port Authority (DPA) had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant Quantum of infrastructural upgradation has been carried out & excellent maritime infrastructure has been created at Vadinar for the 32MMTPA Essar Oil Refinery in Jamnagar District. DPA, Kandla crossed the landmark 100 MMT in cargo throughput for FY 2022-23 on December 28, 2022, thereby becoming the first Major Port to reach three figures in cargo handling, that too in only 3 quarters of a fiscal year.

## 1.2 Green Ports Initiative

Deendayal Port Authority is committed to sustainable development and adequate measures are being taken to maintain the Environmental well-being of the Port and its surrounding environs. Weighing in the environmental perspective for sustained growth, the Ministry of Shipping had started, Project Green Ports" which will help in making the Major Ports across India cleaner and greener. "Project Green Ports" will have two verticals - one is "Green Ports Initiatives" related to environmental issues and second is "Swachh Bharat Abhiyaan".

The Green Port Initiatives include twelve initiatives such as preparation and monitoring plan, acquiring equipment required for monitoring environmental pollution, acquiring dust suppression system, setting up of sewage/waste water treatment plants/ garbage disposal plant, setting up Green Cover area, projects for energy generation from renewable energy sources, completion of shortfalls of Oil Spill Response (OSR) facilities (Tier-I), prohibition of disposal of almost all kind of garbage at sea, improving the quality of harbour wastes etc.

Deendayal Port Authority had also appointed Gujarat Environment Management Institute (GEMI) as an Advisor for “Making Deendayal Port a Green Port - Intended Sustainable Development under the Green Port Initiatives.

Deendayal Port Authority has also signed MoU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Authority. The plantation is being carried out by the Social Forestry division of Kachchh.

### 1.3 Importance of EMP

Port activities can cause deterioration of air and marine water quality in the surrounding areas due to multifarious activities. The pollution problems usually caused by port and harbour activities can be categorized as follows:

1. Air pollutant emissions due to ship emissions, loading and unloading activities, construction emission and emissions due to vehicular movement.
2. Coastal habitats may be destroyed and navigational channels silted due to causeway construction and land reclamation.
3. Deterioration of surface water quality may occur during both the construction and operation phases.
4. Harbour operations may produce sewage, bilge wastes, solid waste and leakage of harmful materials both from shore and ships.
5. Human and fish health may be affected by contamination of coastal water due to urban effluent discharge.
6. Oil pollution is one of the major environmental hazards resulting from port/harbour and shipping operations. This includes bilge oil released from commercial ships handling non-oil cargo as well as the more common threat from oil tankers.
7. Unregulated mariculture activities in the port and harbour areas may threaten navigation safety.

Hence, for the determination of levels of pollution, identification of pollution sources, control and disposal of waste from various point and non-point sources and for prediction of pollution levels for future, regular monitoring and assessment are required during the entire construction and operation phase of a major port. As per the Ministry of Environment, Forest and Climate Change (**MoEF&CC**), The Environmental Management Plan (EMP) is required to ensure sustainable development in the area surrounding the project. Hence, it needs to be an all encompasses plan consist of all mitigation measures for each item wise activity to be undertaken during the construction, operation and the entire life cycle to minimize adverse environmental impacts resulting from the activities of the project. for formulation, implementation and monitoring of environmental protection measures during and after commissioning of projects. The plan indicates the details of various measures and proposed to be taken for appropriate management of the environment of Deendayal Port Authority.

It identifies the principles, approach, procedures and methods that will be used to control and minimize the environmental and social impacts of operational activities associated



with the port. An EMP is a required part of environmental impact assessment of a new port project but could also be evolved for existing ports. It is useful both during the construction and operational phases of the new port but only for operation of existing ports to ensure the effectiveness of the mitigation measures and to give guidance as to the most appropriate way of dealing with any unforeseen effects.

It is extremely essential that port and harbour projects should have an Environmental monitoring and Management Plan (EMMP), which incorporates monitoring of Ambient Air, Drinking Water, Noise, Soil, Marine (water, sediment, ecology) quality along with the collection of online meteorological data throughout the duration of the project.

To ensure the effective implementation of the EMP and weigh the efficiency of the mitigation measures, it is proposed to undertake environmental monitoring both during construction and operation period. In view of the above, Gujarat Environment Management Institute (GEMI) has been awarded with the work **“Preparing and Monitoring of Environmental Monitoring and Management Plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years”** vide letter No. EG/WK/EMC/1023/2011/III/239 dated: 15/02/2023 by DPA.

This document presents the environmental monitoring report (EMR) for Kandla and Vadinar for the month of April -May 2023.

#### 1.4 Objectives and scope of the Study

In line with the work order, the key objective of the study is Environmental Monitoring and preparation the Management Plan at Kandla and Vadinar for a period of 3 years". Environmental monitoring refers to systematic sampling of air, water, soil, noise and ecology in order to monitor the performance/ compliance of a project compliance with Environmental quality standards, and any applicable Statutory Compliance and the effectiveness of mitigation measure in EMP.

The scope of work includes not limited to following:

1. To review the locations of Ambient Air, Ambient Noise, drinking water, and Marine Water, Soil and Sediments monitoring stations within the impacted region in and around DPA establishment, in view of the developmental projects.
2. To assess the Ambient Air quality, quality at 6 stations at Kandla and 2 at Vadinar in terms of gases and particulate matter.
3. To assess the DG stack emissions (gases and particulate matter).
4. To assess Drinking water quality at twenty stations in terms of Physical, Chemical and Biological parameters viz., Color, Odor, turbidity, conductivity, pH, Total Dissolved Solids, chlorides, Hardness, total iron, sulfate, NH<sub>4</sub>, PO<sub>4</sub>, and bacterial count on a monthly basis.
5. To assess the Marine water quality in terms of aquatic Flora and Fauna and Sediment quality in terms of benthic flora and fauna.
6. To assess Marine Water Quality and sediment in term of physical and chemical parameter.

7. To assess the trends of water quality in terms of Marine ecology by comparing the data collected over a specified time period.
8. Every week a sample (Treated wastewater) of the Sewage Treatment Plant (STP) shall be analyzed to see the water quality being discharged by DPA.
9. Noise monitoring will be carried out twice a day at the representative stations for a period of 24 hours.
10. Meteorological parameters are very important from air pollution point of view and precise and continuous data collection is of utmost importance. The data collected is analyzed as per the standards. Meteorological data on wind speed, wind direction, temperature, relative humidity, solar radiation and rainfall will be collected from one permanent station at DPA and one permanent station at Vadinar.
11. To suggest incorporates, mitigation measures, based on the findings of this study and also check compliance with Environmental quality standards, green port initiatives, MIV 2030, and any applicable Statutory Compliance.
12. To recommend Environment management plans on Monitoring programme based on findings of study.



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## **CHAPTER 2: METHODOLOGY**

## 2.1 Study Area:

Under the study, the locations specified by Deendayal Port Authority for the areas of Kandla and Vadinar would be monitored. The details of the study area as follows:

### a. Kandla:

Deendayal Port (Erstwhile Kandla Port) is one of the twelve major ports in India and is located on the West Coast of India, in the Gulf of Kutch at 23001'N and 70013'E in the state of Gujarat in India. Deendayal port primarily services the Northern India hinterland, including the land locked states of Jammu & Kashmir, Uttar Pradesh, Madhya Pradesh and Gujarat. Now, the Major Port Authorities Act 2021 is the governing statute for Administration of Major Ports. Now, on 18 February 2021, Major Port Authorities, (MPA) Act 2021 notified in the Gazette of India same has come into force from 3 November 2021. Under, MPA 2021, Deendayal Port Trust (DPT) have become Deendayal Port Authority (DPA). At Kandla, Deendayal Port has sixteen (16) cargo berths for handling various types of Dry Bulk Cargo viz, fertilizer, food grains, Coal, sulphur, timber, salt, ores etc. and Containers. Apart from dry bulk, DPA has seven (7) oil for handling all types of Liquid Cargo viz. POL, Chemicals etc. at Kandla. Deendayal Port Authority has handled total 135 MMTPA cargo (at Kandla & Vadinar) during the financial year 2022-23.

- **Climatic conditions of Kandla**

Kandla has a semi-desert climate. Temperature varies from 25°C to 44°C during summer and from 10°C to 25°C during winter. The average annual temperature is 24.8 °C. The average rainfall is 410 mm, most of which occurs during the monsoon from the months of June to September.

### b. Vadinar:

**Vadinar** is a small coastal town located in Devbhumi Dwarka district of the state of Gujarat, India at coordinates 22° 27' 16.20" N - 069° 40' 30.01". The offshore oil terminal of the Deendayal Port Authority (DPA) is located in Vadinar and contributes in a large way to the total earnings of this major port. Vadinar is now notable due to the presence of two refineries-one promoted by Reliance Industries and the other by Essar Oil Ltd. The Deendayal Port Authority had commissioned the Off Shore Oil Terminal (OOT) facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, which has a capacity of 54 MMTPA.

It also handled 43.30 MMT at Vadinar (which includes transshipment), the containerized cargo crossed 4.50 lakh TEU during this period, grossing a total of 100 MMT overall. Major commodities handled by the Deendayal Port are Crude Oil, Petroleum product, Coal, Salt, Edible Oil, Fertilizer, Sugar, Timber, Soya bean, Wheat, etc.

- **Climatic conditions of Vadinar**

Vadinar has a hot semi-arid climate, there are three defined seasons. The summer season lasts from March to May and is extremely hot, humid, but dry. The climatic conditions in Vadinar are quite similar to that recorded in its district head quarter in Jamnagar. The yearly mean temperature is 26.7 °C. Rainy season with extremely erratic monsoonal rainfall that averages around 630 millimetres. Tropical cyclones sometimes affect the region during this period. The winter season is from October to February remains hot during the day but has negligible rainfall, low humidity and cool nights to be by far the most comfortable time of year.

The locations of Kandla Port and Vadinar port have been depicted in the **Figure 1** as follows:



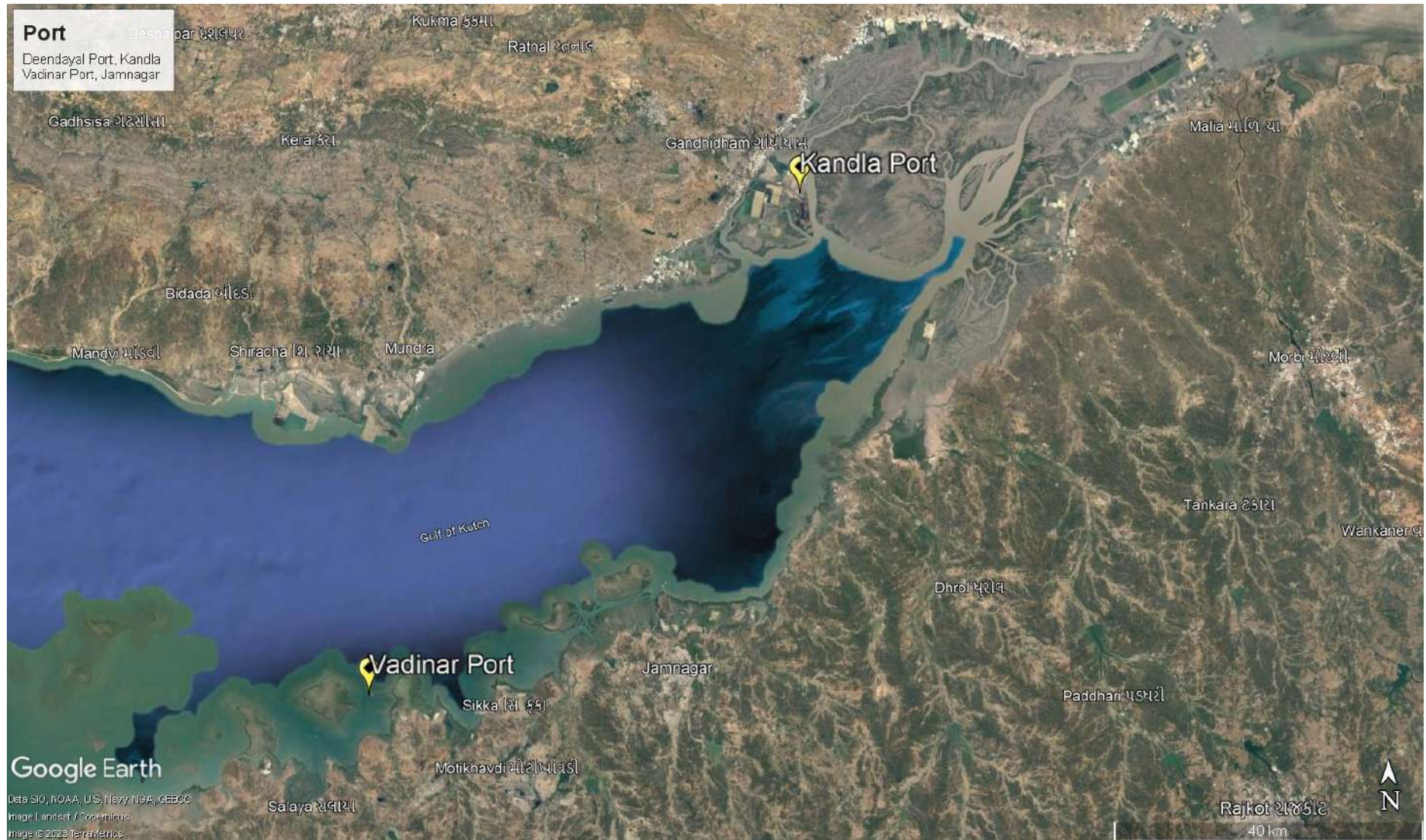


Figure 1: Locations Map of Kandla and Vadinar



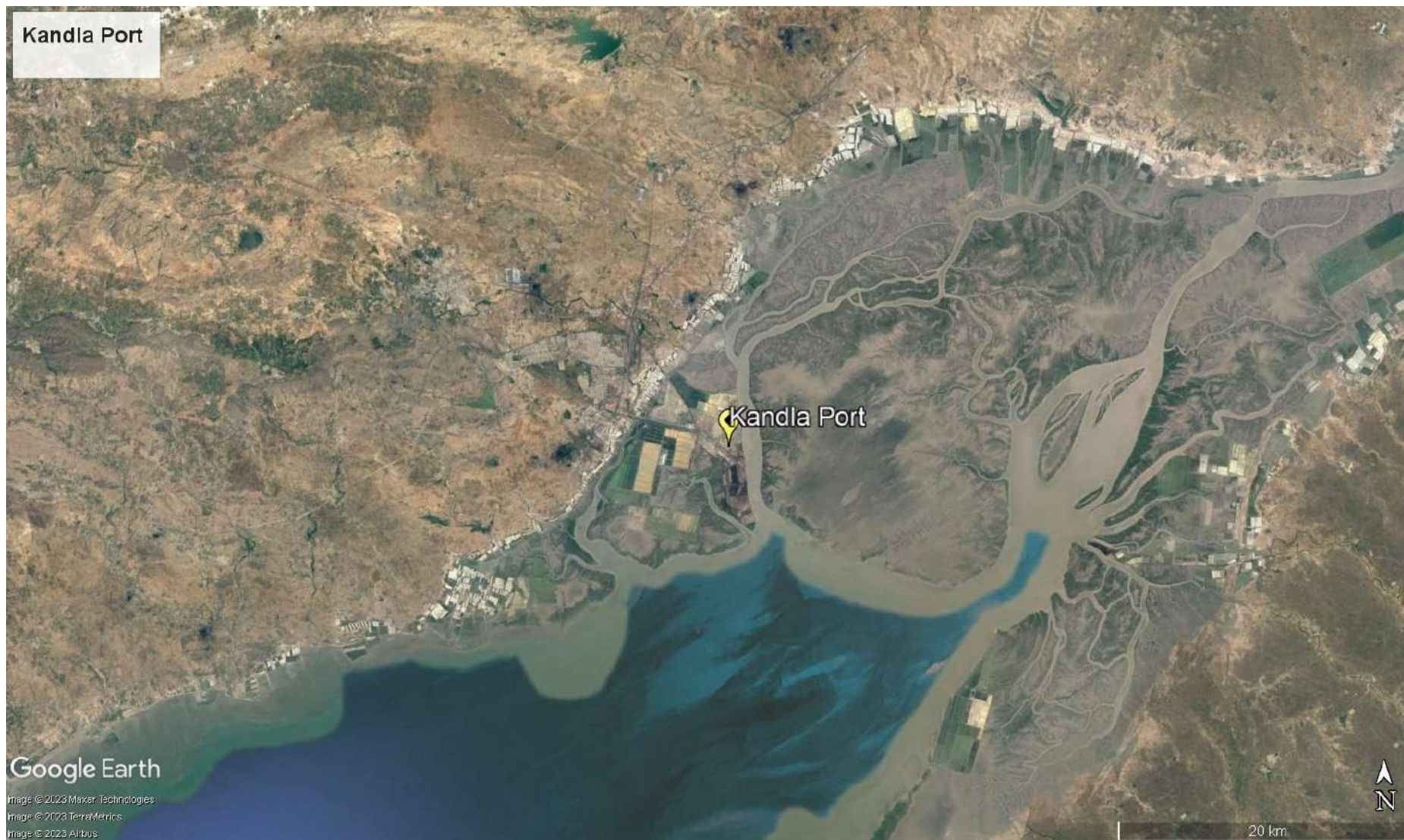


Figure 2: Map of Kandla Port



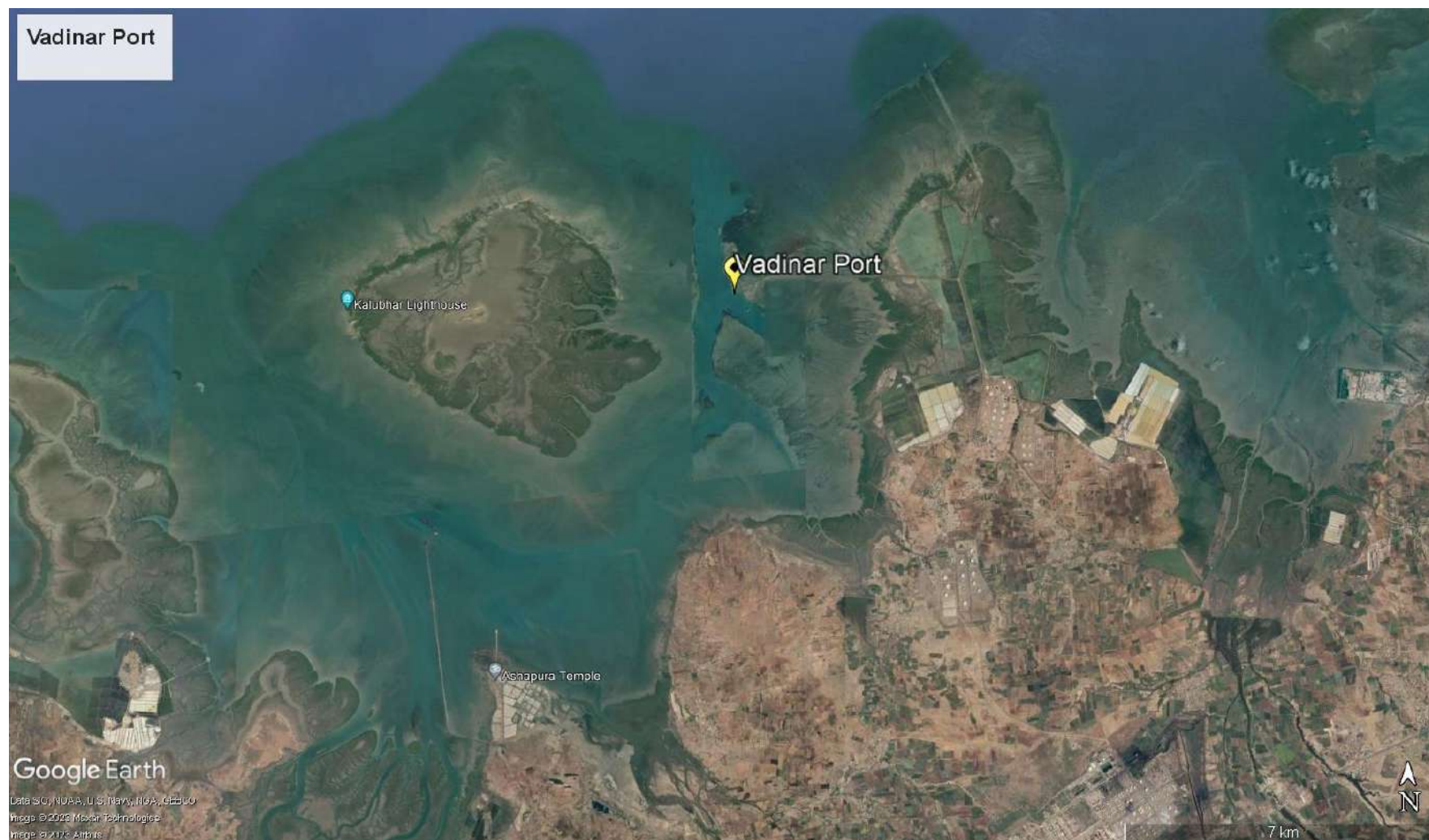
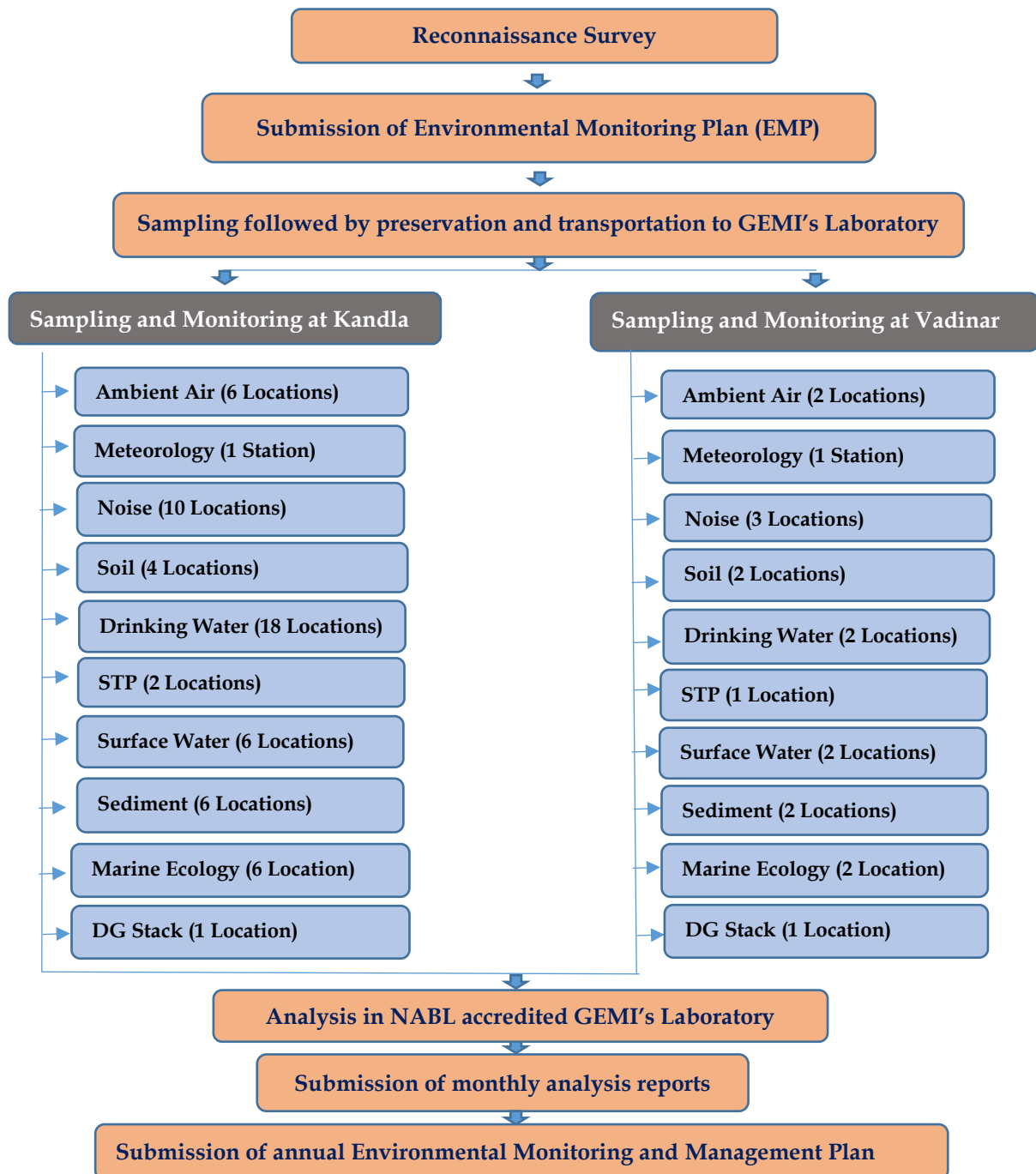


Figure 3: Map of Vadinar Port

## 2.2 Methodology adopted for the study

Methodology is a strictly defined combination of practices, methods and processes to plan, develop and control a project along the continuous process of its implementation and successful completion. The aim of the project management methodology is to allow the control of the whole process of management through effective decision-making and problem solving. The methodology adopted for the present study is as follows:



### 2.3 Environmental Monitoring at Kandla and Vadinar

Regular monitoring of environmental parameters is of immense importance to assess the status of environment during project operation. With the knowledge of baseline conditions, the monitoring programme will serve as an indicator for any deterioration in environmental conditions due to operation of the project, to enable taking up suitable mitigatory steps in time to safeguard the environment. Monitoring is as important as that of control of pollution since the efficiency of control measures can only be determined by monitoring.

Environmental Monitoring Plan (EMP) is very important for monitoring the environmental status of the port for sustainable development. The list of main elements for which Environmental monitoring is to be carried out is mentioned below:

- Meteorology
- Ambient Air
- Noise
- Drinking Water
- DG Stack
- Soil
- Sewage
- Marine (Surface) water
- Marine Sediments
- Marine Ecology

Gujarat Environment Management Institute (GEMI) has been entrusted by Deendayal Port Authority to carry out the monitoring of the various aforementioned environmental aspects of the port, so as to verify effectiveness of Environment management plan; confirm statutory and legal compliance; and identify any unexpected changes. Standard methods and procedures have been strictly adhered to in the course of this study. QA/QC procedures were strictly followed which covers all aspects of the study, and includes sample collection, handling, laboratory analyses, data coding, statistical analyses, presentation and communication of results. All analysis was carried out in GEMI's NABL/MoEF accredited/recognized laboratory.

Under the present study, the details of various sectors of Environment monitoring are described in subsequent chapters.

## **CHAPTER 3: METEOROLOGY MONITORING**

### 3.1 Meteorology Monitoring

Meteorological conditions play a crucial role in dispersion of air pollutants. Meteorological factors play an important role in environmental pollution studies particularly in pollutant transport irrespective of their entry into the environment. The wind speed and direction play a major role in dispersion of environment pollutants. In order to determine the prevailing micro-meteorological conditions at the project site an Automatic Weather Monitoring Stations (AWS) of Envirotech WM280 were installed at both the sites of Kandla and Vadinar at 10 m above the ground. The details of the AWS have been mentioned in **Table 1** as follows:

**Table 1: Details of Automatic Weather Station**

Sr. No.	Site	Location Code	Location Name	Latitude Longitude
1.	Kandla	AWS-1	Environment Laboratory (DPA)	23.00996N 70.22175E
2.	Vadinar	AWS-2	Canteen Area	22.39994N 69.716608E

### 3.2 Methodology

During the study, a continuous automatic weather monitoring station was installed at both the sites to record climatological parameters such as Wind speed, Wind Direction, Relative Humidity, Solar Radiation, Rainfall and Temperature to establish general meteorological regime of the study area. The stations (observatory) were installed at Kandla and Vadinar on 19/04/2023. The methodology adopted for monitoring meteorological data shall be as per the standard norms laid down by Bureau of Indian Standards (BIS) and the India Meteorological Department (IMD).

The details of Automatic Weather Monitoring Station have been mentioned in **Table 2**.

**Table 2: Automatic Weather Monitoring Station details**

Sr. No.	Details of Meteorological Data	Unit of Measurement	Instrument	Frequency
1.	Wind Direction	degree	Automatic Weather Monitoring Station (Envirotech WM280)	Hourly Average
2.	Wind Speed	Km/hr		
3.	Rainfall	mm/hr		
4.	Relative Humidity	% RH		
5.	Temperature	°C		
6.	Solar Radiation	W/m <sup>2</sup>		

The Meteorological parameters were recorded at an interval of 1 hour in a day and the average value for all the Meteorological parameters were summarized for the period of April and May 2023 at both the observatory site.

### 3.3 Results:

The summary of hourly climatological observations recorded at observatory, Kandla during 19<sup>th</sup> April – 16<sup>st</sup> May 2023, with respect to significant parameters has been mentioned in **Table 2**. Monthly average of maximum and minimum daily observed values summarized in **Table 3** have been discussed as follows:

**Table 3: Meteorological data for Kandla and Vadinar**

Details of micro-meteorological data at Kandla Observatory												
Date	Wind Speed (Km/h)			Temperature (°C)			Relative humidity (%)			Solar Radiation (W/m <sup>2</sup> )	Wind Direction (°)	Rainfall (mm)
Stat.	Mean	Max.	Min	Mean	Max	Min	Mean	Max	Min			
April-May 23	8.78	27.02	1.54	31.31	32.21	30.40	61.07	64.12	57.76	105.42	South-south East	0.05
Details of micro-meteorological data at Vadinar Observatory												
Date	Wind Speed (Km/h)			Temperature (°C)			Relative humidity (%)			Solar Radiation (W/m <sup>2</sup> )	Wind Direction (°)	Rainfall (mm)
Stat.	Mean	Max.	Min	Mean	Max	Min	Mean	Max.	Min			
April-May 23	13.24	26.33	7.78	28.17	28.74	28.04	71.08	73.47	70.00	110.76	west and south	0.02



- **Temperature**

- a. Kandla: The ambient Temperature from April to May varies between the range of 26.75-35.23°C for Kandla, with average temperature of 31.31°C.
- b. Vadinar: The ambient temperature for the month of April varies between the range of 25.04-30.62°C for Vadinar, with average temperature of 28.17°C.

- **Relative Humidity**

- a. Kandla: The Relative Humidity recorded between the range of 43.77-69.65%, with average Humidity of 61.07%.
- b. Vadinar: During the study period, the Relative Humidity varies between 64.53-76.05%, with average Humidity of 71.08%.

- **Rainfall**

- a. Kandla: It is observed that, the average Rainfall in the monitoring period was found to be 0.05 mm
- b. Vadinar: The average Rainfall was recorded as 0.02 mm,

- **Wind Speed**

Wind speed and Direction play a significant role in transporting the pollutants and thus decides the air quality.

- a. Kandla: Wind speed recorded ranges between 3.98-18.42 Km/hr
- b. Vadinar: During the study period, the Wind speed recorded, ranges between 6.23-18.08 Km/hr.

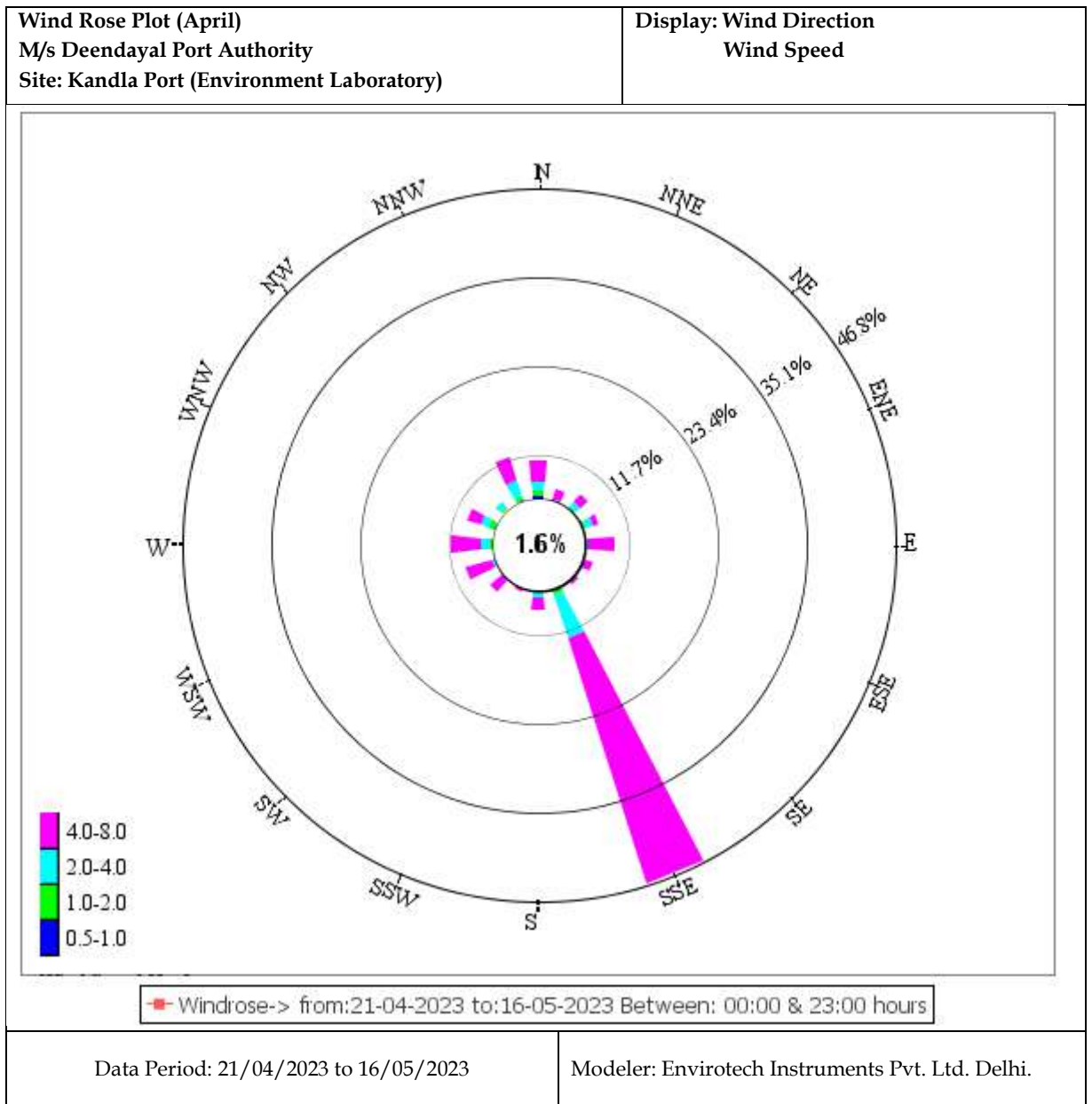
- **Solar Radiation:**

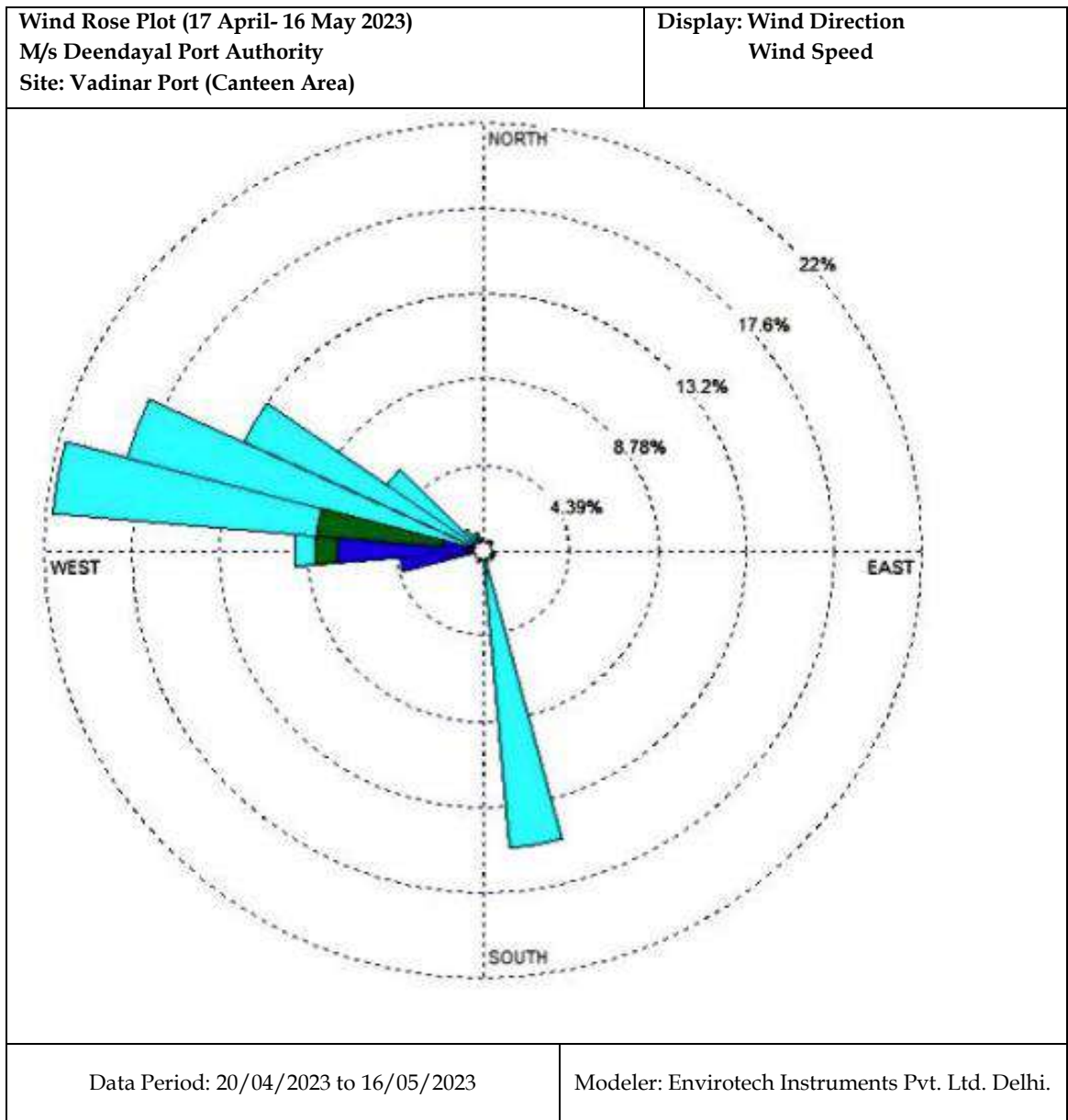
- a. Kandla: The average Solar Radiation for the monitoring period was recorded as 105.42 W/m<sup>2</sup>.
- b. Vadinar: The average Solar Radiation was recorded as 110.76 W/m<sup>2</sup>

- **Wind rose diagram -**

The wind-rose diagram for the Monitoring period has been drawn on the basis of hourly wind speed and direction data.

This wind rose reveals that the prevailing winds in Kandla during the given period predominantly blow from the northwest direction. The wind rose diagram represents that the wind flow at Kandla for the monitoring month towards South-South east. Whereas the winds at Vadinar were observed to flow from west directions.





## **CHAPTER 4: AMBIENT AIR QUALITY MONITORING**

#### 4.1 Ambient Air Quality

To determine the impact of the shipping activities and port operations on the ambient air quality, it is necessary to monitor the ambient air quality of the study area. The prime objective of ambient air quality monitoring with respect to is to assess the present air quality and its conformity to ambient air quality standards (NAAQS, 2009). Ambient air quality in terms of (parameters) are monitored from 17<sup>th</sup> April- 15<sup>th</sup> May 2023 covering 6 weeks.

#### 4.2 Methodology adopted for the Study

The study area represents the area occupied by Deendayal port authority and its associated Port area, facilities, as well as the surrounding area comprising of few villages. The sources of air pollution in the region are mainly vehicular traffic, fuel burning, loading & unloading of dry cargo, fugitive emissions from storage area and dust arising from unpaved village roads, eight locations within the study area were scientifically selected and are based on the following considerations:

- Meteorological conditions;
- Topography of the study area;
- The direction of the wind;
- Representation of the region for establishing current air quality status; and
- Representation with respect to likely impact areas.

The description of various stations monitored at Kandla and Vadinar are given in **Table 4**.

**Table 4: Details of Ambient Air monitoring locations**

Sr. No.	Location Code	Location Name	Latitude Longitude	Significance
1.	Kandla	A-1	Oil Jetty No. 1	Loading of materials, dry cargo handling, liquid containers, emission from ship
2.		A-2	Oil Jetty No. 7	
3.		A-3	Kandla Port Colony	Vehicular activity, dust emission, Traffic
4.		A-4	Marine Bhavan	Construction activity, road dust emission
5.		A-5	Coal Storage Area	Coal Dust, Vehicular activity
6.		A-6	Gopalpuri Hospital	Residential area, dust emission, vehicular activity
7.	Vadinar	A-7	Admin Building	Vehicular activity
8.		A-8	Vadinar Colony	Residential Area, burning waste, vehicular activity

The monitoring locations at Kandla and Vadinar have been depicted in **Figure 4 and 5** respectively follows:





Figure 4: Location Map for Ambient Air Monitoring at Kandla



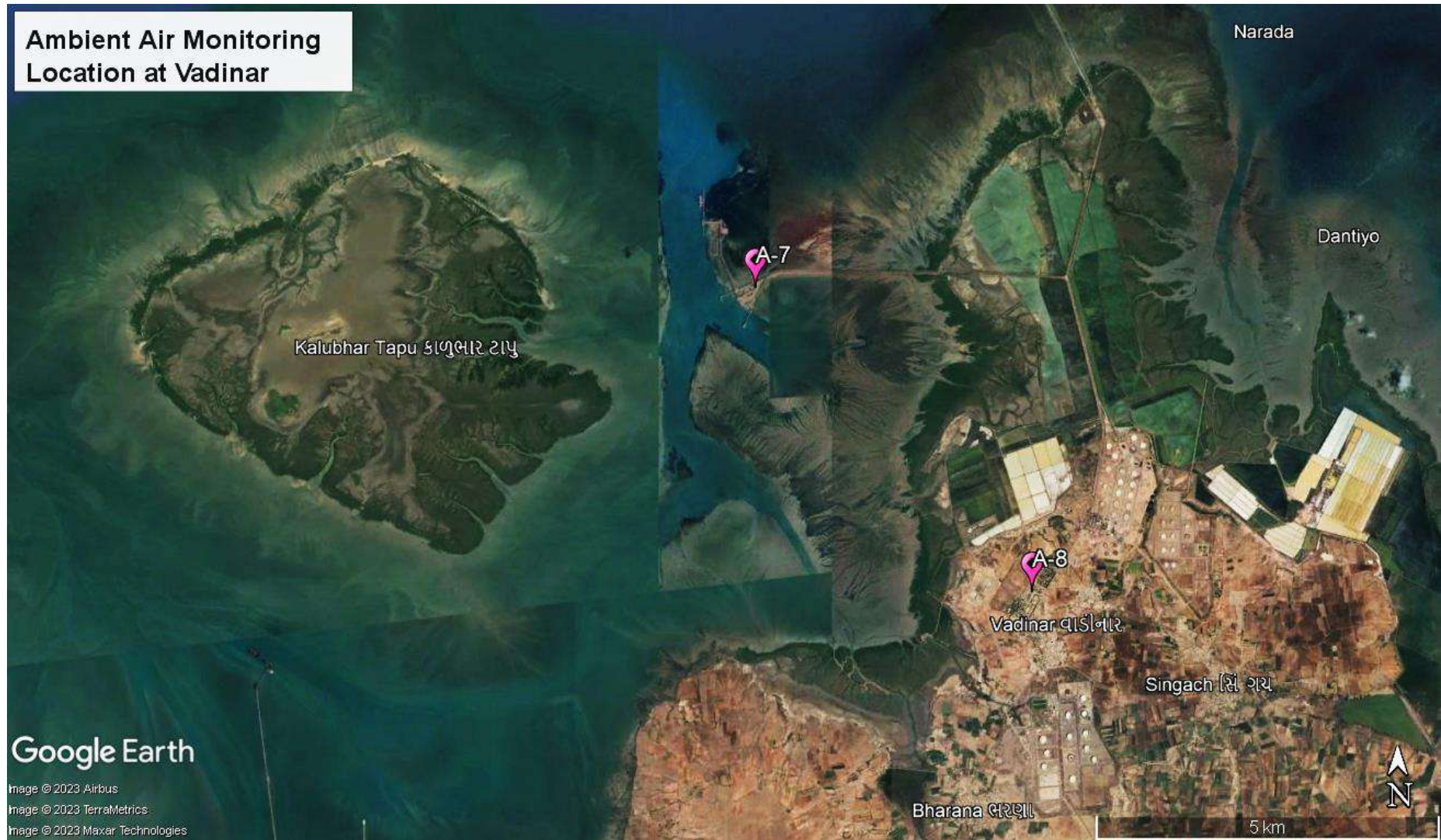


Figure 5: Location Map for Ambient Air Monitoring at Vadinar



### Frequency of AAQ Monitoring

The sampling for Particulate matter (PM<sub>10</sub>, PM<sub>2.5</sub>) and gaseous like SO<sub>x</sub>, NO<sub>x</sub>, CO and Total VOCs were monitored twice in a week for a duration of 24 hours a day. Whereas, the samples of PAH, Benzene and non-Methane VOCs were collected on monthly basis.

### Method of sampling and analysis:

The Sampling of the Ambient Air Quality parameters and analysis is done as per CPCB guidelines of National Ambient Air Quality monitoring. The sampling was performed at a height of 3.5 m (approximately) from the ground level.

For the sampling of PM<sub>10</sub>, calibrated 'Respirable Dust Samplers' were used, where Whatman GF/A microfiber filter paper (size: 8" X 10") was used for the collection of PM<sub>10</sub>. APM- air sampler of the make Envirotech instrument was attached with Respirable Dust Sampler PM<sub>2.5</sub> sampler for monitoring particulate matter of size <2.5 microns. A known volume of ambient air is passed through the cyclone to the initially pre-processed filter paper. The centrifugal force in cyclone acts on particulate matter to separate them into two parts and collected as following: -

Particles <10 μ size (Respirable): GF/A Filter Paper

Particles <2.5 μ size (Respirable): Polytetrafluoroethylene (PTFE)

Sampling and analysis of ambient SO<sub>2</sub> was performed by adopting the 'Improved West and Gaeke Method'. The ambient air, drawn through the draft created by the RDS, is passed through an impinger, containing a known volume of absorbing solution of sodium tetrachloromercurate, at a pre-determined and measured flow rate of 1 liter/minute (L/min). Similarly, NO<sub>x</sub> was performed by adopting the 'Jacob Hochheister Modified' (Na arsenite) method. The impinger contains known volume of absorbing solution of sodium arsenite and sodium hydroxide.

Data has been compiled for PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>x</sub> and NO<sub>x</sub> samples of 24-hour duration on two days a week (i.e., 8 samples were collected at each location). In case of CO, one hourly sample were taken on selected monitoring days using the sensor-based CO Meter. For the parameters Benzene, Methane & Non-methane and Volatile Organic Carbons (VOCs) the Low Volume Sampler is used, where the charcoal tubes are used as sampling media. The sampling in the Low Volume Sampler is carried out as per IS 5182 (Part 11): 2006 RA: 2017, where the ambient air flow rate is maintained at 200 cc/min, the volume of air that passes through the low volume sampler during two hours monitoring is approx. 24 L. Whereas the sampling of PAHs is carried out as per IS: 5182 (Part 12): 2004. Where, the EPM 2000 Filter papers are utilized in the Respirable Dust Sampler (RDS). For the parameters, PAH & Non-methane VOC's, monthly monitoring is carried out. The details of the parameters with their frequency monitored are mentioned in **Table 5:**

Table 5: Parameters for Ambient Air Quality Monitoring

Sr. No.	Parameters	Units	Reference method	Instrument	Frequency
1.	PM <sub>10</sub>	µg/m <sup>3</sup>	IS 5182 (Part 23): 2006	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-23): 2006	Twice in a week
2.	PM <sub>2.5</sub>	µg/m <sup>3</sup>	IS:5182 (Part:24):2019	Fine Particulate Sampler (FPS) conforming to IS:5182 (Part-24): 2019	
3.	Sulphur Dioxide (SO <sub>x</sub> )	µg/m <sup>3</sup>	IS 5182 (Part:2): 2001	Gaseous Attachment conforming to IS:5182 Part-2	
4.	Oxides of Nitrogen (NO <sub>x</sub> )	µg/m <sup>3</sup>	IS:5182 (Part-6): 2006	Gaseous Attachment conforming to IS:5182 Part-6	
5.	Carbon Monoxide	mg/m <sup>3</sup>	GEMI/SOP/AAQM/1 1; Issue no 01, Issue date 17.01.2019: 2019	Sensor based Instrument (Make: Vaibhav Instruments)	
6.	VOC	µg/m <sup>3</sup>	IS 5182 (Part 17): 2004	Low Flow Air Sampler	
7.	Benzene	µg/m <sup>3</sup>	IS 5182 (Part 11): 2006 RA: 2017	Low Flow Air Sampler	
8.	PAH	µg/m <sup>3</sup>	IS: 5182 (Part 12): 2004	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-12): 2004	Monthly
9.	Non-methane VOC	µg/m <sup>3</sup>	IS 5182 (Part 11): 2006	Low Volume Sampler	

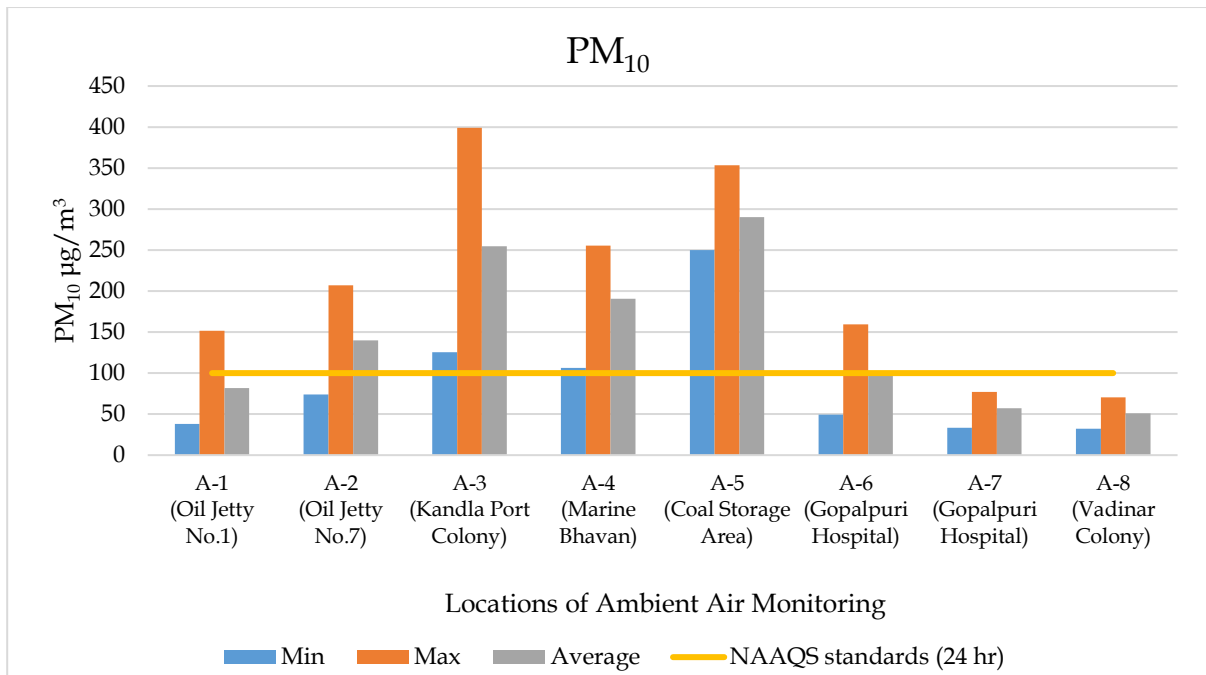
#### 4.3 Result and Discussion:

The summarized results of ambient air quality monitoring for the period from 17<sup>th</sup> April to 15<sup>th</sup> May 2023 are presented in **Table-6 to 15** along with the graphical representation depicted in **Graph 1 to Graph 6**. Various parameters monitored during the study have been presented by their maximum, minimum, average and standard deviation.

Table 6: Summarized results of PM<sub>10</sub> for Ambient Air quality monitoring

PM <sub>10</sub> (µg/m³)										
Sr No	Location  Sampling Date	Kandla						Vadinar		NAAQS standards (24 hr)
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	17-Apr-2023	86.35	144.87	341.95	255.59	211.81	89.13	56.62	42.63	100 µg/m³
2	19-Apr-2023	69.35	135.52	349.89	106.41	305.36	115.90	59.78	56.55	
3	24-Apr-2023	72.27	121.69	399.25	155.37	260.08	159.38	74.25	56.50	
4	26-Apr-2023	151.72	149.37	271.07	185.15	216.88	73.34	76.96	70.37	
5	1-May-2023	81.83	124.52	182.54	156.01	219.18	56.78	33.42	43.40	
6	3-May-2023	58.16	74.14	125.42	252.46	323.61	124.93	33.97	32.10	
7	8-May-2023	72.81	207.10	287.49	207.14	249.87	109.62	56.42	59.48	

PM <sub>10</sub> (µg/m <sup>3</sup> )										
Sr No	Location  Sampling Date	Kandla						Vadinar		NAAQS standards (24 hr)
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
8	10-May-2023	104.33	154.22	204.48	207.03	267.24	128.82	63.83	49.15	
9	15-May-2023	37.94	149.14	128.12	189.98	353.42	49.35	57.77	46.17	
	Minimum	37.94	74.14	125.42	106.41	249.87	49.35	33.42	32.10	
	Maximum	151.72	207.10	399.25	255.59	353.42	159.38	76.96	70.37	
	Average	81.64	140.06	254.47	190.57	290.18	100.81	57.00	51.02	
	Std Dev	32.07	35.06	99.61	47.63	55.45	36.37	15.16	12.38	



Graph 1: Spatial trend in PM<sub>10</sub> Concentration at Monitoring locations

### Interpretation:

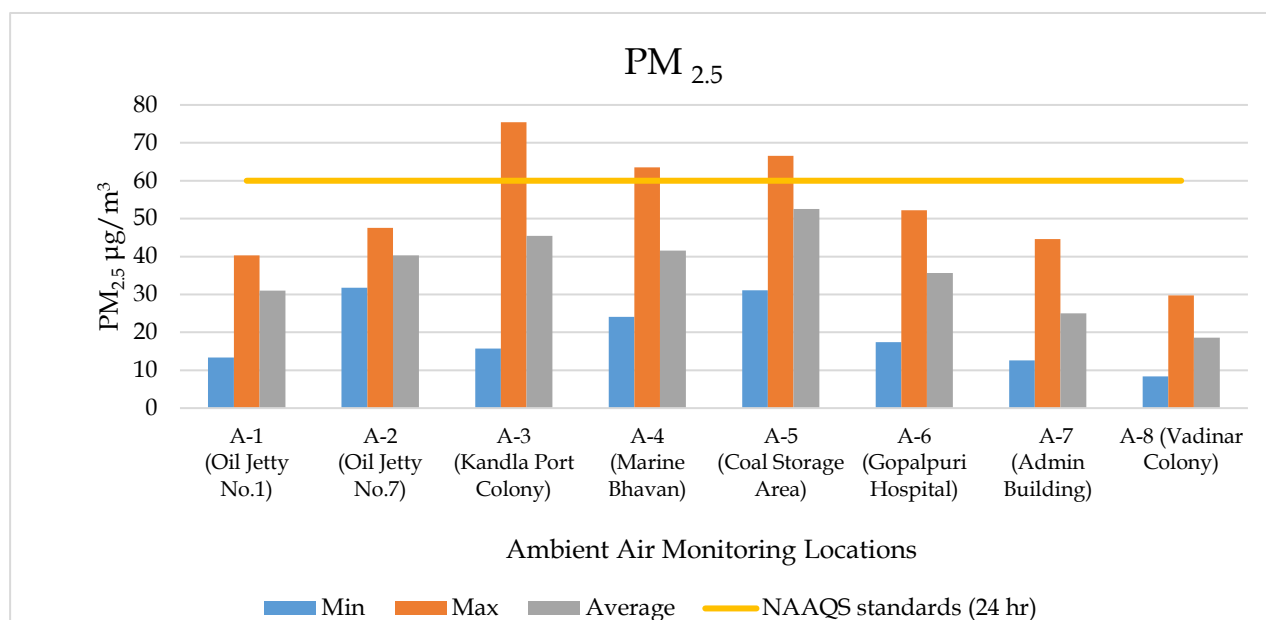
The results were compared with National Ambient Air Quality Standards (NAAQS), 2009 of Central Pollution Control Board (CPCB). Particulate Matter (PM<sub>10</sub>) exceeded the norms at locations (Oil jetty 1, KPT colony, Marine Bhavan, Coal storage area). The highest concentration of PM<sub>10</sub> was observed at location A-3 i.e., Kandla Port Colony (399.25 µg/m<sup>3</sup>), whereas the lowest was observed at A-1 i.e., Oil Jetty No.1 (37.94 µg/m<sup>3</sup>). All the monitored values of PM<sub>10</sub> at station A-2, A-3, A-4 and A5 are exceeding the specified limit of 100 µg/m<sup>3</sup>.

The higher reporting of PM<sub>10</sub> could be due to heavy vehicular traffic, loading and unloading of cargo, dust from construction activities. Emissions and dispersion from construction equipment, work vessels, trucks and other vehicles used in construction work could be a source of Particulate matter. The unloading of coal directly in the truck, using grabs cause coal to disperse in air as well as coal dust to fall and settle on ground. This settled coal dust again mixes with the air while trucks travel through it. Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in increased

suspension of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increases the PM values around marine Bhavan & Coal storage area. Whereas for the Ambient Air locations of Vadinar, the concentration of PM<sub>10</sub> falls within the stipulated norm of 100 µg/m<sup>3</sup>. Kandla Port is a coastal area with extensive salt pans on the western side. Some of these salt pans are temporarily not in use and the hence this barren area is source of fugitive dust. Wind speeds also contribute to increased dispersion of pollutants in the area. Apart from this, dust storms are also common.

**Table 7: Summarized results of PM<sub>2.5</sub> for Ambient Air quality monitoring**

PM <sub>2.5</sub> (µg/m³)										
Sr. No	Location	Kandla						Vadinar		NAAQS standards (24 hr)
	Sampling date	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	17-Apr-2023	40.32	31.73	60.77	49.96	68.52	35.99	40.63	35.08	60 µg/m³
2	19-Apr-2023	28.39	38.62	41.03	45.23	88.51	35.27	42.74	30.15	
3	24-Apr-2023	31.31	47.55	67.13	47.27	56.75	35.27	44.65	28.31	
4	26-Apr-2023	39.87	42.70	32.14	31.82	71.62	36.21	32.58	29.76	
5	1-May-2023	22.23	34.23	28.33	24.06	38.84	34.46	12.61	11.05	
6	3-May-2023	38.73	47.58	38.22	36.51	89.04	25.32	14.52	8.35	
7	8-May-2023	26.60	42.51	75.44	39.65	66.58	48.62	26.09	19.25	
8	10-May-2023	38.44	37.28	50.47	63.55	60.03	52.18	25.99	22.94	
9	15-May-2023	13.32	40.22	15.73	35.86	31.09	17.39	18.87	10.49	
	Minimum	13.32	31.73	15.73	24.06	31.09	17.39	12.61	8.35	
	Maximum	40.32	47.58	75.44	63.55	66.58	52.18	44.65	29.76	
	Average	31.02	40.27	45.47	41.55	52.57	35.63	25.04	18.59	
	Std Dev	9.33	5.46	19.54	11.53	18.89	10.51	11.16	8.81	



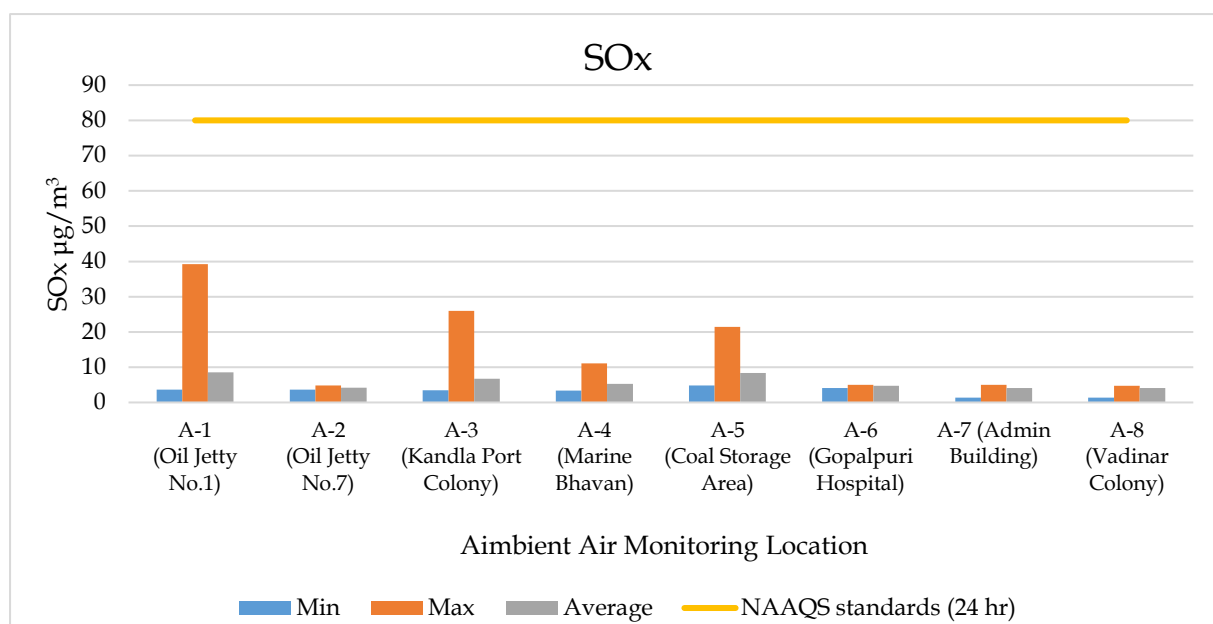
**Graph 2: Spatial trend in PM<sub>2.5</sub> Concentration at Monitoring locations**

The highest PM<sub>2.5</sub> concentration (75.44 µg/m<sup>3</sup>) was recorded at station A-3, Kandla Port Colony which is above the limit prescribed by NAAQS. Whereas majority of the monitored values of PM<sub>2.5</sub> at Kandla were reported well below the specified limit of 60 µg/m<sup>3</sup>. While for Vadinar monitoring station the maximum value for PM<sub>2.5</sub> observed is,

44.65  $\mu\text{g}/\text{m}^3$  at Admin Building (A-7). Similar to values detected for the Respirable Dust i.e.,  $\text{PM}_{10}$ , higher concentration of  $\text{PM}_{2.5}$  was also observed at the Locations A-3 to A-5. This may be attributed to emissions from combustion of gasoline, oil, diesel fuel or wood produce.

**Table 8: Summarized results of  $\text{SO}_x$  for Ambient Air quality**

SO <sub>x</sub> (µg/m <sup>3</sup> )										
Sr. No	Location  Sampling date	Kandla						Vadinar		NAAQS standards (24 hr)
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	17-Apr-2023	5.98	4.8	4.1	3.6	5.33	4.9	4.6	4.6	80 µg/m <sup>3</sup>
2	19-Apr-2023	4.3	4.2	4.9	3.8	7.53	4.6	4.3	4.2	
3	24-Apr-2023	3.9	4.5	4.6	3.7	9.21	4.1	4.51	4.58	
4	26-Apr-2023	7.44	3.6	3.6	3.4	4.8	4.9	1.39	4.69	
5	1-May-2023	39.19	3.8	5.16	3.9	8.65	4.98	3.12	1.4	
6	3-May-2023	4.2	3.9	3.5	8.27	5.15	4.85	4.99	4.67	
7	8-May-2023	3.6	4.6	26.01	11.13	21.47	4.67	4.6	4.25	
8	10-May-2023	4.1	4.0	4.6	4.9	7.97	4.58	4.2	4.36	
9	15-May-2023	3.6	3.6	3.5	3.4	4.8	4.1	1.39	1.4	
	Minimum	3.6	3.6	3.5	3.4	4.8	4.1	1.39	1.4	
	Maximum	39.19	4.8	26.01	11.13	21.47	4.98	4.99	4.69	
	Average	8.57	4.18	6.74	5.28	8.34	4.72	4.06	4.11	
	Std Dev	11.55	0.40	7.25	2.66	5.21	0.27	1.13	1.04	



**Graph 3: Spatial trend in  $\text{SO}_x$  Concentration at Monitoring locations**

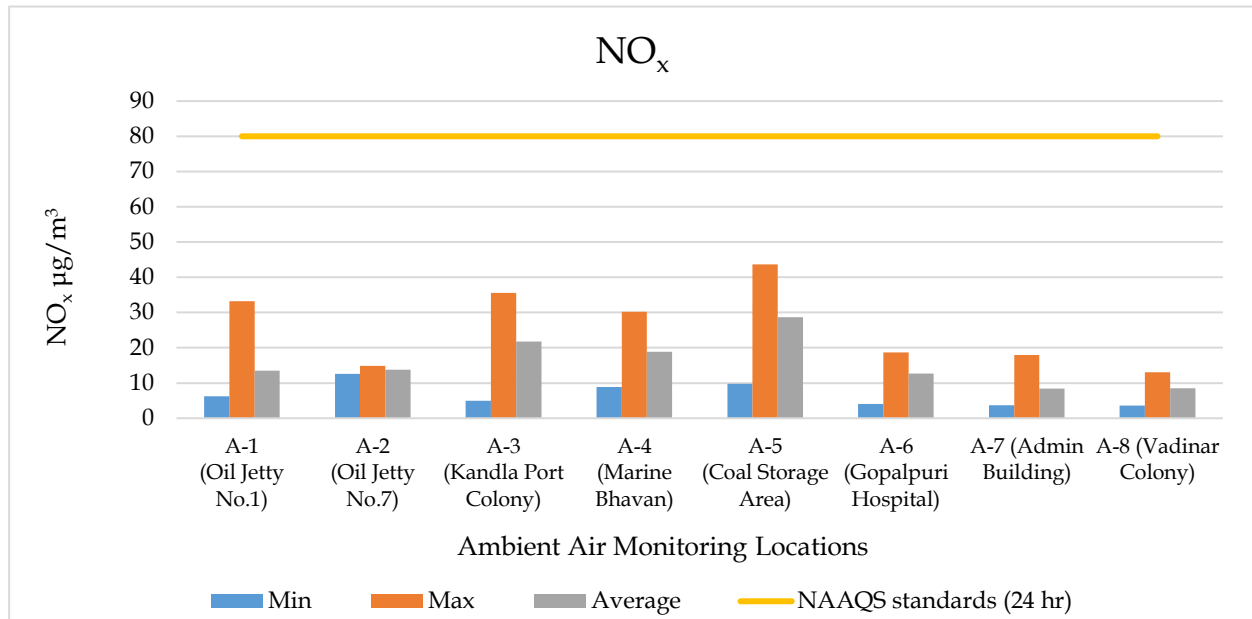
The highest  $\text{SO}_x$  concentration (39.19  $\mu\text{g}/\text{m}^3$ ) was recorded at station A-1, Oil Jetty No.1 area while the lowest  $\text{SO}_x$  concentration was found to be 3.4  $\mu\text{g}/\text{m}^3$  at A-4, Marine Bhavan. From the observed value it is seen that the concentration of  $\text{SO}_x$  falls within the limit prescribed by NAAQS.

Whereas for Vadinar monitoring station the maximum and minimum value for  $\text{SO}_x$  observed is, 4.99  $\mu\text{g}/\text{m}^3$  and 1.39  $\mu\text{g}/\text{m}^3$  at Admin Building (A-7) at different month. The

majority of the monitored values of SO<sub>x</sub> at Vadinar were reported well below the specified limit of 80 µg/m<sup>3</sup>.

**Table 9: Summarized results of NO<sub>x</sub> for Ambient Air quality monitoring**

NO <sub>x</sub> (µg/m <sup>3</sup> )										
Sr No	Location  Sampling date	Kandla						Vadinar		NAAQS standards (24 hr)
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	17-Apr-2023	9.20	12.85	21.94	19.41	27.76	8.70	8.14	9.72	80 µg/m <sup>3</sup>
2	19-Apr-2023	10.02	12.55	19.88	8.90	31.22	10.24	7.64	11.25	
3	24-Apr-2023	6.20	14.87	35.54	18.80	32.57	17.38	17.94	12.81	
4	26-Apr-2023	33.24	13.40	30.12	25.04	20.64	13.24	10.00	10.58	
5	1-May-2023	18.72	14.89	21.27	19.81	21.84	18.68	7.47	13.06	
6	3-May-2023	7.52	14.33	5.00	13.18	25.84	4.08	6.43	6.48	
7	8-May-2023	12.28	13.37	23.49	21.98	32.60	14.12	7.85	7.77	
8	10-May-2023	13.99	13.55	27.64	30.18	43.64	12.00	5.45	5.12	
9	15-May-2023	10.65	14.36	11.05	12.57	9.78	15.61	3.66	3.61	
	Minimum	6.20	12.55	5.00	8.90	9.78	4.08	3.66	3.61	
	Maximum	33.24	14.89	35.54	30.18	43.64	18.68	17.94	13.06	
	Average	13.54	13.80	21.77	18.87	28.67	12.67	8.40	8.49	
	Std Dev	8.26	0.85	9.33	6.60	17.27	4.55	4.65	3.73	

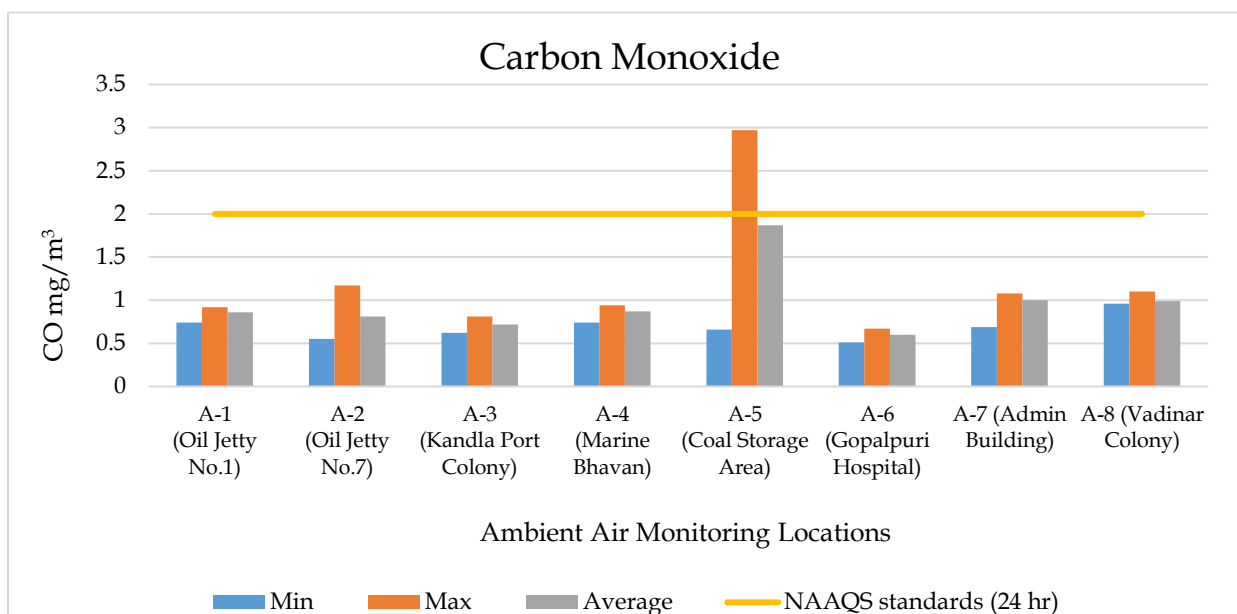


**Graph 4: Spatial trend in NO<sub>x</sub> Concentration at Monitoring locations**

The highest NO<sub>x</sub> concentration 43.64 µg/m<sup>3</sup> was recorded at station A-5, Coal Storage Area. All the monitored values of NO<sub>x</sub> are found well below the specified limit of 80 µg/m<sup>3</sup>. At Vadinar, the concentration of NO<sub>x</sub> was found to be below the NAAQS limit for both the monitoring stations.

Table 10: Summarized results of Carbon Monoxide for Ambient Air quality monitoring

Carbon Monoxide (mg/m <sup>3</sup> )										
Sr No	Location Sampling date	Kandla						Vadinar		NAAQS standards (8 hr)
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	17-Apr-2023	0.90	0.76	0.62	0.89	1.13	0.66	0.88	0.97	2 mg/m <sup>3</sup>
2	19-Apr-2023	0.86	1.06	0.65	0.86	1.16	0.64	0.94	0.89	
3	24-Apr-2023	0.89	1.17	0.63	0.87	1.98	0.65	1.08	1.10	
4	26-Apr-2023	0.91	0.55	0.71	0.92	2.01	0.67	0.69	0.99	
5	1-May-2023	0.91	0.77	0.67	0.91	0.54	0.66	1.01	0.96	
6	3-May-2023	0.74	0.71	0.79	0.94	1.68	0.52	1.03	0.98	
7	8-May-2023	0.92	0.76	0.80	0.83	1.97	0.51	1.04	0.99	
8	10-May-2023	0.75	0.56	0.79	0.87	2.97	0.58	1.08	0.97	
9	15-May-2023	0.84	0.92	0.81	0.74	0.66	0.54	1.04	0.96	
	Minimum	0.74	0.55	0.62	0.74	0.66	0.51	0.69	0.96	
	Maximum	0.92	1.17	0.81	0.94	2.97	0.67	1.08	1.10	
	Average	0.86	0.81	0.72	0.87	1.87	0.60	1.00	0.99	
	Std Dev	0.07	0.21	0.08	0.06	1.16	0.07	0.14	0.05	



Graph 5: Spatial trend in CO Concentration at Monitoring locations

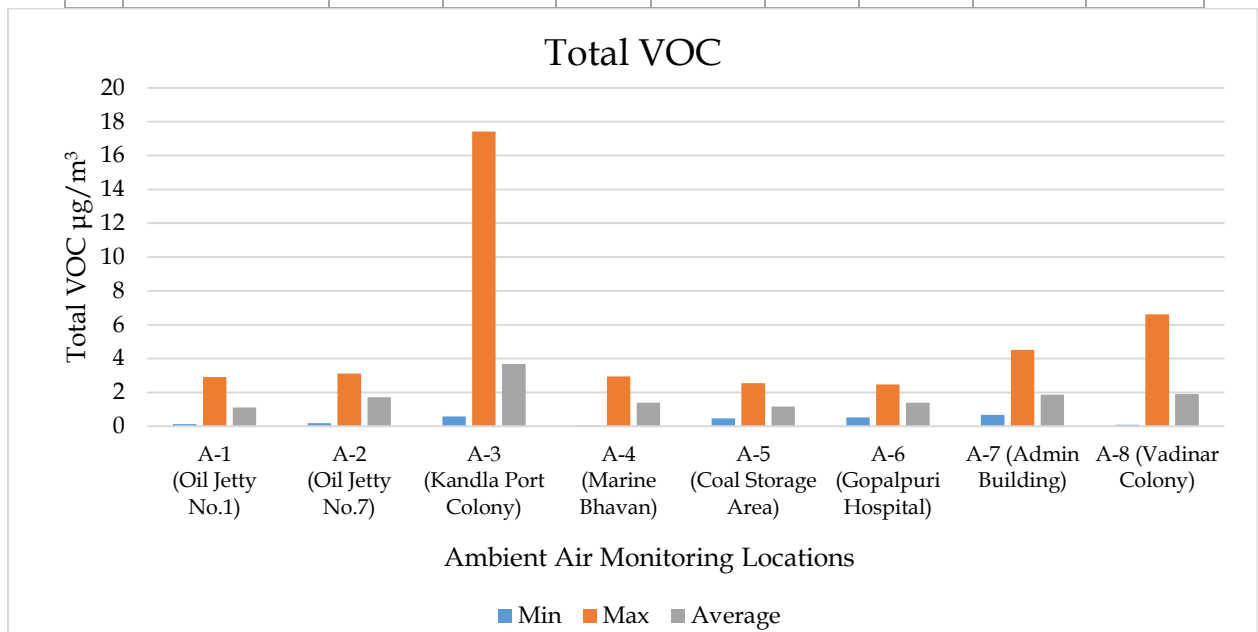
During the monitoring period, the highest CO concentration i.e., 2.97 mg/m<sup>3</sup> was recorded at A-5, Coal Storage Area with mean value 1.87 mg/m<sup>3</sup>. Whereas other monitoring station were recorded the CO concentration well below the specified limit of 2 mg/m<sup>3</sup>.

The levels of CO at monitoring station of Vadinar were found well within the permissible limit. The mean concentration of CO was found 1.00 and 0.99 mg/m<sup>3</sup>, in A-7 (Admin building) and A-8 (Vadinar Colony) respectively. In the coal storage area, as the moisture in the coal is liberated and the coal oxidizes, both heat and carbon monoxide are created. This might be attributed to the higher concentration of Carbon Monoxide in the Coal Storage Area as compared to the other monitored locations.



**Table 11: Summarized results of Total VOC for Ambient Air quality monitoring**

Total VOCs ( $\mu\text{g}/\text{m}^3$ )									
Sr. No	Locations Sampling date	Kandla						Vadinar	
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	17-Apr-2023	0.13	2.54	17.43	2.36	2.54	2.48	4.52	6.62
2	19-Apr-2023	1.32	0.67	2.21	0.04	1.14	2.06	2.6	2.4
3	24-Apr-2023	0.69	2.45	1.97	0.94	0.47	1.84	2.76	2.98
4	26-Apr-2023	2.91	1.99	2.85	1.58	1.85	0.81	0.87	2.45
5	1-May-2023	1.08	2.07	1.83	2.95	0.49	0.52	1.28	0.25
6	3-May-2023	0.97	3.11	2.92	1.74	1.52	2.10	2.09	1.08
7	8-May-2023	1.04	0.19	1.91	0.99	0.58	1.00	1.06	0.08
8	10-May-2023	1.05	2.11	1.47	0.85	0.96	0.85	0.95	0.27
9	15-May-2023	0.65	0.28	0.57	1.09	1.02	0.87	0.68	1.09
	<b>Minimum</b>	0.13	0.19	0.57	0.04	0.47	0.52	0.68	0.08
	<b>Maximum</b>	2.91	3.11	17.43	2.95	2.54	2.48	4.52	6.62
	<b>Average</b>	1.10	1.71	3.68	1.39	1.17	1.39	1.87	1.91
	<b>Std Dev</b>	0.76	1.06	5.20	0.87	0.69	0.72	1.26	2.06


**Graph 6: Spatial trend in Total VOCs Concentration at Monitoring locations**

During the monitoring period, the highest total VOC concentration was observed ( $17.43 \mu\text{g}/\text{m}^3$ ) at A-3, Kandla Port Colony. While at Vadinar monitoring station the highest total VOC concentration was observed  $6.62 \mu\text{g}/\text{m}^3$  at A-8 with mean value  $1.91 \mu\text{g}/\text{m}^3$ . VOCs emitted from an urban source to the atmosphere may cause pollution on a local scale. VOCs are present mainly due to motor vehicles emissions. Gasoline and natural gas are a major source of VOCs that impact outdoor air quality. Vehicle exhaust and burning fossil fuels, wood, and garbage all release VOCs into the atmosphere.

**Table 12: Summarized results of Benzene for Ambient Air quality monitoring**

Benzene ( $\mu\text{g}/\text{m}^3$ )										
Sr. No	Location Sampling date	Kandla						Vadinar		NAAQS standards (24 hr)
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	17-Apr-2023	3.5	1.01	1.43	0.04	1.08	1.08	0.48	0.37	5 $\mu\text{g}/\text{m}^3$

The Ambient air Monitoring location of Kandla recorded the highest Benzene concentration i.e., 1.43  $\mu\text{g}/\text{m}^3$  at A-3, Kandla Port Colony. While at Vadinar monitoring station the highest Benzene concentration was found to be 0.77  $\mu\text{g}/\text{m}^3$  at A-7, Admin Building. Thus, all monitoring station at Kandla and Vadinar recorded the Benzene concentration well below the specified limit of 5  $\mu\text{g}/\text{m}^3$ .

**Table 13: Summarized results of Polycyclic Aromatic Hydrocarbon**

Sr No	Location Components	Kandla						Vadinar	
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
		26-Apr-2023		24-Apr-2023				24-Apr-2023	
1	Napthalene	0.41	17.31	0.49	0.32	1.92	39.82	0.39	0.32
2	Acenaphthylene	0.03	0.48	0.34	0.53	0.03	0.05	0.005	0.005
3	Acenaphthene	0.01	0.45	15.10	119.08	0.02	11.80	0.14	0.12
4	Fluorene	0.04	0.33	22.99	178.72	0.07	27.22	0.05	0.03
5	Anthracene	0.23	0.47	0.88	5.05	0.35	3.78	0.32	0.27
6	Phenanthrene	0.34	0.13	0.08	0.55	0.51	0.78	0.29	0.22
7	Fluoranthene	0.34	0.26	1.43	15.67	0.26	20.36	0.36	0.30
8	Pyrene	0.40	0.26	2.40	42.23	0.33	51.22	0.21	0.01
9	Chrycene	0.39	0.15	0.58	6.27	0.36	5.82	0.22	0.25
10	Banz(a)anthracene	1.17	0.38	1.64	15.42	0.92	16.73	0.32	0.21
11	Benzo[k]fluoranthene	0.98	0.38	0.71	0.64	0.64	4.25	0.31	0.03
12	Benzo[b]fluoranthene	0.89	0.35	0.47	3.97	0.61	6.52	0.25	0.07
13	Benzopyrene	0.75	0.29	0.52	2.85	0.70	3.40	0.32	0.03
14	Indeno[1,2,3-cd]fluoranthene	2.39	0.69	0.80	2.46	1.68	4.61	0.35	0.1
15	Dibenz(ah)anthracene	1.00	0.19	0.21	1.04	0.31	0.46	0.29	0.05
16	Benzo[ghi]perylene	2.34	0.47	0.97	6.07	1.90	6.38	0.27	0.21

Higher concentration of the PAH was observed the period of 17<sup>th</sup> April to 16<sup>th</sup> May 2023. Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous pollutants in urban atmospheres. Anthropogenic sources of total PAHs in ambient air emissions are greater than those that come from natural events. Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, etc. Six sources can be identified such as road dust, oil, coal, vehicles, incineration, and road salt. The road dust and emissions from traffic are the main outdoor source for the PAH concentration. Other outdoor sources of PAHs are industrial plants in and around the DPA premises.

**Table 14: Summarized results of Non-methane VOCs ( $\mu\text{g}/\text{m}^3$ )**

Sr No	Location Sampling date	Kandla						Vadinar	
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	17-Apr-2023	0.12	0.15	0.16	0.17	0.13	0.19	0.15	0.15

The Ambient air Monitoring location of Kandla recorded the highest Non-methane VOC concentration i.e.,  $0.19 \mu\text{g}/\text{m}^3$  at A-6, Gopalpuri Hospital while the lowest Non-methane VOC concentration was found  $0.12 \mu\text{g}/\text{m}^3$  at A-1, Oil Jetty No.1. While at Vadinar monitoring station, the lowest Non-methane VOC concentration was observed  $0.09 \mu\text{g}/\text{m}^3$  at A-7, Admin Building. Thus, all monitoring station at Kandla and Vadinar recorded the Benzene concentration well below the specified limit of  $5 \mu\text{g}/\text{m}^3$ .

#### 4.4 Conclusion:

From the ambient monitoring study conducted for a period (17<sup>th</sup> April-15<sup>th</sup> May 2023), it may be concluded that the particulate matter ( $\text{PM}_{10}$ ), were reported in higher concentrated and apparently were exceeding the NAAQS particularly at 4 locations in Kandla (Oil Jetty No 7, Coal storage area, Kandla port colony and Marine bhavan) while gaseous pollutants ( $\text{NO}_x$ ,  $\text{SO}_x$ , CO, VOCs etc.) falls within the permissible limit. The probable reason contributing to these emissions of pollutants into the atmosphere in and around the port area are summarized as follows-

- Ship Emissions:** Ships primarily emit air pollutants through their exhaust stacks. These emissions include sulfur oxides ( $\text{SO}_x$ ), nitrogen oxides ( $\text{NO}_x$ ), particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), and greenhouse gases (GHGs) such as carbon dioxide ( $\text{CO}_2$ ). The type of fuel used by ships greatly influences the amount and type of emissions produced.
- Port Machinery:** Port activities involve the use of various machinery and equipment, including cranes, forklifts, tugboats, and cargo handling equipment. These machines often rely on diesel engines, which can emit pollutants such as  $\text{NO}_x$ , PM, and CO. Older or poorly maintained equipment tends to generate higher emissions.
- Port Vehicles:** Trucks and other vehicles operating within port and port area contributes to air pollution. Similar to port machinery, diesel-powered vehicles can emit  $\text{NO}_x$ , PM, CO, and other pollutants such as (PAH), VOCs etc. Vehicle traffic and congestion in and around port areas can exacerbate the air quality issues.
- While docked or at anchor, ships may use auxiliary engines to power onboard systems such as lighting, heating, and refrigeration. These engines can emit pollutants and contribute to air pollution, particularly in port areas with significant vessel traffic.

#### 4.5 Suggestive Measures to control the air pollution:

Efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits. To improve air quality the port has adopted a number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in

lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port. To address air pollution from port shipping activities, various measures can be implemented including:

- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle-Mask advised in sensitive areas.
- Covering vehicles with tarpaulin during transportation of construction material to site.
- Ensuring that contractors are maintaining engines and that machinery deployed during construction are complying with emission standards.
- Ensuring frequent water sprinkling on roads to reduce dust vehicular movement on land. The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.
- Use of proper transport methods, such as a conveyor belt, for excavated material and screens around the construction site.
- Temporary pavement of roads in a construction site could considerably reduce dust emission.
- Prohibition of the use of heavy diesel oil as fuel could be a possible means to reduce pollutants Use of Cleaner Fuels: Encouraging or mandating the use of low-sulfur fuels, such as marine gas oil (MGO) or liquefied natural gas (LNG), can significantly reduce sulfur and particulate matter emissions from ships.
- Retrofitting and Engine Upgrades: Retrofitting ships with exhaust gas cleaning systems, also known as scrubbers, can help reduce sulfur emissions. Engine upgrades, such as optimizing fuel combustion and improving engine efficiency, can reduce overall emissions.
- Shore Power Infrastructure: Investing in infrastructure for cold ironing allows ships to connect to the electrical grid while docked, reducing the need for auxiliary engines and associated emissions.
- Improved Port Operations: Implementing efficient cargo-handling processes, optimizing logistics to reduce congestion and idling times, and encouraging use of cleaner port machinery and vehicles can all contribute to reducing air pollution in port areas.
- Inspection of condition of contractor's barges and equipment before start of work and ensuring a maintenance schedule is followed for the equipment used.
- Minimization of movement of project vehicles at night and especially during peak hour traffic (9-11am, 2-3 pm and 5-6pm).
- Regular maintenance of diesel generators engines However, continued efforts are needed to improve air quality and mitigate the impact of port shipping activities on the environment and public health.



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## **CHAPTER 5: NOISE MONITORING**

## 5.1 Noise Monitoring

Noise can be defined as an unwanted sound. It is, therefore, necessary to measure both the quality as well as the quantity of environmental noise in and around the study area. Noise produced during operation stage and thereafter activities may affect surrounding environment impacting the fauna and also the human population working and residing not only at site but also in the nearby areas. Under the scope, the noise monitoring is required to be carried out at 10 locations in Kandla and 3 locations in Vadinar. The sampling locations for noise are confined to commercial areas of DPA. The details of the noise monitoring stations are mentioned in **Table 15** and locations have been depicted in the **Figure 6 and 7** as follow:

**Table 15: Details of noise monitoring locations**

Sr. No.	Location Code	Location Name	Latitude/ Longitude
1.	Kandla	N-1	Oil Jetty 7
2.		N-2	West Gate No.1
3.		N-3	Canteen Area
4.		N-4	Main Gate
5.		N-5	Main Road
6.		N-6	Marin Bhavan
7.		N-7	Port & Custom Building
8.		N-8	Nirman Building
9.		N-9	ATM Building
10.		N-10	Wharf Area/ Jetty
11.	Vadinar	N-11	Near Main Gate
12.		N-12	Near Vadinar Jetty
13.		N-13	Port Colony Vadinar



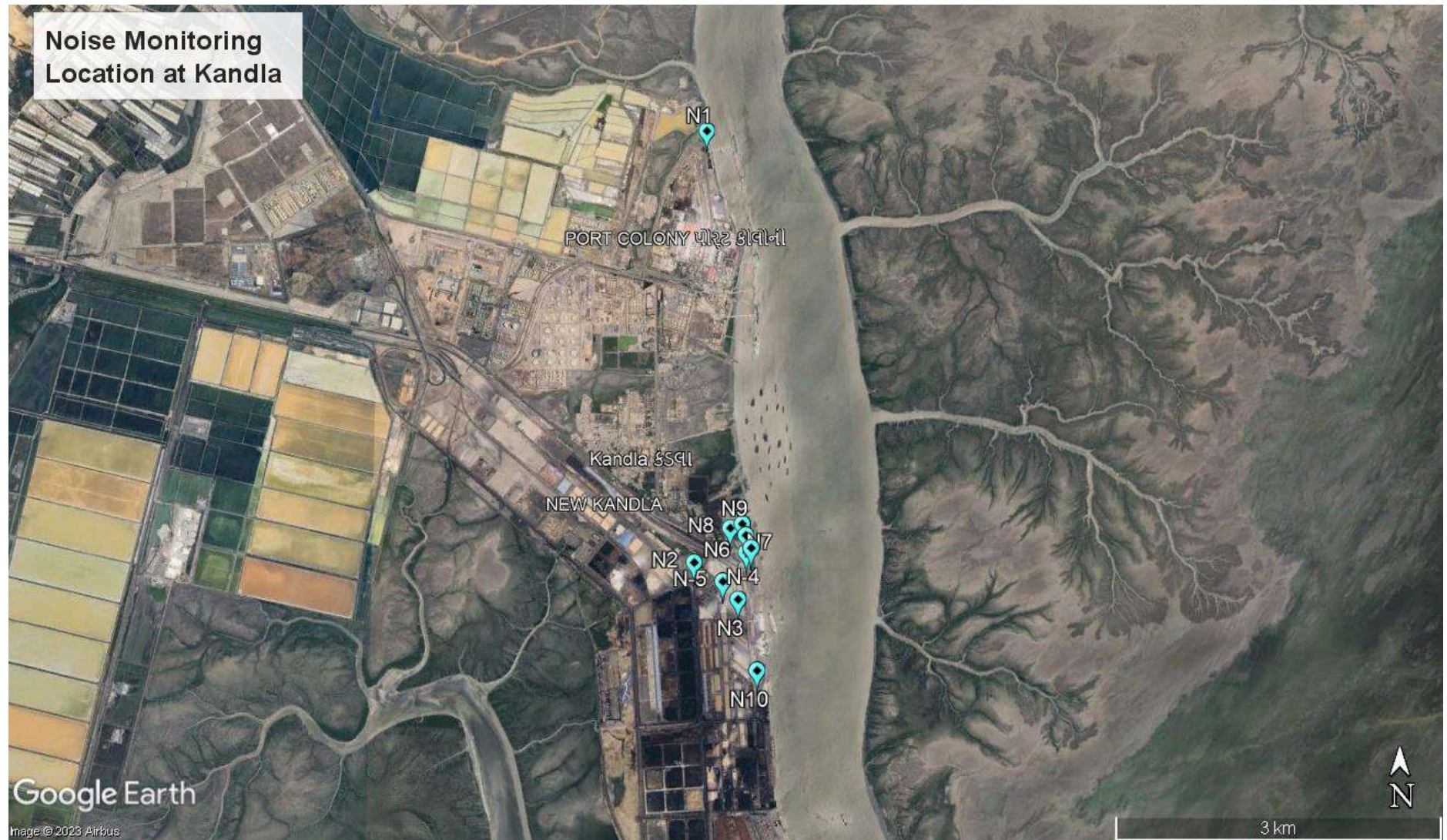


Figure 6: Location Map for Noise Monitoring at Kandla





Figure 7: Location Map for Noise Monitoring at Vadinar

### Frequency of Noise Monitoring

Monitoring was carried out at each noise monitoring station for Leq. noise level (Day and Night), which was recorded for 24 hours continuously for once in a month with the help of Class-1 Sound/Noise Level Meter.

## 5.2 Method of sampling and analysis:

The intensity of sound energy in the environment is measured in a logarithmic scale and is expressed in a decibel (dB(A)) scale. Ordinary sound level meter measures the sound energy that reaches the microphone by converting it into electrical energy and then measures the magnitude in dB(A). In a sophisticated type of sound level meter, an additional circuit (filters) is provided, which modifies the received signal in such a way that it replicates the sound signal as received by the human ear and the magnitude of sound level in this scale is denoted as dB(A). The sound levels are expressed in dB(A) scale for the purpose of comparison of noise levels, which is universally accepted by the international community.

Noise levels were measured using an integrated sound level meter of the make Casella Sound Level Meter (Class-I). It has an indicating mode of Lp and Leq. Keeping the mode in Lp for few minutes and setting the corresponding range and the weighting network in "A" weighting set the sound level meter was run for one-hour time and Leq was measured at all locations.

The day noise levels have been monitored during 6.00am to 10.00pm and night noise levels, during 10.00pm to 6.00am at all the thirteen locations monthly.

**Table 16: Details of the Noise Monitoring that carried out at Kandla and Vadinar**

Sr. No.	Parameters	Units	Reference Method	Instrument
1.	Leq (Day)	dB(A)	IS 9989: 2014	Noise Level Meter (Class-I)
2.	Leq (Night)	dB(A)		

### Standard for Noise

Ministry of Environment & Forests (MoEF) has notified the noise standards vide gazette notification dated February 14, 2000 for different zones under the Environment Protection Act (1986). The specified standards are as mentioned in **Table 17** as follows:

**Table 17: Ambient Air Quality norms in respect of Noise**

Area Code	Category of Area	Noise dB(A) Leq	
		Daytime	Night time
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

**Note:**

- 1 Day time shall mean from 6.00 am to 10.00 pm.
- 2 Night time shall mean from 10.00 pm to 6.00 am.
- 3 Silence zone is defined as area comprising not less than 100 meters around hospitals, educational institutions, courts, religious places or any other area, which is declared as such by the competent authority.

### 5.3 Result and Discussion

The details of the Noise monitoring conducted for the months of April-May 2023 have been summarized in the **Table 18**. The day noise levels have been monitored during 6.00am to 10.00pm and night noise levels, during 10.00pm to 6.00am at all the thirteen locations monthly.

**Table 18: The results of Ambient Noise Quality**

Sr. No.	Station Code	Station Name	Category of Area	Standard	Day Time			Standard	Night Time		
					Max.	Min.	Leq dB(A) Total		Max	Min	Leq dB(A) Total
1	N-1	Oil Jetty 7	A	75	64.5	38.4	53.7	70	56.3	36.9	48.4
2	N-2	West Gate No.1	A	75	66.3	46.1	57.2	70	51.3	39.6	46.6
3	N-3	Canteen Area	B	65	66.2	38.0	54.8	55	51.2	38.6	46.4
4	N-4	Main Gate	A	75	60.8	37.1	52.2	70	50.8	38.6	46.3
5	N-5	Main Road	A	75	64.9	41.4	54.9	70	51.0	33.6	43.5
6	N-6	Marin Bhavan	B	65	60.7	39.0	52.1	55	52.3	44.3	48.5
7	N-7	Port & Custom Building	B	65	66.3	37.6	54.5	55	53.2	37.9	45.7
8	N-8	Nirman Building	B	65	58.7	42.1	51.3	55	58.9	38.5	50.8
9	N-9	ATM Building	B	65	64.5	35.1	54.2	55	53.4	37.3	49.0
10	N-10	Wharf Area/ Jetty	A	75	74.5	42.1	63.1	70	52.7	38.7	48.9
11	N-11	Near Main Gate	A	75	67.7	35.7	56.7	70	54.3	34.3	46.8
12	N-12	Near Vadinar Jetty	A	75	65.3	39.2	54.5	70	54.1	34.7	46.2
13	N-13	Port Colony Vadinar	C	55	58.7	41.8	50.7	45	55.7	36.3	47.8

## 5.4 Data Interpretation:

With reference to the Table 18, during the monitoring period at Kandla highest day time noise was observed at N-10 i.e., Wharf Area/Jetty (74.5 dB(A)). The day time noise levels were observed to be within the prescribed limit of 75 dB(A).

While considering the Night time, highest noise was observed at N-8 i.e., Nirman Building (58.9 dB(A)), whereas lowest noise was observed at N-5 i.e., Main Road area (33.6 dB(A)). The night time noise levels were observed to be within the prescribed limit of 70 dB(A).

For the locations of Vadinar highest and lowest day time noise was observed at N-11 i.e., Near Main Gate as 67.7 dB(A) and 35.7 dB(A) respectively. The day time noise levels were observed to be within the prescribed limit of 75 dB(A).

While considering the Night time, highest noise was observed at N-13 i.e., Port Colony Vadinar (55.7 dB(A)), whereas lowest noise was observed at N-11 i.e., Near Main Gate (34.3 dB(A)). The night time noise levels were observed to be within the prescribed limit of 70dB(A).

## 5.5 Conclusion

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level in all 10 locations at Deendayal Port Authority ranged from 51.3 dB(A) to 63.1 dB(A) while at Vadinar port 3 location ranged from 50.7 dB(A) to 56.7 dB(A) and for The Night Time Average Noise Level in all locations of Deendayal Port Authority ranged from 43.5 dB(A) to 50.8 dB(A) while at Vadinar port ranged from 46.2 dB(A) to 47.8 dB(A) which falls within the permissible limits set for the industrial, commercial and residential area for the daytime.

Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Construction activities may create a problem of noise generated by construction equipment, truck traffic, work vessels and other similar sources. Sources of noise can be individuated in port areas in the following three main areas:

- Passenger car and heavy vehicle (trucks) road traffic (the most important one);
- Goods movement (from machinery such as quay-crane, pumps, etc.);
- Rail traffic noise: rail movement in port and in surrounding areas are prevalent to low speed and of consequence the noise level is not so high, however in highly trafficked areas the problem can be relevant.

## 5.6 Measures against adverse effects

Transmission of noise may reduce with the distance from their sources. Noise could be considerably reduced by adoption of low noise equipment or installation of sound insulation fences. Green belt of plants can be a good barrier. Limitation of working hours may be a possible means to mitigate the nuisances of construction activities.

## **CHAPTER 6: DRINKING WATER MONITORING**



## 6.1 Drinking Water Monitoring

It is necessary to check with the drinking water sources regularly so as to know whether water quality meets the prescribed standards for drinking. Monitoring the drinking water quality is essential to protect human health and the environment. A total of 20 locations (18 at Kandla and 2 at Vadinar) were monitored for Drinking Water. The location map has been depicted in the **Figure 8 and 9** and the details of the drinking water monitoring locations within the premises of DPA have been mentioned in **Table 19**.

**Table 19: Details of Drinking Water Sampling Locations**

Sr. No.	Location Code		Location Name	Latitude/ Longitude
1.	Kandla	DW-1	Oil Jetty 7	23.043527N 70.218456E
2.		DW-2	Port & Custom Building	23.009033N 70.222047E
3.		DW-3	North Gate	23.007938N 70.222411E
4.		DW-4	Workshop	23.009372N 70.222236E
5.		DW-5	Canteen Area	23.003707N 70.221331E
6.		DW-6	West Gate 1	23.006771N 70.217340E
7.		DW-7	Sewa Sadan -3	23.009779N 70.221838E
8.		DW-8	Nirman Building	23.009642N 70.220623E
9.		DW-9	Custom Building	23.018930N 70.214478E
10.		DW-10	Port Colony Kandla	23.019392N 70.212619E
11.		DW-11	Wharf Area/ Jetty	22.997833N 70.223042E
12.		DW-12	Hospital Kandla	23.018061N 70.212328E
13.		DW-13	A.O. Building	23.061914N 70.144861E
14.		DW-14	School Gopalpuri	23.083619N 70.132061E
15.		DW-15	Guest House	23.078830N 70.131008E
16.		DW-16	E- Type Quarter	23.083306N 70.132422E
17.		DW-17	F- Type Quarter	23.077347N 70.135731E
18.		DW-18	Hospital Gopalpuri	23.081850N 70.135347E
19.	Vadinar	DW-19	Near Vadinar Jetty	22.440759N 69.675210E
20.		DW-20	Near Port Colony	22.401619N 69.716822E



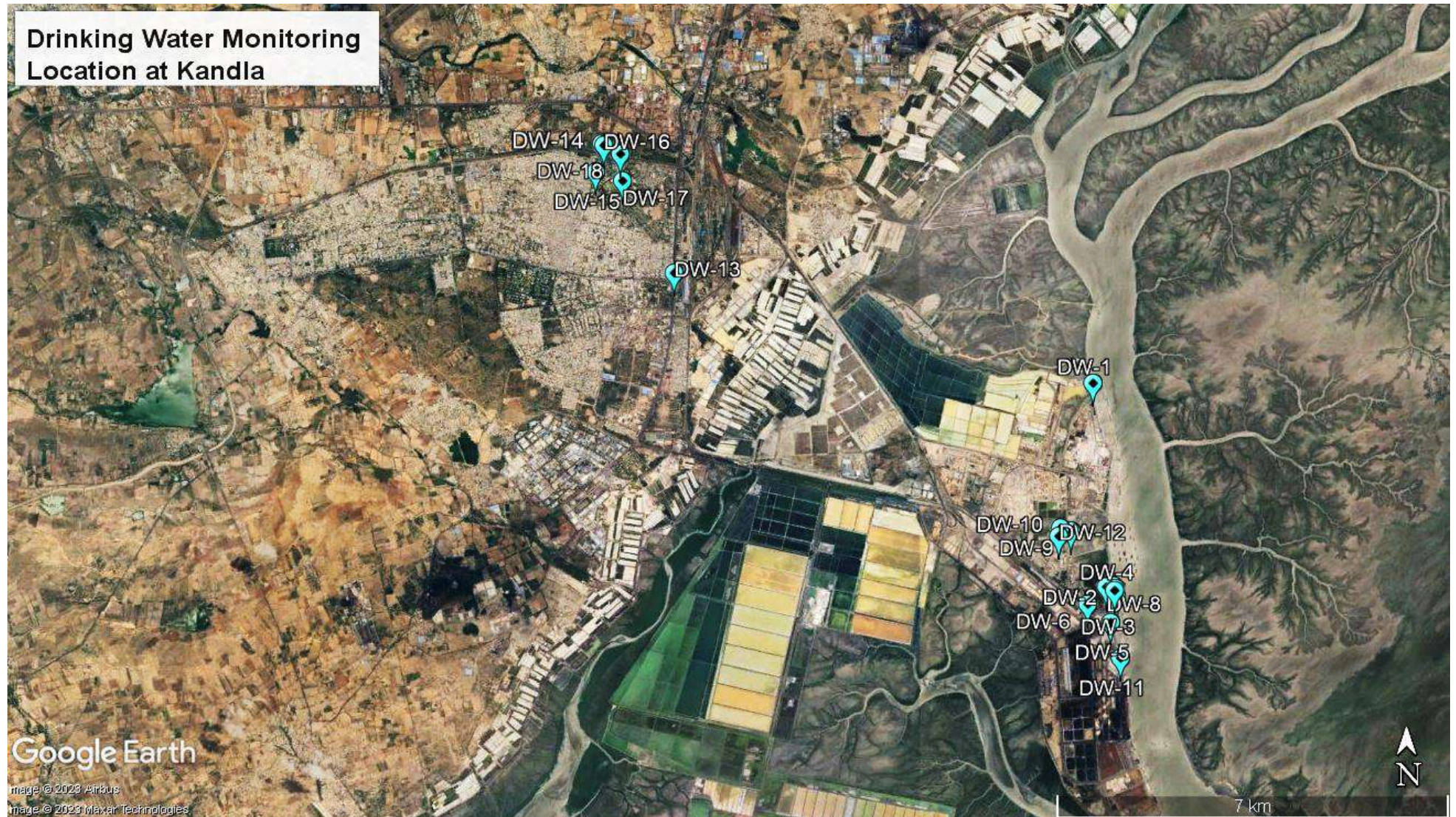


Figure 8: Location Map for Drinking Water Monitoring for Kandla





Figure 9: Location Map for Drinking Water Monitoring at Vadinar

## 6.2 Methodology of Monitoring:

The water samples were collected from the finalized sampling locations and analyzed for physico-chemical and microbiological parameter. The analysis of these samples collected was carried out as per APHA, 23<sup>rd</sup> Edition and Indian Standard method in GEMI's NABL Accredited Laboratory, Gandhinagar. GEMI has followed the CPCB guideline as well as framed its own guidelines for the collection of water/wastewater samples, under the provision of Water (Preservation and Control of Pollution) Act 1974, titled as '**Sampling Protocol for Water & Wastewater**'; approved by the Government of Gujarat vide letter no. ENV-102013-299-E dated 24-04-2014. The samples under the study were collected and preserved as per the said Protocol. The samples were analyzed for selected parameters to establish the existing water quality of the study area. The parameters finalized to assess the drinking water quality have been mentioned in **Table 20** as follows:

**Table 20: List of parameters for Drinking Water Quality monitoring**

Sr. No.	Parameters	Units	Reference method	Instrument
1.	pH	-	APHA, 23 <sup>rd</sup> Edition (Section-4500-H <sup>+</sup> B):2017	pH Meter
2.	EC	μS/cm	APHA, 23 <sup>rd</sup> Edition (Section-2510 B):2017	Conductivity Meter
3.	Turbidity	NTU	APHA, 23 <sup>rd</sup> Edition (Section -2130 B):2017	Nephlo Turbidity Meter
4.	TDS	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-2540 C):2017	Vaccum Pump with filtration assembly and Oven
5.	TSS	mg/L	APHA, 23 <sup>rd</sup> Edition, 2540 D: 2017	
6.	Chloride	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-4500-Cl-B):2017	Titration Apparatus
7.	Total Hardness	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-2340 C):2017	
8.	Ca Hardness	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-3500-Ca B):2017	
9.	Mg Hardness	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-3500-Mg B):2017	
10.	Free Residual Chlorine	mg/L	APHA 23 <sup>rd</sup> Edition, 4500	
11.	Fluoride	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-4500-F-D):2017	UV- Visible Spectrophotometer
12.	Sulphate	mg/L	APHA, 23 <sup>rd</sup> Edition (Section 4500-SO <sub>4</sub> -2-E):2017	
13.	Sodium	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-3500-Na-B):2017	Flame Photometer
14.	Potassium	mg/L	APHA, 23 <sup>rd</sup> Edition, 3500 K-B: 2017	
15.	Salinity	mg/L	APHA, 23 <sup>rd</sup> Edition (section 2520 B, E.C. Method)	Salinity /TDS Meter

Sr. No.	Parameters	Units	Reference method	Instrument
16.	Nitrate	mg/L	APHA, 23 <sup>rd</sup> Edition, 4500 NO <sub>3</sub> - B: 2017	UV- Visible Spectrophotometer
17.	Nitrite	mg/L	APHA, 23 <sup>rd</sup> Edition, 4500 NO <sub>2</sub> -B: 2017	
18.	Hexavalent Chromium	mg/L	APHA, 23 <sup>rd</sup> Edition, 3500 Cr B: 2017	
19.	Manganese	mg/L	APHA, 23 <sup>rd</sup> Edition, ICP Method 3120 B: 2017	ICP-OES
20.	Mercury	mg/L	EPA 200.7	
21.	Lead	mg/L	APHA ICP 23 <sup>rd</sup> Edition (Section- 3120 B):2017	
22.	Cadmium	mg/L	APHA ICP 23 <sup>rd</sup> Edition (Section- 3120 B):2017	
23.	Iron	mg/L	APHA ICP 23 <sup>rd</sup> Edition (Section- 3120 B):2017	
24.	Total Chromium	mg/L	APHA ICP 23 <sup>rd</sup> Edition (Section- 3120 B):2017	
25.	Copper	mg/L	APHA, 23 <sup>rd</sup> Edition, ICP Method 3120 B: 2017	ICP-OES
26.	Zinc	mg/L	APHA ICP 23 <sup>rd</sup> Edition (Section- 3120 B):2017	
27.	Arsenic	mg/L	APHA ICP 23 <sup>rd</sup> Edition (Section- 3120 B):2017	
28.	Colour	mg/L	APHA, 23 <sup>rd</sup> Edition, 2120 B:2017	Color Comparator
29.	Total Coliforms	MPN/ 100ml	IS 15185: 2016	LAF/ Incubator

### 6.3 Conclusion Result and discussion:

The drinking water quality of the locations at Kandla and Vadinar and its comparison with the to the standard (Drinking Water Specifications i.e., IS: 10500:2012) have been summarized in **Table 21**.

**Table 21: Summarized Result of Drinking Water quality**

Sr. No.	Parameters	Units	Standard values as per IS		Kandla																		Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
1.	pH	-	6.5-8.5	-	7.35	7.15	7.36	7.26	7.27	7.31	7.45	7.42	7.24	7.23	7.33	7.19	7.62	7.65	7.55	7.53	7.6	7.28	7.46	7.45
2.	Colour	Hazen	5	15	1	1	1	1	1	1	1	1	1	1	1	1	1	5	1	1	1	1	5	20
3.	EC	μS/cm	-	-	198	38	138	36	42	48	36	40	315	138	55	62	24	551	58	146	150	38	115	683
4.	Salinity	mg/L	-	-	0.10	0.02	0.07	0.02	0.02	0.02	0.02	0.02	0.15	0.07	0.02	0.03	0.02	0.27	0.03	0.07	0.07	0.02	0.06	0.33
5.	Turbidity	NTU	1	5	BQL	BQL	0.7	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	5.3
6.	Chloride	mg/L	250	1000	46.9	7.50	30.99	8.5	10.32	12.59	7.5	10.50	72.48	25.99	13.54	12.50	7.50	80.97	12.50	25.99	26.49	11.5	19.99	90.47
7.	Total Hardness	mg/L	200	600	15	10	10	15	10	15	10	15	15	10	15	15	10.0	160	15	20	20	10	20	160
8.	Ca Hardness	mg/L	-	-	5	5	5	5	5	5	5	5	5	5	5	5	5.0	90	5	10	10	5	5	80
9.	Mg Hardness	mg/L	-	-	10	5	5	10	5	10	5	10	10	5	10	10	5.0	70	10	10	10	5	15	80
10.	Free Residual Chlorine	mg/L	0.2	1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
11.	TDS	mg/L	500	2000	100	20	72	20	22	25	20	22	158	70	29	30	28	278	32	76	78	20	62	346
12.	TSS	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	12
13.	Fluoride	mg/L	1.0	1.5	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
14.	Sulphate	mg/L	200	400	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	25.84	BQL	BQL	BQL	BQL	BQL	40.57





Sr. No.	Parameters	Units	Standard values as per IS		Kandla																		Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
15.	Nitrate	mg/L	45	-	9.59	1.09	3.27	BQL	BQL	BQL	BQL	BQL	3.615	7.458	BQL	BQL	BQL	3.564	1.223	1.097	1.191	BQL	15.79	18.54
16.	Nitrite	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17.	Sodium	mg/L	-	-	24.1	BQL	13.00	BQL	12	13.6	BQL	BQL	41.55	13	12.8	BQL	BQL	50.93	BQL	16.83	17.51	BQL	7.55	54.55
18.	Potassium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
19.	Hexavalent Chromium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.041	0.015
20.	Odour	TON	Agreeable		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	0.01	0.05	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	0.003	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	0.05	1.5	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	16.25	BQL
24.	Iron	mg/L	0.3	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	1.478	BQL
25.	Lead	mg/L	0.01	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	10.53	BQL
26.	Manganese	mg/L	0.1	0.3	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	139.03	93.717
27.	Mercury	mg/L	0.001	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL



Sr. No.	Parameters	Units	Standard values as per IS		Kandla																		Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
28.	Total Chromium	mg/L	0.05	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Zinc	mg/L	5	15	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Total Coliform*	CFU/100ml	Shall not be detected		5	390	BQL	25	5	5	BQL	BQL	BQL	BQL	5	5	BQL	135	BQL	7650	2350	5	2850	130000

A: Acceptable, P:Permissible, BQL: Below Quantification limit Turbidity (QL=0.5), Free Residual Chlorine (QL=2), Total Suspended Solids (QL=2), Fluoride (QL=0.3), Sulphate (QL=10), Nitrate as NO<sub>3</sub> (QL=1), Nitrite as NO<sub>2</sub> (QL=0.1), Sodium as Na (QL=5), Potassium as K (QL=5), Hexavalent Chromium (QL=0.01), Arsenic (QL=5), Cadmium (QL=2), Copper (QL=5), Iron (QL=0.1), Lead (QL=2), Manganese (QL=40), Mercury (QL=0.5), Total Chromium (QL=5), Zinc (QL=0.5)

**\*Note:** For Total Coliform, one MPN is equivalent to one CFU. The use of either methods; MPN or CFU for the detection of bacteria are considered valid measurements for bacteria limits.

#### 6.4 Data Interpretation:

- **pH:** The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. At Kandla, the pH values for drinking water samples ranged from 7.15-7.65 and mean value was 7.37 while at Vadinar pH ranged from 7.45-7.46 and mean value was 7.45.
- **Turbidity:** Turbidity measurements are used to determine how clear and clean a water sample is. Small particles like clay, silt, algae, and microorganisms can be suspended in water and cause light scattering, giving water a milky or cloudy appearance. At the drinking water locations of Kandla, the turbidity was observed to be "Below the detection Limit" for majority of the locations, except location DW-3 (0.7 NTU). Whereas, for Vadinar the turbidity was observed to be "Below the detection Limit" for DW-19 and 5.3 NTU for DW-20.
- **Total Dissolved Solids (TDS):** Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. During the study period, TDS values at Kandla varied between 20 to 278 mg/L. The average TDS value was found 114.8 mg/L. The minimum value for TDS was 20 mg/L at DW-2, DW-4, DW-7 and DW-18 and maximum was 278 mg/L at DW-14. The average TDS was 61.11 mg/L. Whereas, at Vadinar TDS ranged from 62-346 mg/L and mean was 204 mg/L.
- **Electrical Conductivity** is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected ranged from 24-551  $\mu\text{S}/\text{cm}$  with the average value as 117.38  $\mu\text{S}/\text{cm}$ . While at Vadinar, the value of EC ranged from 115-683  $\mu\text{S}/\text{cm}$  with the average value as 399  $\mu\text{S}/\text{cm}$ .
- **Chlorides:** Excessive chloride concentration increase rates of corrosion of metals in the distribution system. The Chloride concentration varied from 7.5-80.97 mg/L, with the average value as 23.57 mg/L. The lowest concentration was observed at DW-2, DW-7 and DW-13, while the highest was observed at DW-14. While at Vadinar, the concentration varied from 19.99-90.47 mg/L. With the average chloride concentration as 55.23 mg/L. The lowest concentration was observed at DW-19, while the highest was observed at DW-20.
- **Total Hardness:** Hardness is caused by compounds of calcium and magnesium, and by a variety of other metals. The Total Hardness concentration varied from 10-160 mg/L, with the average value as 21.66 mg/L. The highest was observed at DW-14. While at Vadinar, the concentration varied from 20-160 mg/L. With the average Total Hardness concentration as 90 mg/L. Hardness at all the locations was observed to have concentrations within the norms specified. The hardness of water is according to the IS standards and it is not harmful for local inhabitants.
- The parameters Free Residual Chlorine, Total Suspended Solids, Fluoride, Sulphate, Nitrate, Nitrite, Sodium, Hexavalent Chromium, Potassium, and the metals Arsenic, Cadmium, Copper, Iron, Lead, Manganese, Mercury, Total Chromium and Zinc were all observed to have concentrations "Below the Quantification Limit (BQL)" at majority of the locations for both the monitoring period.

- Bacteriological Analysis of the drinking water at Kandla and Vadinar reveals that the Total Coliforms were detected at majority of the locations of Kandla and Vadinar. This shows that drinking water samples is unfit for human consumption. Reporting such high concentration of Coliforms indicates certain external influx may contaminate the source. Hence, it should be checked at every distribution point.

### 6.5 Conclusion

- These results were compared with permissible limits as prescribed in IS 10500:2012 – Drinking Water Specification. It may be concluded from the analysis data that amongst the drinking water parameters so monitored, the parameters such as TDS, Total hardness, chloride, fluoride were observed to be well below the acceptable limit of IS standard at all the 20 monitoring locations. Whereas Total Coliforms were found to be present in all the drinking water samples collected from both the locations.
- Low TDS water shall contain lower mineral content, Normal drinking water provides about 20% of your dietary intake of dissolved minerals. So, which means by consuming such water may result in mineral deficiency. Further, it may increase the metal leaching.
- Bacteriological Analysis of the drinking water at Kandla and Vadinar reveals that the drinking water samples is unfit for human consumption.
- Appropriate water treatment processes should be implemented to remove or inactivate coliform bacteria that include disinfection with chlorine, ultraviolet (UV) light, or ozone etc. Filtration systems can also help remove bacteria, sediment, and other impurities.
- Further, a regular monitoring program to test the quality of drinking water at various stages, including the source, purification plants, distribution network, and consumer endpoints would help in early detection of coliform bacteria or other microbial contaminants.



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## **CHAPTER 7: DG STACK MONITORING**

## 7.1 DG Stack Monitoring

A diesel generator is a mechanical-electrical machine that produces electrical energy (electricity) from diesel fuel. They are used by the residential, commercial, charitable and governmental sectors to provide power in the event of interruption to the main power, or as the main power source. Diesel generating (DG) sets are generally used in places without connection to a power grid, or as an emergency power supply if the grid fails. These DG sets utilize diesel as fuel and generate and emit the air pollutants such as Suspended Particulate Matter, SO<sub>x</sub>, NO<sub>x</sub>, CO, etc. from the stack during its functioning. The purpose of stack sampling is to determine emission levels from plant processes to ensure they are in compliance with any emission limits set by regulatory authorities to prevent macro environmental pollution. The stack is nothing but chimney which is used to disperse the hot air at a great height, emissions & particulate matters that are emitted. Hence, monitoring of these stacks attached to DG Sets is necessary in order to quantify the emissions generated from it.

As defined in scope by Deendayal Port Authority (DPA), the monitoring of DG Stack shall be carried out at two locations, one at Kandla and one at Vadinar. The details of the DG Sets at Kandla and Vadinar have been mentioned in **Table 22** as follows:

**Table 22: Details of DG Set monitoring locations**

Sr. No.	Location Code	Location Name	Latitude/ Longitude
1.	DG-1	Kandla	22.98916N 70.22083E
2.	DG-2	Vadinar	22.44155N 69.67419E

The map depicting the locations of DG Stack Monitoring to be monitored in Kandla and Vadinar have been mentioned in **Map 10 and 11** as follows:





Figure 10: Location Map for DG Set monitoring at Kandla





Figure 11: Location Map for DG Set monitoring at Vadinar

### Frequency of DG Monitoring

Monitoring is required to be carried out once a month for both the locations of Kandla and Vadinar.

## 7.2 Method of sampling and analysis:

Under the study, the list of parameters to be monitored under the projects for the Soil Quality Monitoring been mentioned in **Table 23** as follows:

**Table 23: Parameters to be monitored under the study**

Sr. No.	Parameter	Unit	Instrument
1.	Suspended Particulate Matter	mg/Nm <sup>3</sup>	Stack Monitoring Kit
2.	Sulphur Dioxide (SO <sub>2</sub> )	mg/Nm <sup>3</sup>	Sensor based Flue Gas Analyzer (Make: TESTO, Model 350)
3.	Oxides of Nitrogen (NO <sub>x</sub> )	mg/Nm <sup>3</sup>	
4.	Carbon Monoxide	mg/Nm <sup>3</sup>	
5.	Carbon Dioxide	mg/Nm <sup>3</sup>	

The methodology for monitoring of DG Set has been mentioned as follows:

The monitoring of DG Stack is carried out as per the IS:11255 and USEPA Method. The Stack monitoring kit is used for collecting representative samples from the stack to determine the total amount of pollutants emitted into the atmosphere in a given time. Source sampling is carried out from ventilation stack to determine the emission rates/or characteristics of pollutants. Sample collected must be such that it truly represents the conditions prevailing inside the stack. Whereas the parameters Sulphur Dioxide, Oxides of Nitrogen (NO<sub>x</sub>), Carbon Monoxide and Carbon Dioxide, the monitoring is carried out by using the sensor-based Flue Gas Analyzer.

As per CPCB or Indian standards for Industrial Stack Monitoring the flue gas emission from DG set emissions should not exceed the limit as mentioned in **Table 24**.

**Table 24: Standards for stack emission**

Sr. No.	Stack Monitoring Parameters for DG Sets	Stack Monitoring Limits / Standards As per CPCB (mg/Nm <sup>3</sup> )
1.	Particulate Matter	150
2.	Sulphur Dioxide (SO <sub>2</sub> )	40
3.	Oxides of Nitrogen (NO <sub>x</sub> )	25
4.	Carbon Monoxide	1%

During the monitoring period, the DG sets were not utilized, and hence monitoring was not conducted.



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## **CHAPTER 8: SOIL QUALITY MONITORING**

## 8.1 Soil Quality Monitoring:

The purpose of soil quality monitoring is to track changes in the features and characteristics of the soil, especially the chemical properties of soil occurring at specific time intervals under the influence of human activity. Soil quality assessment helps to determine the status of soil functions and environmental risks associated with various practices prevalent at the location.

As defined in scope by Deendayal Port Authority (DPA), Soil Quality Monitoring shall be carried out at Six locations, four at Kandla and two at Vadinar. The details of the soil monitoring locations within the Port area of DPA are mentioned in **Table 25**:

**Table 25: Details of the Soil quality monitoring locations**

Sr. No.	Location Name		Location Code	Latitude Longitude
1.	Kandla	Oil Jetty 7	S-1	23.043527N 70.218456E
2.		IFFCO Plant	S-2	23.040962N 70.216570E
3.		Khori Creek	S-3	22.970382N 70.223057E
4.		Nakti Creek	S-4	23.033476N 70.158461E
5.	Vadinar	Near SPM	S-5	22.400026N 69.714308E
6.		Near Vadinar Jetty	S-6	22.440759N 69.675210E

The map depicting the locations of Soil Quality Monitoring to be monitored in Kandla and Vadinar have been mentioned in **Map 12 and 13** as follows:



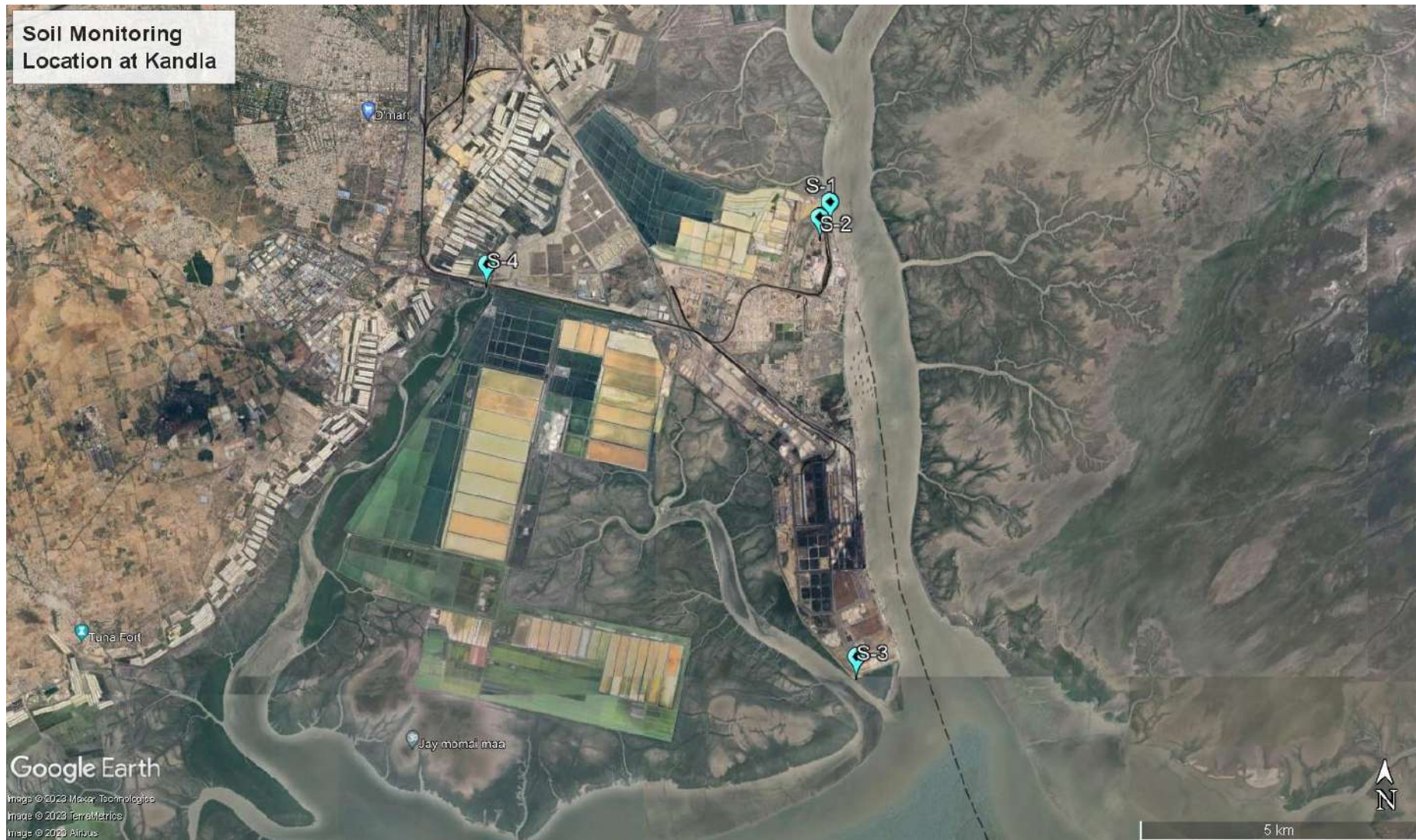


Figure 12: Location Map for Soil Quality Monitoring at Kandla





Figure 13: Location Map for Soil Quality Monitoring at Vadinar

## 8.2 Methodology of Monitoring:

As per the defined scope by Deendayal Port Authority (DPA), the sampling and analysis of Soil quality has been carried out on monthly basis.

The samples of soil collected from the locations of Kandla and Vadinar and analyzed for the various physico-chemical parameter. Collection and analysis of these samples was carried out as per established standard methods and procedures. The samples were analyzed for selected parameters to get the present soil quality status and its and environmental risks associated with various practices prevalent at the location. GEMI has framed its own guidelines for collection of soil samples titled as '*Soil Sampling Manual*'. Soil samples were collected from up to 30 cm depth below the surface using scrapper, filled in polythene bags, labelled on-site with specific location code and name and sent to GEMI's laboratory for further detailed analysis. The samples collected from all locations are homogeneous representative of each location. The list of parameters to be monitored under the projects for the Soil Quality Monitoring been mentioned in **Table 26** as follows:

**Table 26: List of parameters to be monitored for Soil Quality**

Sr. No.	Parameters	Units	Reference method	Instruments
1.	TOC	%	Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934)	Titration Apparatus
2.	Organic Carbon	%		
3.	Inorganic Phosphate	mg/Kg	Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017 Determination of Available Phosphorus in Soil	UV-Visible Spectrophotometer
4.	Texture	-	Methods Manual Soil Testing in India January 2011,01	Hydrometer
5.	pH	-	IS 2720 (Part 26): 1987	pH Meter
6.	Conductivity	μS/cm	IS 14767: 2000	Conductivity Meter
7.	Particle size distribution & Silt content	-	Methods Manual Soil Testing in India January 2011	Sieves Apparatus
8.	SAR	meq/L	Procedures for Soil Analysis, International Soil Reference and Information Centre, 6 <sup>th</sup> Edition 2002 13-5.5.3 Sodium Absorption Ratio (SAR), Soluble cations	Flame Photometer

Sr. No.	Parameters	Units	Reference method	Instruments
9	Water Holding Capacity	%	NCERT, Chapter 9, 2022-23 and Water Resources Department Laboratory Testing Procedure for Soil & Water Sample Analysis	Muffle Furnace
10	Aluminium	mg/Kg	EPA Method 3051A	ICP-OES
11	Chromium	mg/Kg		
12	Nickel	mg/Kg		
13	Copper	mg/Kg	Methods Manual Soil Testing in India January, 2011, 17a	
14	Zinc	mg/Kg	Methods Manual Soil Testing in India January, 2011, 17a	
15	Cadmium	mg/Kg	EPA Method 3051A	
16	Lead	mg/Kg		
17	Arsenic	mg/Kg		
18	Mercury	mg/Kg		

### 8.3 Result and Discussion

The analysis results of physical analysis of the soil samples collected during environmental monitoring mentioned in **Table 27** are shown below:

**Table 27: Results of Soil Quality**

Sr. No	Location Parameters	Unit	Kandla				Vadinar	
			S-1 (Oil Jetty 7)	S-2 (IFFCO Plant)	S-3 (Khor Creek)	S-4 (Nakti Creek)	S-5 (Near SPM)	S-6 (Near Vadinar Jetty)
1	pH	-	7.69	8.27	7.27	8.04	7.92	8.5
2	Conductivity	µS/cm	8840	6040	39600	11700	111	625
3	Inorganic Phosphate	mg/Kg	11.01	27.6	20.31	11.46	5.64	5.1
4	Organic Carbon	%	0.03	0.38	1.88	0.46	0.85	0.3
5	Organic Matter	%	0.06	0.66	3.23	0.79	1.47	0.52
6	SAR	meq/L	1.05	0.67	1.10	1.65	0.10	0.25
7	Aluminium	mg/Kg	1392.53	1368.22	1569.23	1388.41	1480.53	1425.50
8	Chromium	mg/Kg	69.98	69.92	79.56	70.18	106.00	91.88
9	Nickel	mg/Kg	33.32	27.54	27.16	31.51	40.89	42.68
10	Copper	mg/Kg	25.33	51.65	148.05	50.49	123.18	98.20
11	Zinc	mg/Kg	52.29	155.24	100.20	61.30	83.05	52.89
12	Cadmium	mg/Kg	BQL	1.07	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	9.30	17.33	3.45	7.24	BQL	0.91
14	Arsenic	mg/Kg	4.87	8.4	BQL	4.03	BQL	BQL
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	45.54	45.29	25.98	45.84	39.85	54.23
17	Sand	%	70.7	72.28	60.08	76.33	51.84	53.62
18	Silt	%	9.77	13.86	29.74	11.84	12.24	36.08
19	Clay	%	19.53	13.86	10.18	11.84	35.92	10.3
20	Texture		Sandy loam	Loamy Sand	Sandy loam	Sandy loam	Sandy loam	Sandy loam

Under the project, in order to classify the soil quality of Kandla and Vadinar, the “Standard Soil Classification” has been adopted from Hand Book of Agriculture, ICAR, New Delhi. The classification is mentioned in the **Table 28** as follows for the parameters pH, Electrical Conductivity and Organic Carbon.

**Table 28: Classification of soil parameters as mentioned in Hand Book of Agriculture**

Sr. No.	Soil Parameters	Classification
1.	pH	<p>&lt;4.5 Extremely acidic</p> <p>4.51-5.50 Very strongly acidic</p> <p>5.51-6.00 moderately acidic</p> <p>6.01-6.50 slightly acidic</p> <p>6.51-7.30 Neutral</p> <p>7.31-7.80 slightly alkaline</p> <p>7.81-8.50 moderately alkaline</p> <p>8.51-9.0 strongly alkaline</p> <p>&gt;9.00 very strongly alkaline</p>
2.	EC (ppm) (1ppm = 640 $\mu$ mhos)	<p>Up to 1.00 Average</p> <p>1.01-2.00 harmful to germination</p> <p>2.01-3.00 harmful to crops (sensitive to salts)</p>
3.	Organic Carbon	<p>Up to 0.2: very less</p> <p>0.21-0.4: less</p> <p>0.41-0.5 medium,</p> <p>0.51-0.8: on an average sufficient</p> <p>0.81-1.00: sufficient</p> <p>&gt;1.0 more than sufficient</p>

#### 8.4 Data Interpretation:

- pH**

For the month of April 2023, the value of pH ranges from 7.27-8.27, highest at location S-2 IFFCO Plant; while the average value was 7.81. Whereas, at Vadinar highest pH was observed at S-6 i.e., near Jetty Area (8.5) with the average soil pH as 8.21. As per the classification mentioned in the Handbook of Agriculture, the pH in Kandla varies from the Neutral to moderately alkaline. Whereas, pH of Soil at Vadinar was found to be moderately alkaline.

- Electrical Conductivity (EC)**

During the study period, at Kandla the value of EC ranges from 6040-39600  $\mu$ S/cm, highest at location S-3 Khorri creek (11700  $\mu$ S/cm) and lowest at S-2 IFFCO Plant (6040  $\mu$ S/cm); while the average value was 16545  $\mu$ S/cm. Whereas, at Vadinar highest EC was observed at S-6 i.e., near Jetty Area (6.25  $\mu$ S/cm) and lowest was observed at S-5 i.e., Near SPM (111  $\mu$ S/cm), while the average value was 368  $\mu$ S/cm.

As per the classification mentioned in the Handbook of Agriculture, the Electrical Conductivity at Kandla the status of soil quality was found to be harmful to crops. Whereas, at Vadinar EC was observed to be below the average value of 640  $\mu$ S/cm.

- Inorganic Phosphate**

During the monitoring period at Kandla the value of Inorganic Phosphate ranges from 11.01-27.6 mg/Kg, highest at location S-2 IFFCO Plant (27.6 mg/Kg) and lowest at S-1 Oil Jetty-7 (11.01 mg/Kg); while the average value was 17.595 mg/Kg. Whereas, at



Vadinar highest Inorganic Phosphate was observed at S-6 i.e., near Jetty Area (5.1 mg/Kg) and lowest was observed at S-5 i.e., Near SPM (5.64 mg/Kg), while the average value was 5.37 mg/Kg.

- **Total organic Carbon (TOC)**

At Kandla the value of TOC ranges from 0.03 to 1.88 % highest at location S-3 Khoricreek (1.18%) and lowest at S-1 Oil Jetty-7 (0.03%); while the average value was 0.68%. Whereas, at Vadinar highest TOC was observed at S-5 i.e., Near SPM (0.85%) and lowest was observed at S-6 i.e., near Jetty Area (0.3%). As per the classification mentioned in the Handbook of Agriculture, the Organic Carbon at Kandla and Vadinar was on an average in sufficient concentration.

- **Heavy Metals**

For the sampling period, the concentration of **Aluminium** in the soil samples at varies from 1368.22 to 1569.23 mg/kg at Kandla and 1425.5 to 1480.53 mg/kg at Vadinar with mean value reported as 1429.59 and 1453.01 mg/kg at Kandla and Vadinar monitoring station respectively

The concentration of **Chromium** in the soil samples varies from 69.92 to 79.5623 mg/kg at Kandla and 91.88 to 106mg/kg at Vadinar with mean value 72.41 and 98.94 mg/kg at Kandla and Vadinar monitoring station respectively.

The concentration of **Nickel** in the soil samples of DPA Kandla varies from 27.16 to 33.32 mg/kg at Kandla and 40.89 to 42.68 mg/kg at Vadinar with mean value 29.88 and 41.78 mg/kg at Kandla and Vadinar monitoring station respectively.

The concentration of **Copper** in the soil samples of DPA Kandla varies from 25.33 to 148.05 mg/kg and 98.2 to 123.18 mg/kg at Vadinar with mean value 68.88 and 110.69 mg/kg at Kandla and Vadinar monitoring station respectively.

The concentration of **Zinc** in the soil samples of DPA Kandla varies from 52.29 to 155.24 mg/kg and 52.89 to 83.05mg/kg at Vadinar with mean value 92.25 and 67.97 mg/kg at Kandla and Vadinar monitoring station, respectively.

The concentration of **Lead** in the soil samples of DPA Kandla varies from 3.45 to 17.33 mg/kg and BQL to 0.91 mg/kg at Vadinar with mean value 9.33 and 0.91 mg/kg at Kandla and Vadinar monitoring station, respectively.

The concentration of **Arsenic** in the soil samples of DPA Kandla varies from BQL to 8.4 mg/kg with mean value 5.76 mg/Kg and observed below the detection Limit for Vadinar.

The concentration of **Water Holding Capacity** in the soil samples of DPA Kandla varies from 25.98 to 45.84% and 39.85 to 54.23% at Vadinar and mean value 40.66% and 47.04 % for Kandla and Vadinar respectively.

Heavy Metals like **Mercury and Cadmium** in the Soil was found to “Below the detection limit” for majority the soil samples collected at Kandla and Vadinar.

The soil texture observed at all the locations of Kandla and Vadinar for the sampling period was “Sandy Loam”.

### 8.5 Conclusion:

The soil quality of Kandla and Vadinar was assessed based on the Handbook of Agriculture. As per the said comparison, the pH in Kandla varies from the Slightly acidic to moderately alkaline. Whereas, pH of Soil at Vadinar was found to be moderately alkaline, the Organic Carbon at Kandla and Vadinar was on an average in sufficient concentration, whereas, the Electrical Conductivity at Kandla for both the months of April and May was found to be harmful to crops. There are several reasons that can contribute to soil quality degradation at port areas, such as:

- **Contamination:** Port areas are prone to various types of contamination due to the handling, storage, and transportation of goods and materials. Spills of hazardous substances, leakage from storage tanks, and improper disposal of waste can result in soil contamination. Chemicals such as heavy metals, petroleum products, and industrial pollutants can accumulate in the soil, making it less suitable for plant growth and potentially harmful to human health.
- **Erosion:** Ports are often located near coastlines or rivers, where erosion can be a significant issue. The construction of port infrastructure, such as breakwaters, jetties, and embankments, can alter natural sediment flow and wave patterns, leading to increased erosion of nearby soils. Erosion can cause loss of topsoil, which is rich in organic matter and essential nutrients for plant growth.
- **Increased salinity:** Ports situated in coastal areas may experience saltwater intrusion into the soil. Dredging activities, land reclamation, and alteration of natural water flow can disrupt the balance between freshwater and saltwater, resulting in increased salinity in the soil. High salt concentrations can hinder plant growth, reduce crop productivity, and adversely affect soil structure.
- **Compaction:** Heavy machinery, trucks, and containers moving in port areas can exert significant pressure on the soil, leading to compaction. Compacted soils have reduced pore spaces, limiting air and water movement and impeding root penetration. This can result in poor drainage, decreased nutrient availability, and restricted plant growth.
- **Loss of organic matter:** Port areas often undergo significant land transformation, including the removal of vegetation and topsoil during construction. The removal of organic matter-rich topsoil reduces the soil's fertility and capacity to retain moisture, making it less suitable for supporting plant life.

### 8.6 Measures against adverse effects

Addressing soil quality degradation at port areas requires implementing measures such as proper soil management practices, regular monitoring and testing for contaminants, erosion control measures, and the use of sustainable construction techniques. Additionally, promoting the restoration of vegetation and implementing strategies to minimize the introduction and spread of invasive species can help mitigate soil degradation in port areas.

## **CHAPTER 9: SEWAGE TREATMENT PLANT MONITORING**

## 9.1 Sewage Treatment Plant (STP) Monitoring:

The principal objective of Sewage Treatment Plant is to remove contaminants from sewage to produce an effluent that is suitable to discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. As defined in the scope by Deendayal Port Authority (DPA), Kandla, the Sewage Water Treatment Plant Monitoring as to be carried out at three locations, one at Kandla, one at Gopalpuri and one STP at Vadinar. The samples each from the treated wastewater of the STP have to be collected weekly. The details of the locations of Sewage Treatment Plants to be monitored for Kandla and Vadinar are as mentioned in **Table 29** as follows:

**Table 29: Details of the monitoring locations of Sewage Water Treatment Plants**

Sr. No..	Location Code		Location Name	Latitude Longitude
1.	Kandla	STP-1	STP Kandla	23.021017N 70.215594E
2.		STP-2	STP Gopalpuri	23.077783N 70.136759E
3.	Vadinar	STP-3	STP at Vadinar	22.406289N 69.714689E

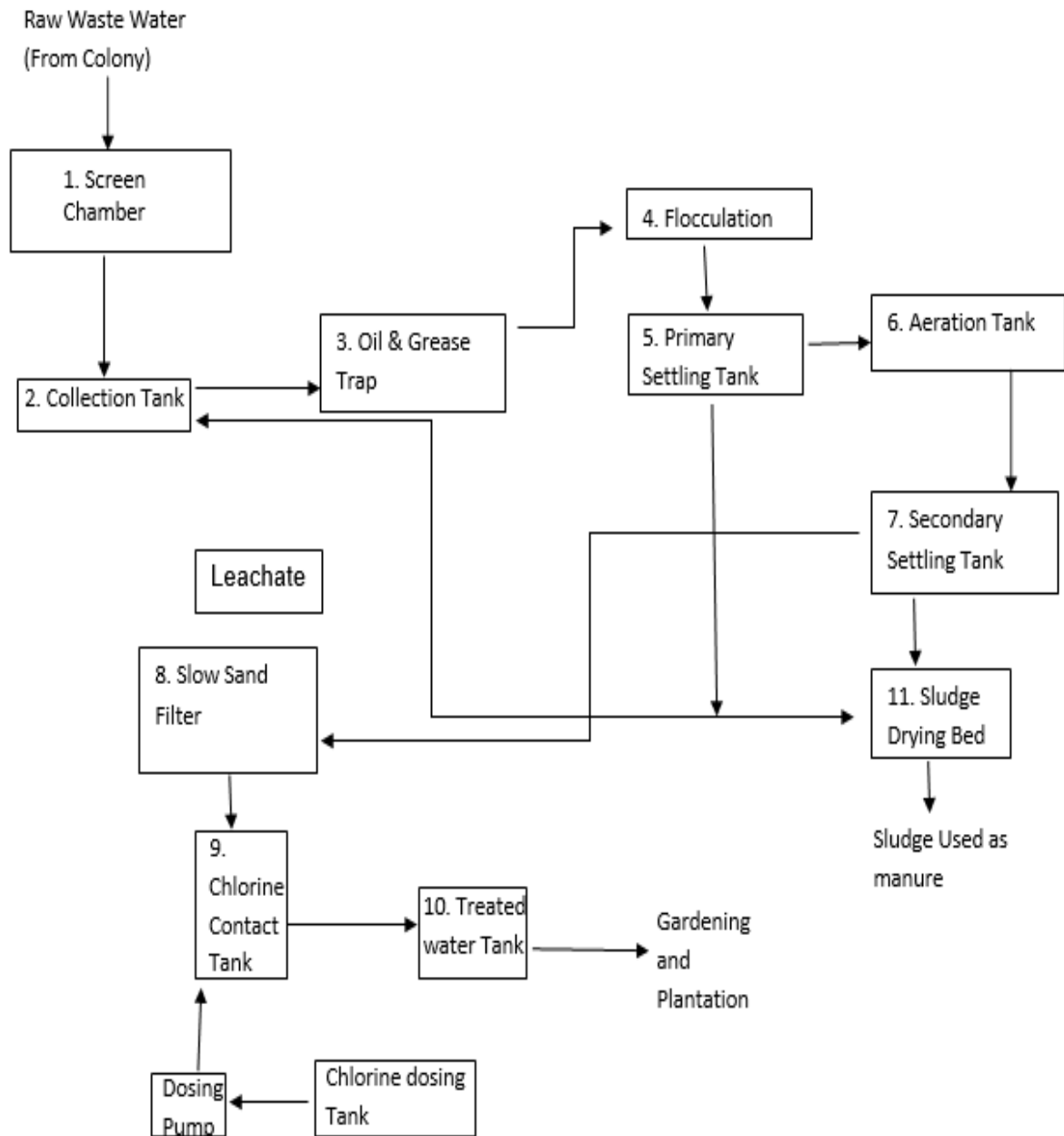
The Consolidated Consent and Authorization (CC&A) issued by the Gujarat Pollution Control Board (GPCB) were referred for the details of the Sewage Treatment Plant (STP) for Kandla and Gopalpuri. The said CC&A of Kandla and Gopalpuri suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 30**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

**Table 30: Norms of treated effluent as per CC&A for Kandla**

Sr. No.	Parameters	Prescribed limits
1.	pH	6.5-8.5
2.	BOD (3 days at 27°C)	30 mg/L
3.	Suspended Solids	100 mg/L
4.	Fecal Coliform	< 1000 MPN/100 ml

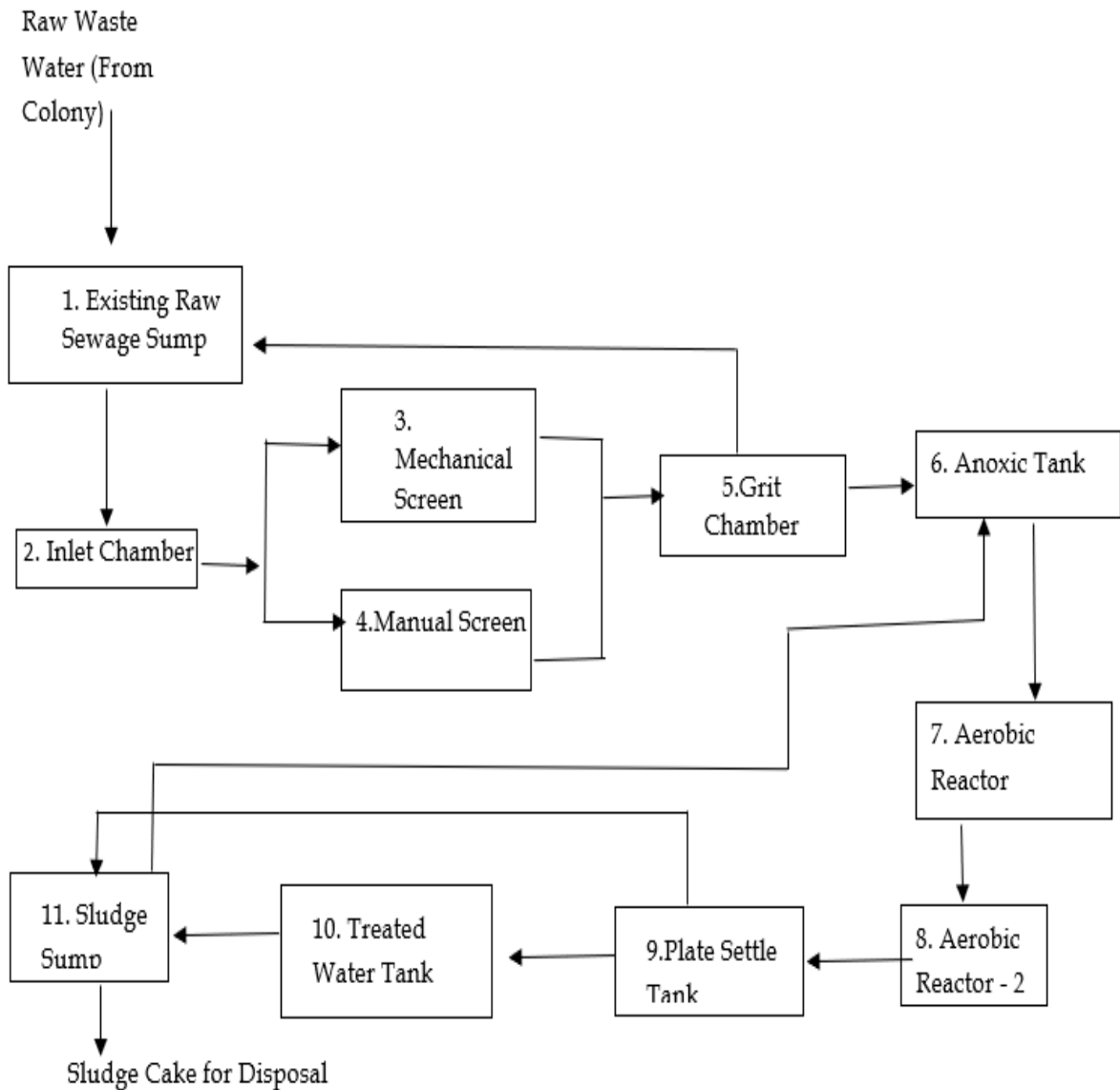
The detailed process flow diagram of the Kandla and Gopalpuri STP have been mentioned in **Figure 14 and 15** as follows:

### Process Flow Diagram of Kandla Sewage Treatment Plant (STP)



**Figure 14: Process flow diagram of Kandla STP**

### Process Flow Diagram of Gopalpuri Sewage Treatment Plant (STP)



**Figure 15: Process flow diagram of Gopalpuri STP**

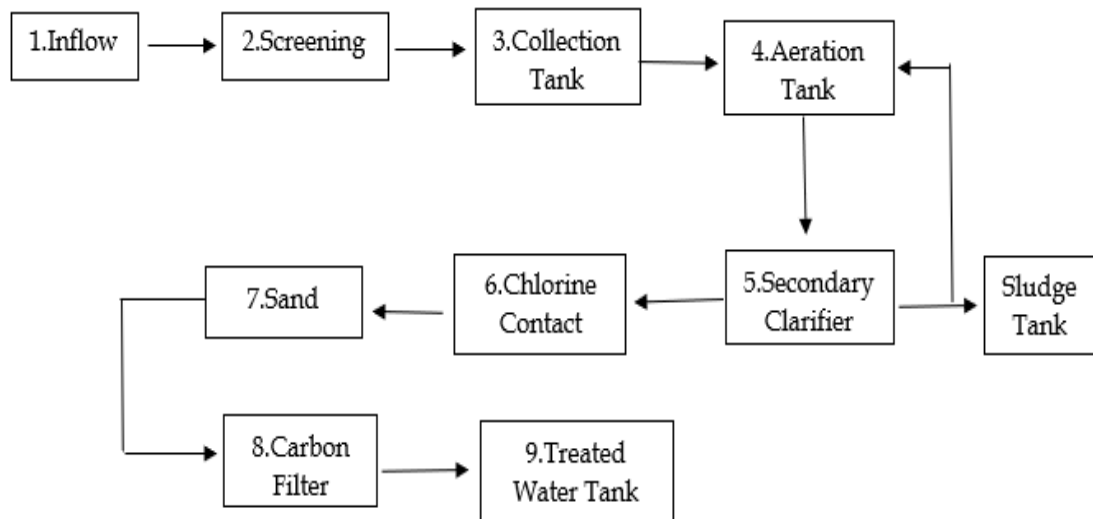
The STP at Vadinar has been built with a treatment capacity of 450 KLD/day. The Consolidated Consent and Authorization (CC&A) issued by the Gujarat Pollution Control Board (GPCB) were referred for the details of the Sewage Treatment Plant (STP) for Kandla and Gopalpuri. The said CC&A of the Vadinar STP suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 31**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.



**Table 31: Norms of treated effluent as per CC&A for Vadinar**

Sr. No.	Parameters	Prescribed limits
1.	pH	5.5-9
2.	BOD (3 days at 27°C)	10 mg/L
3.	Suspended Solids	20 mg/L
4.	Fecal Coliform	Desirable 100 MPN/100 ml Permissible 230 MPN/100 ml
5.	COD	50 mg/L

The detailed process flow diagram of the Vadinar STP have been mentioned in **Figure 16** as follows:



**Figure 16: Process flowchart for the Vadinar STP**

The map depicting the locations of Sewage Water Treatment Plant Monitoring to be monitored in Kandla and Vadinar have been shown in **Figure 17 and 18** as follows:



Figure 17: Location Map for STP Monitoring at Kandla





Figure 18: Location Map for STP Monitoring at Vadinar

## 9.2 Methodology of Monitoring:

As per the defined scope by Deendayal Port Authority (DPA), the sampling and analysis of water samples from the inlet and outlet of the STP of Kandla and Vadinar are carried out once a week, i.e., four times a month.

The water samples were collected from inlet and the outlet of the STP's and analyzed for physico-chemical and microbiological parameter. Collection and analysis of these samples was carried out as per established standard methods and procedures for the examination of water. The samples were analyzed for selected parameters to establish the existing water quality of the inlet and outlet points of the STP. GEMI has framed its own guidelines for collection of water/wastewater samples titled as 'Sampling Protocol for Water & Wastewater'; which has been approved by the Government of Gujarat vide letter no. ENV-102013-299-E dated 24-04-2014 under the provision of Water (Preservation and Control of Pollution) Act 1974. The sample collection and preservation are done as per the said Protocol.

Under the project, the list of parameters to be monitored for the STP have been mentioned in **Table 32** as follows:

**Table 32: List of parameters monitored for STP's at Kandla and Vadinar**

Sr. No.	Parameters	Units	Reference method	Instruments
1.	pH	-	APHA, 23 <sup>rd</sup> edition, 4500- H <sup>+</sup> B, 2017	pH Meter
2.	TDS	mg/L	APHA, 23 <sup>rd</sup> Edition, 2540 C: 2017	Vacuum Pump with filtration assembly and Oven
3.	TSS	mg/L		
4.	DO	mg/L	APHA, 23 <sup>rd</sup> Edition, 4500 C: 2017	Titration Apparatus
5.	COD	mg/L	APHA, 23 <sup>rd</sup> Edition, 5220 B: 2017	Titration Apparatus plus Digester
6.	BOD	mg/L	IS-3025, Part 44, 1993	BOD Incubator plus Titration Apparatus
7.	SAR	meq/L	IS 11624: 2019	Flame Photometer
8.	Total Coliforms	MPN/100ml	IS 1622: 2019	LAF/ Incubator

## 9.3 Result and Discussion

The quality of the water samples collected from the inlet and the outlet of the STP's of Kandla and Vadinar has been summarized in **Table 33 and 34** for the monitoring period. The said water quality has been represented in comparison with the standard values specified in the Consolidated Consent and Authorization (CC&A) of the STPs.



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**Table 33: Water Quality of inlet and outlet of STPs for Kandla**

Sr No.	Parameter	Units	GPCB Norms (Kandla)	Kandla															
				Week 3 (April)				Week 4 (April)				Week 1 (May)				Week 2 (May)			
				STP-1 (I)	STP-1 (O)	STP-2 (I)	STP-2 (O)	STP-1 (I)	STP-1 (O)	STP-2 (I)	STP-2 (O)	STP-1 (I)	STP-1 (O)	STP-2 (I)	STP-2 (O)	STP-1 (I)	STP-1 (O)	STP-2 (I)	STP-2 (O)
1.	pH	-	6.5-8.5	7.04	7.15	6.97	8.88	7.22	7.4	7.14	7.18	6.96	7.1	7.06	7.09	7.13	7.21	6.85	7.37
2.	TDS	mg/L	-	2522	3586	484	820	2688	4616	512	546	2564	3776	588	556	2280	3612	528	512
3.	TSS	mg/L	100	148	66	146	10	918	88	52	6	1648	32	138	12	102	28	150	4
4.	DO	mg/L	-	BQL	2	6.6	BQL	BQL	3.21	BQL	6.6	BQL	1	BQL	7.6	BQL	3.4	BQL	4.8
5.	COD	mg/L	-	255.06	117.41	275.3	76.92	307.5	202.2	200.8	60.24	135.46	277.09	388.65	67.73	156.63	96.39	333.33	68.27
6.	BOD	mg/L	30	65.77	25.1	56	18.45	80.78	27.89	40.16	11.12	32	52.4	76.1	13	36.45	22	71	15.1
7.	SAR	meq/L	-	11.36	12.58	2.71	2.89	12.65	14.98	2.67	2.85	9.69	12	3.63	3.31	12.81	16.02	3.48	3.22
8.	Total Coliforms	MPN/100ml	<1000	1600	1600	1600	BQL	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600

**Table 34: Water Quality of inlet and outlet of STP for Vadinar**

Sr No.	Parameter	Units	GPCB Norms (Vadinar)	Vadinar (April)				Vadinar (May)			
				Week 3		Week 4		Week 1		Week 2	
				STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)
1.	pH	-	5.5-9	7.1	7.08	7.32	7.38	7.1	7.18	7.15	7.42
2.	TDS	mg/L	-	496	468	515	446	538	458	536	450
3.	TSS	mg/L	20	64	36	61	21	40	10	26	12
4.	DO	mg/L	-	BQL	4.6	BQL	4.24	BQL	1.7	0.5	7.4
5.	COD	mg/L	50	197.58	52.42	184.54	54.5	149.19	40.32	165.99	48.58
6.	BOD	mg/L	10	45	11	36.24	10.88	31	8	37.1	10
7.	SAR	meq/L	-	2.96	3.06	3.44	3.20	3.13	3.03	3.3	2.98
8.	Total Coliforms	MPN/100ml	100-230	1600	1600	1600	1600	1600	1600	1600	1600

BQL: Below Quantification limit; Total Suspended Solids (QL=2), Dissolved Oxygen (QL=0.5)



#### 9.4 Data Interpretation:

- **pH:** As per the norms, pH of the treated domestic effluent should conform to the standard of 6.5-8.5. the pH for the STP-1 and STP-2 of Kandla. Whereas for STP-3 at Vadinar falls within the 5.5-9 and hence conforms to the stipulated norms.
- **Total Suspended Solids:** The TSS for the STP-1 and STP-2 of Kandla and STP-3 of Vadinar falls within the stipulated norms of 100 mg/L and hence conforms to the norms specified.
- As per the norms, the **Chemical Oxygen Demand (COD)** for the outlet for Vadinar STP shall be 50 mg/L. COD exceeds slightly for month of April 2023 for Vadinar STP. Whereas, the COD was observed to comply with the stipulated norms for the month of May 2023.
- The main focus of wastewater treatment plants is supposed to reduce the **BOD** in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The final treated outlet was observed to have BOD values within the stipulated norms at STP-1, STP-2 and STP-3 for the sampling conducted during the month of April and May 2023. Exceeding value of BOD were observed at STP-1, during the sampling conducted in the first week of May 2023.
- The **Total Coliforms** were observed to exceed the norms at all the locations of the STP outlets of Kandla and Vadinar. This indicates that the method of disinfection applied is not adequate.



## 9.5 Conclusions:

During the monitoring period, only Total Coliforms and COD at STP Kandla, are found exceeding the limit while rest of the sewage parameters for STP outlet were within norms of CCA at both the monitoring sites. The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) STP and Vadinar STP were in line with the standards set by the Central Pollution Control Board. Regular monitoring of the STP performance should be conducted on regular basis to ensure adequate treatment as per the norms.

## 9.6 Remedial Measures:

- The quantum of raw sewage (influent) entering the STP should be monitored flow meter. If the quantity of the sewage exceeds the treatment capacity of the treatment plant, then provision of additional capacity of collection sump should be provided.
- The adequacy and efficacy of the stages of Sewage treatment units shall be conducted.
- The treatment parameters such as retention time, Mixed Liquor Suspended Solids (MLSS), Mixed liquor volatile suspended solids (MLVSS), Recirculation rate, sludge generation, etc should be monitored timely.
- During the treatment, the required retention time and rate of aeration should be maintained, so that the efficiency of the treatment plant is maintained.
- The dosage of chemicals administered during the treatment should be reviewed and alterations in the dosage should be done.
- The results show the presence of total coliforms; hence the method of disinfection (Chlorination) sodium or calcium Hypochlorite can be used.
- Effectiveness of any technology depends on factors such as the specific pollutants in the wastewater, plant size, local regulations, and available resources. There are several processes that may be implemented such as - Advanced oxidation process involve using strong oxidants to break down complex organic compounds. Methods like Fenton's reagent (hydrogen peroxide and iron catalyst) and UV/H<sub>2</sub>O<sub>2</sub> treatment can help in reducing COD through oxidation.
- Electrochemical processes like Electrocoagulation (EC) and Electrooxidation (EO) that involve the application of an electric current to facilitate the removal of pollutants through coagulation, flocculation, and oxidation. These methods can be useful for treating sewage containing various pollutants.
- Enhanced biological treatment processes, such as Moving Bed Biofilm Reactors (MBBR), Integrated Fixed-film Activated Sludge (IFAS) systems, and Membrane Bio-Reactors (MBRs) are utilised to improve the efficiency of organic matter and nutrient removal from wastewater.



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## **CHAPTER 10: MARINE WATER QUALITY MONITORING**

## 10.1 Marine Water:

Deendayal Port is one of the largest ports of the country and thus, is engaged in wide variety of activities such as movement of large vessels, oil tankers and its allied small and medium vessels and handling of dry cargo several such activities whose waste if spills in water, can cause harmful effects to marine water quality.

Major water quality concerns at ports include wastewater and leakage of toxic substances from ships, stormwater runoff, etc. This discharge of wastewater, combined with other ship wastes which includes sewage and wastewater from other on-board uses, is a serious threat to the water quality as well as to the marine life. As defined in the scope by Deendayal Port Authority (DPA), the Marine Water sampling and analysis has to be carried out at a total of eight locations, six at Kandla and two at Vadinar. The marine water sampling was be carried out with the help of Niskin Sampler with a capacity of 5L. The Niskin Sampler is a device used to take water samples at a desired depth without the danger of mixing with water from other depths. The details of the locations to be monitored is as mentioned in **Table 35**:

**Table 35: Details of the sampling locations for Marine water**

Sr. No.	Location Code	Location Name	Latitude Longitude
1.	Kandla	MW-1	Near Passenger Jetty One
2.		MW-2	Kandla Creek (nr KPT Colony)
3.		MW-3	Near Coal Berth
4.		MW-4	Khori Creek
5.		MW-5	Nakti Creek (nr Tuna Port)
6.		MW-6	Nakti Creek (nr NH-8A)
7.	Vadinar	MW-7	Near SPM
8.		MW-8	Near Vadinar Jetty

The map depicting the locations of Marine Water to be sampled and analysed in Kandla and Vadinar have been mentioned in **Map 19 and 20** as follows:





Figure 19: Location Map for Marine Water Monitoring at Kandla



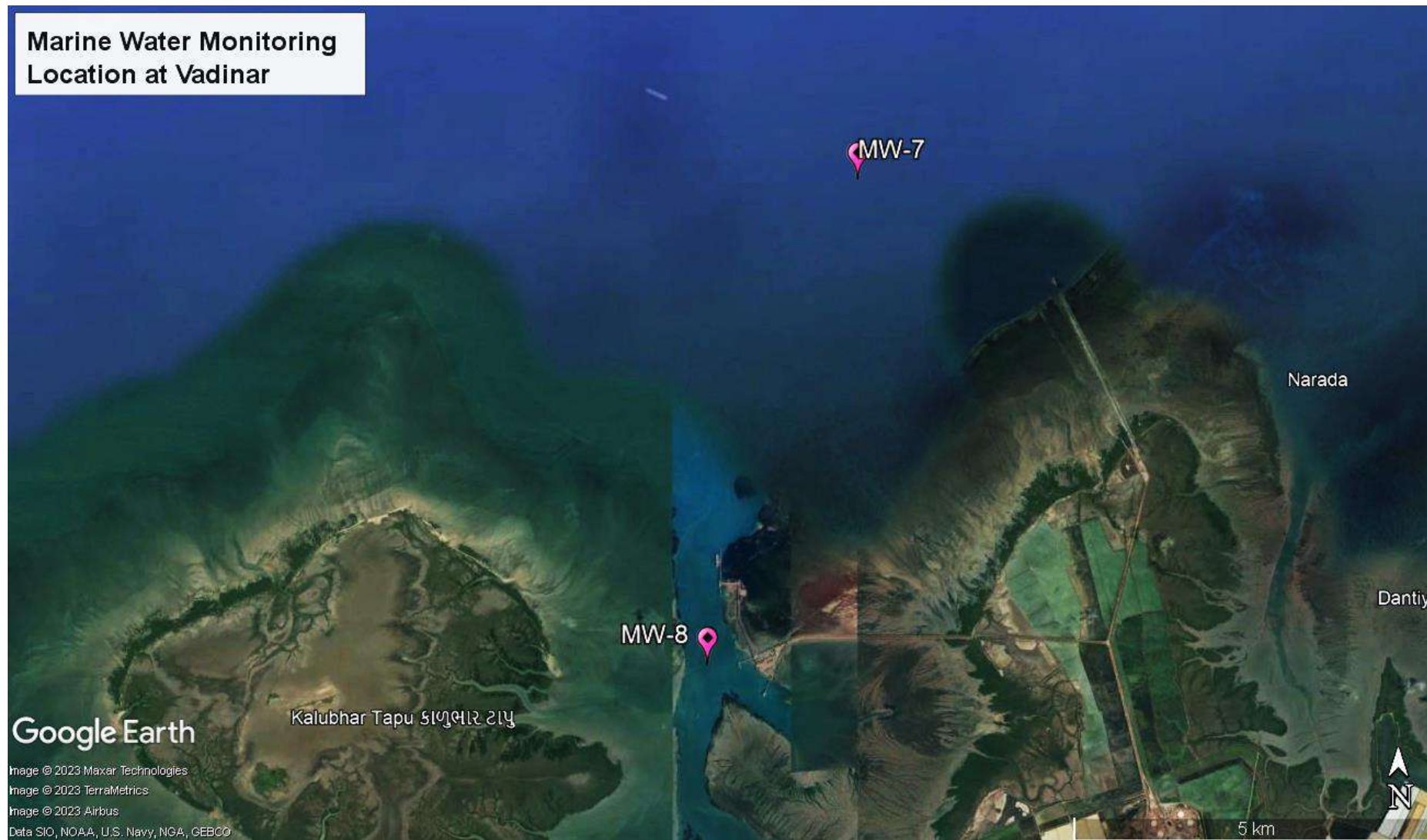


Figure 20: Location Map for Marine Water Monitoring at Vadinar



## Frequency

As defined in the scope by Deendayal Port Authority (DPA), the sampling and analysis of Marine Water has to be carried out once a month at the eight locations (i.e., six at Kandla and two at Vadinar).

## 10.2 Methodology

Similar to the methodology adopted for the sampling and monitoring of Drinking water under the study, the sampling of Marine Water was carried out as per the '**Sampling Protocol for Water & Wastewater**' developed by GEMI as well as the CPCB guidelines. The water samples collected through the Niskin Sampler are collected in a clean bucket to reduce the heterogeneity. From the collected water sample 1 liter of water sample is separated in an opaque plastic bottle for the estimation of chlorophyll. The list of parameters to be monitored under the project for the Marine Water quality have been mentioned in **Table 36** along with the analysis method and instrument.

**Table 36: List of parameters monitored for Marine Water**

Sr. No	Parameters	Units	Reference method	Instrument
1.	Electrical Conductivity	μS/cm	APHA, 23 <sup>rd</sup> Edition (Section-2510 B):2017	Conductivity Meter
2.	Dissolved Oxygen (DO)	mg/L	APHA, 23 <sup>rd</sup> Edition, 4500 O C, 2017	Titration Apparatus
3.	pH		APHA, 23 <sup>rd</sup> Edition (Section-4500-H+B):2017	pH meter
4.	Color	Hazen	APHA, 23 <sup>rd</sup> Edition, 2120 B: 2017	Color comparator
5.	Odour		IS 3025 Part 5: 2018	Heating mantle & odour bottle
6.	Turbidity	NTU	IS 3025 Part 10: 1984	Nephlo Turbidity Meter
7.	Total Dissolved Solids (TDS)	mg/L	APHA, 23 <sup>rd</sup> Edition (Section-2540 C):2017	Vaccum Pump with Filtration Assembly and Oven
8.	Total Suspended Solids (TSS)	mg/L	APHA, 23 <sup>rd</sup> Edition, 2540 D: 2017	
9.	Particulate Organic Carbon	mg/L	APHA, 23 <sup>rd</sup> Edition, 2540 D and E	TOC analyser
10.	Chemical Oxygen Demand (COD)	mg/L	IS-3025, Part- 58: 2006	Titration Apparatus plus Digester
11.	Biochemical Oxygen Demand (BOD)	mg/L	IS-3025, Part 44,1993,	BOD Incubator plus Titration apparatus
12.	Silica	mg/L	APHA, 23 <sup>rd</sup> Edition, 4500 C, 2017	UV- Visible Spectrophotometer
13.	Phosphate	mg/L	APHA,23 <sup>rd</sup> Edition, 4500 P-D: 2017	

Sr. No	Parameters	Units	Reference method	Instrument
14.	Sulphate	mg/L	APHA, 23rd Edition, 4500 SO4-2 E: 2017	
15.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3-B: 2017	
16.	Nitrite	mg/L	APHA, 23rd Edition, 4500 NO2- B: 2017	
17.	Sodium	mg/L	APHA,23rd Edition, 3500 Na-B: 2017	Flame photometer
18.	Potassium	mg/L	APHA,23rd Edition, 3500 K-B: 2017	
19.	Manganese	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES
20.	Iron	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	
21.	Total Chromium	mg/L	APHA, 23rd Edition, 3500 Cr B: 2017	
22.	Hexavalent Chromium	mg/L		UV- Visible Spectrophotometer
23.	Copper	mg/L	APHA, 23rd Edition, ICP Method 3120 B: 2017	ICP-OES
24.	Cadmium	mg/L		
25.	Arsenic	mg/L		
26.	Lead	mg/L		
27.	Zinc	mg/L		
28.	Mercury	mg/L	EPA 200.7	
29.	Floating Material (Oil grease scum, petroleum products)	mg/L	APHA, 23rd Edition, 5520 C: 2017	Soxhlet Assembly
30.	Total Coliforms (MPN)	MPN/ 100ml	IS 1622: 2019	LAF/ Incubator

### 10.3 Result and Discussion

The quality of the Marine water samples collected from the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 37**. The said water quality has been represented in comparison with the standard values as stipulated by CPCB.

Table 37: Results of Analysis of Marine Water Sample

Sr. No.	Parameters	Unit	Primary Water Quality Criteria for Class SW-IV Waters	Kandla						Vadinar	
				MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8
1.	Density	kg/m <sup>3</sup>	-	1.021	1.021	1.022	1.021	1.022	1.022	1.022	1.022
2.	pH	-	6.5-9.0	7.76	7.74	7.83	7.81	7.84	8.04	8.07	8.11
3.	Color	Hazen	No Noticeable	9	12	15	10	9	11.6	4	5
4.	EC	μS/cm	-	60,391	58,491	57,913	54,179	55,587	61,528	55,871	52,119
5.	Turbidity	NTU	-	>50	>50	>50	>50	>50	>50	3.2	4.5
6.	TDS	mg/L	-	41,930	39,386	38,688	38,072	39,434	38,587	34,950	34,892
7.	TSS	mg/L	-	184	334	124	740	642	852	220	151
8.	COD	mg/L	-	72	76	81	81	71	78	75	75
9.	DO	mg/L	3.0 mg/L	5.6	5.5	5.4	5.6	5.7	5.7	7.3	7.4
10.	BOD	mg/L	5.0 mg/L	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	2747.55	2665.78	2433.35	2684.05	2771.15	3156.54	2212.35	2441.56
13.	Nitrate	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
14.	Nitrite	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
15.	Phosphate	mg/L	-	0.46	0.09	1.46	0.75	0.57	0.54	0.64	1.43
16.	Silica	mg/L	-	0.32	1.51	0.65	2.79	1.74	0.33	BQL	BQL
17.	Sodium	mg/L	-	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000
18.	Potassium	mg/L	-	385.03	397.63	347.34	424.53	423.34	442.63	321.10	351.13
19.	Hexavalent Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	-	-	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	-	5.10	6.07	BQL	12.01	7.60	10.2	BQL	BQL
24.	Iron	mg/L	-	1.03	1.05	2.2	5.4	3.9	5.3	BQL	BQL
25.	Lead	mg/L	-	BQL	1.7	1.32	6.2	2.21	3.41	BQL	BQL
26.	Manganese	mg/L	-	73.11	75.21	85.71	121.79	86.75	86.24	BQL	BQL
27.	Total Chromium	mg/L	-	BQL	5.62	BQL	15.71	8.25	BQL	BQL	BQL
28.	Zinc	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Mercury	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Total Coliform	MPN /100 ml	500/100 ml	900	35	10	55	30	44	BQL	BQL
31.	Particulate Organic Carbon	mg/L	-	0.32	0.16	0.56	0.25	0.35	0.29	0.36	0.39

Sr. No.	Parameters	Unit	Primary Water Quality Criteria for Class SW-IV Waters	Kandla						Vadinar	
				MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8
32.	Floating Material (Oil grease scum, petroleum products)	mg/L	10 mg/L	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit; Turbidity (DL=50), Biochemical Oxygen Demand (QL=3), Oil & Grease (QL=1), Nitrate as NO<sub>3</sub> (QL=1), Nitrite as No<sub>2</sub> (QL=0.1), Phosphorous (QL=0.5), Silica (QL=0.05), Sodium as Na (QL=10,000), Hexavalent Chromium (QL=0.01), Arsenic (QL=5), Cadmium (QL=2), Copper (QL=5), Iron (QL=0.1), Lead (QL=2), Manganese (QL=40), Total Chromium (QL=5), Zinc (QL=0.5), Mercury (QL=0.5)

#### 10.4 Data Interpretation:

The Marine water quality of Deendayal Port Harbor waters at Kandla and Vadinar has been monitored for various physico-chemical and biological parameters during the high tide at sampling time.

- The parameter **pH** was observed in the range of 7.74-8.04, with the average pH as 7.83 for the locations of Kandla, whereas for the locations of Vadinar, pH was observed in the range of 8.07-8.11, with the average pH as 8.09.
- The **Color** was observed in the range of 9-15 Hazen, with the average color as 11.1 Hazen for the locations of Kandla, whereas for the locations of Vadinar, color was observed in the range of 4-5 Hazen, with the average color as 4.5 Hazen.
- The **Density** of marine water for the locations of Kandla and Vadinar was observed to vary from 1.021-1.022 Kg/m<sup>3</sup>.
- Turbidity** for all locations of Kandla was observed >50 NTU for all the locations. Whereas for the locations of Vadinar, lower values of turbidity were observed. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble color organic compounds, plankton and microscopic organisms. Turbidity affects the amount of light penetrating to the plants for photosynthesis.
- The parameter **Electrical conductivity (EC)** was observed in the range of 54179-61528 µS/cm, with the average EC as 58014.83 µS/cm for the locations of Kandla, whereas for the locations of Vadinar, EC was observed in the range of 52119-55871 µS/cm, with the average EC as 53995 µS/cm.

- **Total Dissolved Solids (TDS)** values in the studied area during high Tide varied between 38072-41930 mg/L at DPA Kandla and 34892-34950 mg/L at Vadinar with the average value as 39349.5 mg/L and 34921 mg/L respectively for Kandla and Vadinar.
- **Total Suspended Solids (TSS)** values in the studied area during high Tide varied between 124-852 mg/L at DPA Kandla and 151-220 mg/L at Vadinar, with the average value as 479.33 mg/L and 185.5 mg/L respectively for Kandla and Vadinar.
- **Chemical Oxygen Demand (COD)** values in the studied area varied between 71-81 mg/L at DPA Kandla and 74-75 mg/L at Vadinar, with the average value as 76.5 mg/L and 74.5 mg/L respectively for Kandla and Vadinar.
- **Dissolved Oxygen (DO)** level in the studied area during high Tide varied between 5.4-5.7 mg/L at DPA Kandla and 7.3-7.4 mg/L at Vadinar. The value of DO was found to exceed the minimum concentration of 3.0 mg/L for majority of the locations, which represents that the marine water quality is good and hence suitable for the aquatic species.
- The parameters BOD, Oil & Grease, Nitrate, Nitrite, Hexavalent Chromium, Arsenic, Cadmium, Zinc and Mercury were observed to have concentrations “Below the Quantification Limits (BQL)” for all the locations of Kandla and Vadinar.
- **Sulphate** concentration in the studied area during high Tide varied between 2433.35-3415.54 mg/L at DPA Kandla and 2212.35-2441.56 mg/L at Vadinar.
- The concentration of **Phosphate** in the studied area during high Tide varied between 0.09-1.46 mg/L at DPA Kandla, while at Vadinar, the concentration of Phosphate was observed to range from 0.64-1.43 mg/L at Vadinar.
- The concentration of **Potassium** in the studied area during high Tide varied between 347.34-442.63 mg/L at DPA Kandla and 321.10-351.13 mg/L at Vadinar, with the average value as 403.41 mg/L and 336.11 mg/L respectively for Kandla and Vadinar.
- The concentration of **Sodium** was detected to be >10,000 mg/L for the locations of Kandla and Vadinar.
- Under the study, the parameters BOD, Oil and Grease, Hexavalent and Total Chromium, Nitrate, Nitrite, Arsenic, Lead, Manganese, Cadmium, Zinc and Mercury were found to have concentrations “Below the detection limit” for both the locations of Kandla and Vadinar.
- **Total Coliforms (TC)** at Kandla were observed to be within the range of 10-900 MPN/100 ml. On the contrary, the TC were observed “Below the detection limit” for the months at Vadinar.
- **Floating Material (Oil grease scum, petroleum products)** was observed to be “Below the quantification limit” all the locations of Kandla and Vadinar.

## 10.5 Conclusion

During the Monitoring period, marine water samples were analysed and found in line with Primary Water Quality criteria for class-IV Waters (For Harbour Waters).

## 10.6 Measures against adverse effects

Appropriate regulations on ship discharges and provision of reception facilities are indispensable for proper control of emissions and effluent from ships. Detection of spills is also important for regulating ship discharges. Since accidental spills are unavoidable, recovery vessels, oil fences, and treatment chemicals should be prepared with a view to minimizing dispersal. Proper contingency plans and a prompt reporting system are keys to prevention of oil dispersal. Periodical clean-up of floating wastes is also necessary for preservation of port water quality.



## **CHAPTER 11: MARINE SEDIMENT QUALITY MONITORING**

### 11.1 Marine Sediment Monitoring:

Marine sediment, or ocean sediment, or seafloor sediment, are deposits of insoluble particles that have accumulated on the seafloor. These particles have their origins in soil and rocks and have been transported from the land to the sea, mainly by rivers but also by dust carried by wind. The unconsolidated materials derived from pre-existing rocks or similar other sources by the process of denudation are deposited in water medium is known as sediment. For a system, like a port, where large varieties of raw materials and finished products are handled, expected sediment contamination is obvious.

The materials or part of materials spilled over the water during loading and unloading operations lead to the deposition in the harbour water along with sediment and thus collected as harbour sediment sample. These materials, serve as receptor of many trace elements, which are prone to environment impact. In this connection it is pertinent to study the concentration and distribution of environmentally sensitive elements in the harbour sediment. However, human activities result in accumulation of toxic substances such as heavy metals in marine sediments. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulation. Metals affect the ecosystem because they are not removed from water by self-purification, but accumulate in sediments and enter the food chain.

As defined in the scope by Deendayal Port Authority (DPA), the Marine Sediment sampling is required to be carried out once in a month at total eight locations, i.e., six at Kandla and two at Vadinar. The sampling of the Marine Sediment is carried out using the Van Veen Grab Sampler of the make Holy Scientific Instruments Pvt. Ltd. The Van Veen Grab sampler is an instrument to sample (disturbed) sediment up to a depth of 20-30 cm into the sea bed. While letting the instrument down on the seafloor, sediment can be extracted. The details of the locations of Marine Sediment to be monitored under the study are mentioned in **Table 38** as follows:

**Table 38: Details of the sampling locations for Marine water**

Sr. No	Location Code	Location Name	Latitude Longitude
1.	Kandla	MS-1	Near Passenger Jetty One
2.		MS-2	Kandla Creek
3.		MS-3	Near Coal Berth
4.		MS-4	Khori Creek
5.		MS-5	Nakti Creek (near Tuna Port)
6.		MS-6	Nakti Creek (near NH-8A)
7.	Vadinar	MS-7	Near SPM
8.		MS-8	Near Vadinar Jetty

The map depicting the locations of Marine Sediment sampling in Kandla and Vadinar have been mentioned in **Map 21 and 22** as follows:





Figure 21: Location Map of Marine Sediment Monitoring at Kandla



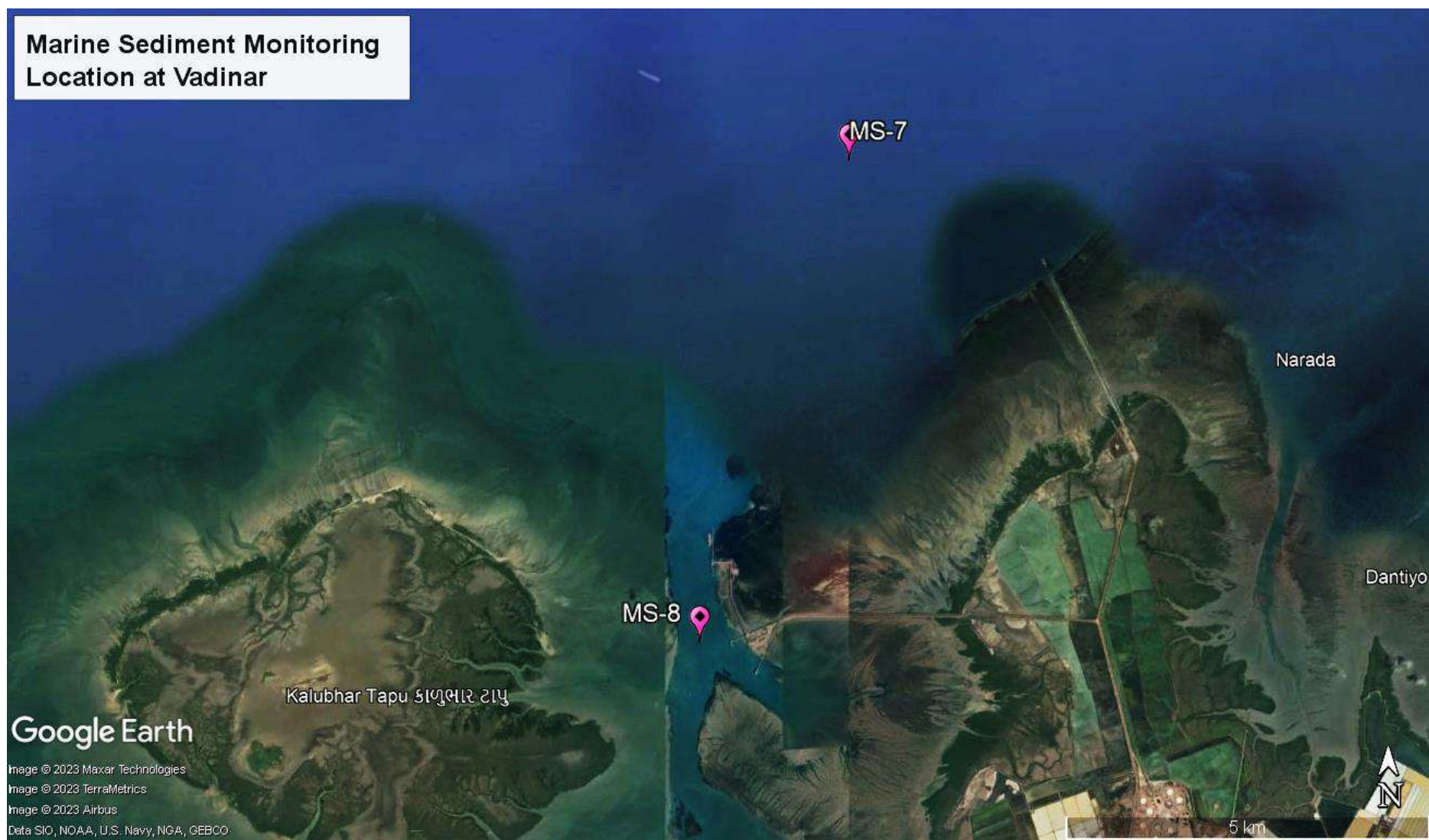


Figure 22: Locations Map of Marine Sediment Monitoring at Vadinar

The list of parameters to be monitored under the projects for the Marine Sediment sampling been mentioned in **Table 39** as follows:

**Table 39: List of parameters to be monitored for Sediments at Kandla and Vadinar**

Sr. No.	Parameters	Units	Reference method	Instruments
1.	Texture		Methods Manual Soil Testing in India January 2011,01	Hydrometer
2.	Organic Matter	%	Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934)	Titration apparatus
3.	Inorganic Phosphates	mg/Kg	Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017	UV- Visible Spectrophotometer
4.	Silica	mg/Kg	EPA METHOD 6010 C & IS: 3025 (Part 35) – 1888, part B	
5.	Phosphate	mg/Kg	EPA Method 365.1	
6.	Sulphate as SO <sub>4</sub> -(Available)	mg/Kg	IS: 2720 (Part 27) - 1977	
7.	Nitrite	mg/Kg	ISO 14256:2005	
8.	Nitrate	mg/Kg	Methods Manual Soil Testing in India January, 2011, 12	
9.	Calcium as Ca	mg/Kg	Methods Manual Soil Testing in India January 2011, 16.	Titration Apparatus
10.	Magnesium as Mg	mg/Kg	Method Manual Soil Testing in India January 2011	
11.	Sodium	mg/Kg	EPA Method 3051A	Flame Photometer
12.	Potassium	mg/Kg	Methods Manual Soil Testing in India January, 2011	
13.	Aluminium	mg/Kg	EPA Method 3051A	ICP-OES
14.	Chromium	mg/Kg		
15.	Nickel	mg/Kg		
16.	Zinc	mg/Kg		
17.	Cadmium	mg/Kg		
18.	Lead	mg/Kg		
19.	Arsenic	mg/Kg		
20.	Mercury	mg/Kg		

## 11.2 Result and Discussion

The quality of Marine Sediment samples collected from the locations of Kandla and Vadinar has been summarized in the **Table 40**.

Table 40: Summarized Results of Marine Sediment Quality

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Inorganic Phosphate	kg/Hectare	16.85	14.37	11.55	18.94	14.25	17.34	14.55	18.51
2.	Phosphate	mg/Kg	3247.85	1497.25	2571.43	2671.98	3741.91	3541.28	2357.68	3217.54
3.	Organic Matter	mg/Kg	0.32	1.60	0.50	1.21	0.94	1.14	0.26	0.38
4.	Sulphate as SO <sup>4-</sup>	mg/Kg	759	849	555	496	768	732	296	179.43
5.	Calcium as Ca	mg/Kg	2657	1259	962	1102	1089	1162	2585	2463
6.	Magnesium as Mg	mg/Kg	1259	924	764	987	1032	953	1348	1167
7.	Silica	g/Kg	498.5	465.12	571.51	549.6	531.88	487.2	379.45	492.5
8.	Nitrite	mg/Kg	0.75	0.18	0.15	0.19	0.16	0.13	0.11	0.12
9.	Nitrate	mg/Kg	19.75	20.98	10.22	21.64	9.67	15.34	25.33	24.82
10.	Sodium	mg/Kg	3410	3670	4432	3940	3725	2394	9082	8854
11.	Potassium	mg/Kg	241	276	264	294	322	394	1082	1028
12.	Aluminium	mg/Kg	3517.25	4834.50	4317.46	4552.39	3751.85	4579.21	4138.27	4528.35
13.	Chromium	mg/Kg	56.17	32.74	42.38	53.30	51.33	36.71	45.20	41.85
14.	Nickel	mg/Kg	16.80	11.54	18.94	25.60	24.00	12.80	14.70	20.50
15.	Zinc	mg/Kg	38.22	32.11	48.20	34.98	19.54	32.00	42.80	40.30
16.	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17.	Lead	mg/Kg	6.1	5.84	4.25	5.85	5.71	4.24	6.88	7.41
18.	Arsenic	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	2.74	5.17
19.	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Texture		Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam

### 11.3 Data Interpretation

- **Inorganic Phosphate** was observed in the range of 11.55 to 18.94 Kg/Ha for Kandla and 11.85 to 15.84 Kg/Ha for Vadinar.
- **Phosphate** was observed in the range of 1497.25 to 3741.91 mg/Kg for Kandla and 2357.68 to 3217.54 mg/Kg for Vadinar.
- **Organic Matter** was observed in the range of 0.32 to 1.6 % for Kandla and 0.26 to 0.38 % for Vadinar.
- **Sulphate** was observed in the range of 496 to 849 mg/Kg for Kandla and 179.43 to 296 mg/Kg for Vadinar.
- **Calcium** was observed in the range of 962 to 2657 mg/Kg for Kandla and 2463 to 2585 mg/Kg for Vadinar.
- **Magnesium** was observed in the range of 764 to 1259 mg/Kg for Kandla and 1167 to 1348 mg/Kg for Vadinar.
- **Nitrate** was observed in the range of 9.67 to 21.64 mg/Kg for Kandla and 24.82 to 25.33 mg/Kg for Vadinar.
- **Nitrite** was observed in the range of 0.13 to 0.75 mg/Kg for Kandla and 0.11 to 0.12 for Vadinar.



- **Sodium** was observed in the range of 2394 to 4432 for Kandla and 8854 to 9082 mg/Kg for Vadinar.
- **Silica** was observed in the range of 465.12 to 571.51 mg/Kg for Kandla and 379.45 to 492.5 mg/Kg.
- **Potassium** was observed in the range of 241 to 394 mg/Kg for Kandla and 1028 to 1082 mg/Kg for Vadinar.
- **Aluminium** was observed in the range of 3517.25 to 4834.5 mg/Kg for Kandla and 4138.27 to 4528.35 mg/Kg for Vadinar.
- **Mercury** was observed below the detection limit was limit for Kandla and Vadinar.
- Texture was observed to be “**Sandy Loamy**” in both Kandla and Vadinar.

### Heavy Metals

The sediment quality of Kandla and Vadinar has been compared with respect to the Average Standard guideline applicable for heavy metals in marine sediment specified by EPA have been mentioned in **Table 41**.

**Table 41: Standard Guidelines applicable for heavy metals in sediments**

Sr. No.	Metals	Sediment quality (mg/kg)			Source
		Not polluted	Moderately polluted	Heavily polluted	
1.	As	<3	3-8	>8	EPA
2.	Cu	<25	25-50	>50	
3.	Cr	<25	25-75	>75	
4.	Ni	<20	20-50	>50	
5.	Pb	<40	40-60	>60	
6.	Zn	<90	90-200	>200	
7.	Cd	-	<6	>6	
ND = Not Detected					

(Source: G Perin et al. 1997)

The details of the said comparison have been mentioned in the **Table 42** as follows:

**Table 42: Comparison of Heavy metals with Standard value in marine sediment**

Sr. No.	Parameters	Kandla						Vadinar	
		MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Arsenic	BQL	BQL	BQL	BQL	BQL	BQL	2.74	5.17
2.	Copper	5.6	11.4	4.2	6.8	12	8.9	5.5	8.2
3.	Chromium	56.17	32.74	42.38	53.30	51.33	36.71	45.20	41.85
4.	Nickel	16.80	11.54	18.94	25.60	24.00	12.80	14.70	20.50
5.	Lead	6.1	5.84	4.25	5.85	5.71	4.24	6.88	7.41
6.	Zinc	38.22	32.11	48.20	34.98	19.54	32.00	42.80	40.30
7.	Cadmium	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

- **Arsenic** was observed below the detection limit for Kandla in both the monitoring period of April and May. While for Vadinar 2.74 to 5.17 mg/Kg range in the month of

April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Arsenic in range of 3-8 mg/Kg which indicate the moderately polluted status of Sediment for both the April and May, 2023.

- **Copper** was observed in the range of 4.2 to 12 mg/Kg for Kandla and 5.5 to 8.2 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Copper <25 mg/Kg which indicate the non-polluted status of Sediment for both the April and May, 2023.
- **Chromium** was observed in range of 32.74 to 56.17 mg/Kg for Kandla and 41.85 to 45.2 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Chromium in range of 25-75 mg/Kg which indicates that the sediment is moderately polluted for both April and May, 2023.
- **Nickel** was observed in the range of 11.54 to 25.60 mg/Kg for Kandla and 14.17-20.50 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Nickel in range of 20-50 mg/Kg which indicate the moderately polluted Sediment for both the April and May, 2023.
- **Lead** was observed in the range of 4.24 to 6.10 mg/Kg for Kandla and 6.88 to 7.41 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Lead <40 mg/Kg which indicate the non-polluted status of Sediment for both the April and May, 2023.
- **Zinc** was observed in the range of 19.54 to 48.20 mg/Kg for Kandla and 40.30 to 42.8 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Zinc <90 mg/Kg which indicate the non-polluted status of Sediment for both the April and May, 2023.
- **Cadmium** was observed below the detection limit was limit for Kandla and Vadinar in both April and May month, which indicates that the sediment is non polluted.

#### 11.4 Conclusion:

Analysis of the sediments does not indicate any pollution. However, it may be noted that, the sediments are highly dynamic being constantly deposited and carried away by water currents. Hence maintaining the quality of sediments is necessary as it plays a significant role in regulating the quality of the marine water and the marine ecology.

## **CHAPTER 12: MARINE ECOLOGY MONITORING**

## 2.4 Marine Ecological Monitoring

The monitoring of the biological and ecological parameters is important in order to assess the marine environment. A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval. Deendayal Port and its surroundings have mangroves, mudflats and creek systems as major ecological entities.

As defined in the scope by Deendayal Port Authority (DPA), the Marine Ecological Monitoring is required to be carried out once a month specifically at eight locations, six at Kandla and two at Vadinar. The sampling of the Benthic Invertebrates has been carried out with the help of D-frame nets, whereas the sampling of zooplankton and phytoplankton has been carried out with the help of Plankton Nets (60 micron and 20 micron). The details of the locations of Marine Ecological Monitoring have been mentioned in **Table 43** as follows:

**Table 43: Details of the sampling locations for Marine Ecological**

Sr. No.	Location Code		Location Name	Latitude Longitude
1.	Kandla	ME-1	Near Passenger Jetty One	23.017729N 70.224306E
2.		ME-2	Kandla Creek (near KPT Colony)	23.001313N 70.226263E
3.		ME-3	Near Coal Berth	22.987752N 70.227923E
4.		ME-4	Khori Creek	22.977544N 70.207831E
5.		ME-5	Nakti Creek (near Tuna Port)	22.962588N 70.116863E
6.		ME-6	Nakti Creek (near NH - 8A)	23.033113N 70.158528E
7.	Vadinar	ME-7	Near SPM	22.500391N 69.688089E
8.		ME-8	Near Vadinar Jetty	22.440538N 69.667941E

The map depicting the locations of Marine Ecological monitoring in Kandla and Vadinar have been mentioned in **Map 23 and 24** as follows:





Figure 23: Locations Map of Marine Ecological Monitoring at Kandla





**Figure 24: Locations Map of Marine Ecological Monitoring at Vadinar**



The various parameters to be monitored under the study for Marine Ecological Monitoring are mentioned in **Table 44** as follows:

**Table 44: List of parameters to be monitored for Marine Ecological Monitoring**

Sr. No.	Parameters
1.	Productivity (Net and Gross)
2.	Chlorophyll-a
3.	Pheophytin
4.	Biomass
5.	Relative Abundance, species composition and diversity of phytoplankton
6.	Relative Abundance, species composition and diversity of zooplankton
7.	Relative Abundance, species composition and diversity of benthic invertebrates (Meio, Micro and macro benthos)
8.	Particulate Oxidisable Organic Carbon
9.	Secchi Depth

## 2.5 Sampling Methodology

### Processing for chlorophyll estimation:

Samples for chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grinded in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm.

**Phytoplankton** in the marine environment: Phytoplanktons are free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio-purifier and bio-indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem. The phytoplankton includes a wide range of photosynthetic and phototrophic organisms.

Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (*Bacillariophyceae*) and Dinoflagellates (*Dinophyceae*). Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as Cyanophytes (Bluegreen algae). Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts. Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

**Zooplankton** includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes. Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of 'biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior. The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

### **Diversity Index**

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

- The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time. Biodiversity is commonly expressed through indices based on species richness and species abundances. Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

### 1. Simpson's index:

A reasonably high level of dominance by one or a small number of species is indicated by the range of **0.89 to 0.91**. The general health and stability of the ecosystem may be impacted by this dominance. Community disturbances or modifications that affect the dominant species may be more likely to have an impact. The dominating species determined by the Simpson's index can have big consequences on how the community is organised and how ecological interactions take place.

The formula for calculating D is presented as:

$$D = 1 - \sum (p_i^2)$$

Where,  $\sum$  = Summation symbol,  $p_i$  = Relative abundance of the species

### 2. Shannon-Wiener's index:

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index (H), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species. Shannon-Wiener's index (H) reproduces community parameters to a single number by using an equation are as follow:

$$H' = \sum p_i * \ln (p_i)$$

Where,  $\sum$  = Summation symbol,

$p_i$  = Relative abundance of the species,

$\ln$  = Natural logarithm

More diverse ecosystems are considered healthier and more resilient. Higher diversity ecosystems typically exhibit better stability and greater tolerance to fluctuations. e.g., The Shannon diversity index values between 2.19 and 2.56 indicate relatively high diversity within the community compared to communities with lower values. It suggests that the community likely consists of a variety of species, and the species are distributed somewhat evenly in terms of their abundance.

### 3. Margalef's diversity index:

The number of species is significantly related to the port's vegetation cover surface, depth, and photosynthetic zone. The habitat heterogeneity is a result of these three elements. Species richness is related to the number of distinct species present in the analysed area. Margalef's index has a lower correlation with sample size. Small species losses in the community over time are likely to result in inconsistent changes.

Margalef's index  $D_{Mg}$ , which is also a measure of species richness and is based on the presumed linear relation between the number of species and the logarithm of the number of individuals. It is given by the formula:

$$D_{Mg} = \frac{S-1}{\ln N}$$

Where N = total number of individuals collected

S = No. of taxa or species or genera

#### 4. Berger-Parker index:

This is a useful tool for tracking the biodiversity of deteriorated ecosystems. Environmental factors have a considerable impact on this index, which accounts for the dominance of the most abundant species over the total abundance of all species in the assemblage. The preservation of their biodiversity and the identification of the fundamental elements influencing community patterns are thus critical for management and conservation. Successful colonising species will dominate the assemblage, causing the Berger-Parker index to rise, corresponding to well-documented successional processes. The environmental and ecological features of the system after disturbance may therefore simply but significantly determine the identity of the opportunistic and colonising species through niche selection processes.

The Berger-Parker index is a biodiversity metric that focuses on the dominance or relative abundance of a single species within a community. It provides a measure of the most abundant species compared to the total abundance of all species present in the community. Mathematically, it can be represented as follows:

$$d = \frac{N_{max}}{N_i}$$

Where,

$N_{max}$  = Max no of individuals of particular genera or species

$\sum N_i$  = Total no of individuals obtained.

The resulting value of the Berger-Parker index ranges between 0 and 1. A higher index value indicates a greater dominance of a single species within the community. Conversely, a lower index value suggests a more even distribution of abundance among different species, indicating higher species diversity. The range of the Berger-Parker index can be interpreted as when the index value is close to 0, it signifies a high diversity with a more even distribution of abundances among different species. In such cases, no single species dominates the community, and there is a balanced representation of various species.

5. **Relative Abundance:** The species abundance distribution (SAD) from disturbed ecosystems follows even/ uneven pattern. E.g., If relative abundance is 0.15, then the found species are neither highly dominant nor rare.

$$RA = \frac{\text{No. of Individuals of Sp.}}{\text{Total no. of Individual}} * 100\%$$

#### 6. Evenness index-

Evenness index determines the homogeneity (and heterogeneity) of the species' abundance. Intermediate values between 0 and 1 represent varying degrees of evenness or unevenness in the distribution of individuals among species. Value of species evenness represents the degree of redundancy and resilience in an ecosystem. High species evenness = All species of a community can perform similar ecological activities or functions= even utilization of available ecological niches = food web more stable = ecosystem is robust (resistant to disturbances or environmental changes). Intermediate values between 0 and 1 represent variable degrees of evenness or unevenness.

$$EI = \frac{H}{\ln(S)}$$

Where,

H= Shannon value

ln(S) = the natural logarithm of the number of different species in the community

## 2.6 Result and Discussion and Conclusion

The details of Marine Ecological Monitoring conducted for the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 45**.

**Table 45: Summarized Results of Biomass, Net Primary Productivity (NPP), Gross Primary Productivity (GPP), Pheophytin and Chlorophyll**

Sr. No.	Parameters	Units	Kandla						Vadinar	
			ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
1.	Biomass	mg/l	78	81	111	88	85	91	26	32
2.	Net Primary Productivity	mg/L/hr	7.21	8.25	7.33	8.87	8.32	7.12	6.52	7.64
3.	Gross Primary Productivity	mg/L/hr	8.55	7.12	8.32	8.71	6.45	7.13	6.94	5.74
4.	Pheophytin	mg/m <sup>3</sup>	NIL	3	NIL	NIL	NIL	6	7.21	6.74
5.	Chlorophyll-a	mg/m <sup>3</sup>	3.16	BQL	1.82	BQL	4.23	BQL	1.34	BQL
6.	Particulate Oxidizable Organic Carbon	mg/L	0.32	0.16	0.56	0.25	0.35	0.29	0.36	0.39
7.	Secchi Depth	ft	0.89	0.84	0.76	0.91	0.72	0.81	5.30	4.26

- Biomass:**

The value of **Biomass** reported from location ME-1 to ME-6 in range between 78-111 g/m<sup>2</sup> where highest biomass present in ME-3 (Near Coal Berth) and lowest biomass present in ME-1 (Near passenger Jetty 1) during sampling period. In Vadinar, the value of biomass was observed 26 g/m<sup>2</sup> at ME-7 (Near SPM), monitoring station and 32 g/m<sup>2</sup> in ME-8 (Near Vadinar Jetty).

- Chlorophyll-a**

In the sub surface water, the monitoring station reported the maximum **Chlorophyll-a** value at ME-5 (Nakti creek) i.e., 4.23 mg/m<sup>3</sup> and the value observed to be "Below the detection limit" at three locations (ME-2, ME-4 and ME-6) during the sampling. In the Vadinar, the value of chlorophyll-a was observed 1.34 mg/m<sup>3</sup> at ME-7 (Near SPM), monitoring station and ME-8 (Near Vadinar Jetty) recorded below the detection limit.

- **Pheophytin**

The level of **Pheophytin** was detected or found nil in majority of the monitoring location in Kandla except for location ME-2 and 6 (Kandla and Nakti Creek) where it was recorded 3 and 6, respectively. While it was observed 7.21 and 6.74 in ME-7 (Near SPM) and ME-8 (Near Vadinar Jetty) respectively, in Vadinar.

- **Secchi Depth**

In monitoring station of Kandla from ME-1 to ME-6 the level of **Secchi Depth** was observed between 0.72 to 0.91 ft whereas the value recorded in Near SPM (ME-7) is 5.30ft and in Near Vadinar Jetty is 4.26 ft.

- **Productivity (Net and Gross)**

**Gross primary productivity (GPP)** is the rate at which organic matter is synthesised by producers per unit area and time (GPP). The amount of carbon fixed during photosynthesis by all producers in an ecosystem is referred to as gross primary productivity. The monitoring station reported **GPP** value in range between 6.45-8.71 mg/L/hr where the highest value recorded in Khori creek and lowest recorded at Nakti creek (near Tuna port) during sampling period. In the Vadinar, the value of **GPP** was observed 6.94 mg/L/hr at ME-7 (Near SPM) monitoring station and ME-8 (Near Vadinar Jetty) recorded 5.74 mg/L/hr.

**Net primary productivity**, is the amount of fixed carbon that is not consumed by plants, and it is this remaining fixed carbon that is made available to various consumers in the ecosystem. The Net primary productivity of the monitoring location at Kandla from (ME-1 to ME-6) has been estimated to be between 7.12 to 8.87 mg/L/hr, while for Vadinar the value of NPP recorded 6.52 mg/L/hr and 7.64 mg/L/hr in ME-7 and ME-8 during the monitoring month.

- **Particulate Oxidisable Organic Carbon**

For the month of April, the concentration of the Particulate oxidisable organic Carbon was observed to fall within the range of 0.16-0.35 mg/L at Kandla and 0.36-0.39 mg/L for Vadinar.

- **Ecological Diversity**

**Phytoplankton:** For the evaluation of the Phytoplankton population in DPA Kandla and Vadinar within the immediate surroundings of the port, sampling was conducted between **mid-April to May, 2023**. Total 8 sampling locations were studied i.e. sampling locations (6 from Kandla and two from Vadinar). The details of variation in abundance and diversity in phytoplankton communities is mentioned in **Table 46**.

**Table 46: Phytoplankton variations in abundance and diversity in sub surface sampling stations**

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
<i>Bacillaria sp.</i>	460	700	680	750	660	850	650	700
<i>Biddulphia sp.</i>	650	510	-	650	-	-	755	350
<i>Chaetoceros sp.</i>	350	765	680	530	755	550	800	480
<i>Chlamydomonas sp.</i>	150	560	-	-	380	860	420	545
<i>Cyclotella sp.</i>	-	-	800	540	650	880	-	390
<i>Ditylum sp</i>	900	780	390	685	-	350	450	600



Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
<i>Coscinodiscus sp.</i>	-	500	950	320	600	820	785	-
<i>Fragilaria sp.</i>	650	600	580	-	700	-	710	840
<i>Gomphonema sp.</i>	550	840	-	360	-	350	900	-
<i>Gyrosigma sp.</i>	410	500	650	750	-	685	400	655
<i>Pleurosigma sp.</i>	-	385	-	480	-	700	455	350
<i>Navicula sp.</i>	800	750	440	885	670	600	550	400
<i>Nitzschia sp.</i>	785	550	600	500	750	540	800	685
<i>Skeletonema sp.</i>	500	765	480	-	-	740	655	-
<i>Synedra sp.</i>	800	480	-	556	-	700	-	750
<i>Planktothrix sp.</i>	-	780	500	680	730	750	500	-
<i>Oscillatoria sp.</i>	940	-	670	-	845	800	-	785
<b>Density-Units/l</b>	<b>7945</b>	<b>9465</b>	<b>7420</b>	<b>7686</b>	<b>6740</b>	<b>10175</b>	<b>8830</b>	<b>7530</b>
<b>No. of genera</b>	<b>13</b>	<b>15</b>	<b>12</b>	<b>13</b>	<b>10</b>	<b>15</b>	<b>14</b>	<b>13</b>

The phytoplankton community of the sub surface water in the Kandla and Vadinar was represented by, Diatoms, blue green algae and Cynobacteria. Diatoms were represented by 14 genera, Blue green algae were represented by 1 genera and Cynobacteria were represented by 2 genera during the sampling period.

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from 6800-7220 units/L, while for Vadinar its density of phytoplankton observed 6535 units/L at ME-7 and 8360 units/L at ME-8. During the sampling, phytoplankton communities were dominated by *Cyclotella sp.* and *Navicula sp.* in Kandla, while *Nitzschia sp.* in Vadinar.

**Table 47: Species richness Index and Diversity Index in Phytoplankton**

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	12	12	14	13	16	13	12	14
Individuals	7450	8745	9155	9100	10310	7990	8025	9650
Shannon diversity	2.49	2.68	2.46	2.53	2.29	2.68	2.61	2.52
Simpson 1-D	0.91	0.93	0.91	0.92	0.90	0.93	0.92	0.98
Species Evenness	0.97	0.99	0.99	0.99	0.99	0.99	0.99	0.98
Margalef richness	1.34	1.53	1.23	1.34	1.02	1.52	1.43	1.34
Berger-Parker	0.12	0.09	0.13	0.12	0.13	0.09	0.10	0.11
Relative abundance	0.16	0.16	0.16	0.17	0.15	0.15	0.16	0.17

- **Shannon-Wiener's Index (H)** of phytoplankton communities at the sampling stations was in the range of 2.29-2.68 between selected sampling stations from ME-1 to ME-6 with an average value of 2.52 at Kandla creek and nearby creeks which indicate the higher and stable diversity. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 2.52-2.61 between selected sampling stations with an average value of 2.56 at Vadinar. The apportionment of the numbers of individuals

among the species observed higher in Nakti Creek in Kandla and Near Vadinar Jetty (Vadinar).

- In the month of **April**, **Margalef's diversity index** (Species Richness) of phytoplankton communities in the Kandla and nearby creeks sampling stations was varying from 1.02-1.53 with an average of 1.33 during the sampling. While for Vadinar Margalef's diversity index (Species Richness) of phytoplankton communities observed 1.43 at ME-7 and 1.34 at ME-8 with an average value of 1.38.
- **Simpson diversity index (1-D)** of phytoplankton communities was ranged between 0.90-0.93 at Kandla creek and nearby creeks, with an average of 0.91 in studied location. Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was 0.92 at ME-7 and 0.98 at ME-8 with an average of 0.92. Both the Monitoring station of Kandla and Vadinar shows a good diversity of phytoplankton communities.
- **Berger-Parker Index (d)** of phytoplankton communities in the sampling stations was in the range of 0.09-0.13 between selected sampling stations from ME-1 to ME-6 with an average value of 0.11 at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of 0.10-0.11 with an average value of 0.11 All the monitoring station signifies a low diversity with an even distribution among the different species.
- **Relative Abundance** of phytoplankton communities in the sampling stations was in the range of 0.15-0.17 between selected sampling stations from ME-1 to ME-6 with an average value of 0.15 at Kandla creek and nearby creeks. Relative Abundance of phytoplankton communities in the sampling stations was in the range of 0.16-0.17 with an average value of 0.17 at Vadinar. The average relative abundance is found in range of 0.15, thus the studied species can be stated as neither highly dominant nor rare.
- The **Species Evenness** is observed in the range of 0.99 to 1 for all the eight-monitoring station of Kandla and Vadinar, indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species. The details of variation in abundance and diversity in zooplankton communities is mentioned in **Table 48**.

**Table 48: Zooplankton variations in abundance and diversity in sub surface sampling stations**

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
<i>Acartia sp.</i>	-	3	1	4	3	1	2	
<i>Acrocalanus</i>	1	2	7	4	1	1	3	5
<i>Amoeba</i>	6	1		3	6	2	4	1
<i>Brachionus sp.</i>	2	4	2	1		8	5	-
<i>Calanus sp.</i>	1	1	-	3	-	2	2	2
<i>Cladocera sp.</i>	1	-	-	2	1	1	2	3
<i>Copepod larvae</i>	3	8	5	6	5	3	10	3
<i>Cyclopoida</i>	2	4	1	3	2	-	1	1
<i>Diaptomus sp.</i>	4	1	3	1	10	1	1	3
<i>Eucalanus sp.</i>	5	-	1	4	4	8	7	9
<i>Mysis sp.</i>	-	11	8	4	-	2	7	-
<i>Oithona sp.</i>	1	2	5	2	1	2	3	9

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
<i>Paracalanus sp.</i>	12	10	13	18	15	15	20	17
<b>Density Unit/L</b>	<b>38</b>	<b>47</b>	<b>46</b>	<b>55</b>	<b>48</b>	<b>46</b>	<b>66</b>	<b>53</b>
<b>No. of genera</b>	<b>11</b>	<b>11</b>	<b>10</b>	<b>13</b>	<b>10</b>	<b>12</b>	<b>12</b>	<b>10</b>

A total of 13 groups/taxa of zooplankton were recorded in Kandla and Vadinar during the study period which mainly constituted by copepods, branchiopoda, monogononata, fish and shrimp larval forms. Copepods had the largest representation at all stations from (ME-1 to ME-8). The density of Zooplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from 67-187 units/L, while for Vadinar its density of phytoplankton observed 198 units/L at ME-7 and 133 units/L at ME-8. During the sampling, zooplankton communities were dominated by *Mysis sp.* in Kandla, while *Paracalanus sp.* in both the monitoring location of Kandla and Vadinar.

**Table 49: Species richness Index and Diversity Index in Zooplankton**

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	11	11	10	13	10	12	12	10
Individuals	38	47	46	55	48	46	66	53
Shannon diversity	2.05	2.08	1.99	2.23	1.94	2.03	2.15	1.95
Simpson (1-D)	0.85	0.87	0.85	0.86	0.84	0.84	0.86	0.83
Species Evenness	0.85	0.87	0.86	0.87	0.84	0.82	0.87	0.85
Margalef	2.75	2.6	2.35	2.99	2.32	2.87	2.63	2.27
Berger-Parker	0.32	0.23	0.28	0.33	0.31	0.33	0.3	0.32
Relative abundance	28.95	23.4	21.74	23.64	20.83	26.09	18.18	18.87

- **Shannon-Wiener's Index (H)** of Zooplankton communities, at sampling stations was in the range of 1.94-2.23 between selected sampling stations from ME-1 to ME-6 with an average value of 2.05 at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of zooplankton communities in the sampling stations was in the range of 1.95-2.15 between selected sampling stations with an average value of 2.05 at Vadinar. The diversity of zooplankton species was observed to be less in both the monitoring location of Kandla and Vadinar.
- **Margalef's diversity index** (Species Richness) of zooplankton communities in the Kandla and nearby creeks sampling stations was varying from 2.32-2.99 with an average of 2.64 during the sampling. While for Vadinar Margalef's diversity index (Species Richness) S of zooplankton communities observed 2.63 at ME-7 and 2.27 at ME-8 with an average of 2.45. The higher value was observed in Khori creek (ME-4), Kandla and in ME-7 (near SPM), Vadinar.
- **Simpson diversity index (1-D)** of zooplankton communities was ranged between 0.84-0.87 at all sampling stations in Kandla creek and nearby creeks, with an average of 0.85. While for Vadinar, Simpson diversity index (1-D) of zooplankton communities was 0.86 at ME-7 and 0.83 at ME-8 with an average of 0.84.

- **Berger-Parker Index (d)** of zooplankton communities in the sampling stations was in the range of 0.23-0.33 between selected sampling stations from ME-1 to ME-6 with an average value of 0.3 at Kandla creek and nearby creeks. Berger-Parker Index (d) of zooplankton communities in Vadinar sampling stations was found in range of 0.3–0.32 with an average value of 0.31. All the monitoring station signifies a low diversity with an even distribution among the different species.
- **Relative Abundance** of zooplankton communities at sampling stations was in the range of 20.83-28.95 between selected sampling stations from ME-1 to ME-6 with an average value of 24.10 at Kandla creek and nearby creeks. Relative Abundance of zooplankton communities in the sampling stations was in the range of 18.18–18.87 with an average value of 18.52 at Vadinar.
- The **Species Evenness** is observed in the range of 0.82 to 0.87 for all the eight-monitoring station of Kandla and Vadinar, the highest value recorded in ME-2,4&7 (Kandla & Khorri Creek, near SPM), Kandla & Vadinar and the lowest value found in ME-6 (Nakti Creek).

**Table 50: Benthic Fauna variations in abundance and diversity in sub surface sampling stations at Kandla and Vadinar**

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
<i>Diapatra sp.</i>	1	2	1	6	2	4	1	3
<i>Mollusca sp.</i>	3	1	4	3	1	-	1	-
<i>Odonata sp.</i>	4	1	1	-	1	3	4	5
<i>Coleoptera sp.</i>	1	2	2	3	-	1	3	1
<i>Crustacea sp.</i>	-	1	3	5	1	3	1	-
<i>Hemiptera sp.</i>	3	6	-	2	2	1	-	1
<i>Tricoptera sp.</i>	3	6	4	-	2	5	2	1
<b>Density-Units/l</b>	<b>15</b>	<b>19</b>	<b>15</b>	<b>19</b>	<b>9</b>	<b>17</b>	<b>12</b>	<b>11</b>
<b>No of genera</b>	<b>6</b>	<b>7</b>	<b>6</b>	<b>5</b>	<b>6</b>	<b>6</b>	<b>6</b>	<b>5</b>

Few Benthic organisms were observed in the collected sample by using the Van-Veen grabs during the sampling conducted in the month of April and May from DPA Kandla and Vadinar. Majority of the species were found under the Macro-benthic organisms during the sampling period were represented by *Diapatra sp.*, *Mollusca sp.*, *Odonata sp.*, *Crustacea sp.* Etc. The density of benthic fauna was varying from 10-14- Unit/L. The dominating benthic communities at Kandla Creek and nearby creek (Nakti and Khorri creek) were represented *Diapatra sp.* While lowest number of benthic species was represented by *Hemiptera sp.* Their population was found as 16 Unit /L at Near SPM and 5 Unit/L near Vadinar Jetty area during both the sampling period.

**Table 51: Species richness Index and Diversity Index in Benthic Organism**

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	6	7	6	5	6	6	6	5
Individuals	15	19	15	19	9	17	12	11
Shannon diversity	1.68	1.67	1.66	1.54	1.74	1.65	1.63	1.37
Simpson 1-D	0.86	0.81	0.85	0.81	0.92	0.84	0.85	0.76
Species Evenness	0.94	0.86	0.93	0.96	0.97	0.92	0.91	0.85
Margalef	1.85	2.04	1.85	1.36	2.28	1.76	2.01	1.67
Berger-Parker	0.27	0.32	0.27	0.32	0.22	0.29	0.33	0.45
Relative abundance	40	36.84	40	26.32	66.67	35.29	50	45.45

- **Shannon-Wiener's Index (H)** of Benthic organisms at sampling stations was in the range of 1.54-1.74 between selected sampling stations from ME-1 to ME-6 with an average value of 1.65 at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of Benthic organisms in the sampling stations was in the range of 1.37-1.63 between selected sampling stations with an average value of 1.5 at Vadinar. Diversity of zooplankton species was observed to be less in both the monitoring location of Kandla and Vadinar.
- **Margalef's diversity index** (Species Richness) of Benthic organisms in the Kandla and nearby creeks sampling stations was varying from 1.36-2.28 with an average of 1.85 during the sampling period. While for Vadinar Margalef's diversity index (Species Richness) of Benthic organisms observed 2.01 at ME-7 and 1.67 at ME-8 with an average of 1.84.
- **Simpson diversity index (1-D)** of Benthic organisms was ranged between 0.81-0.92 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.84. The highest value was observed at ME-5. While for Vadinar Simpson diversity index (1-D) of benthic organism was 0.85 at ME-7 and 0.76 at ME-8 with an average of 0.80 during the sampling period.
- **Berger-Parker Index (d)** of Benthic organisms in the sampling stations was in the range of 0.22-0.32 between selected sampling stations from ME-1 to ME-6 with an average value of 0.28 at Kandla creek and nearby creeks. Berger-Parker Index (d) of Benthic organisms in Vadinar sampling stations was found in range of 0.33-0.45 with an average value of 0.39. Thus, all the eight-monitoring station of Kandla and Vadinar signifies a moderate diversity with an even distribution among the different species.
- **Relative Abundance** of benthic organism at sampling stations was in the range of 26.32-66.67 between selected sampling stations from ME-1 to ME-6 with an average value of 40.85 at Kandla creek and nearby creeks. Relative Abundance of phytoplankton communities in the sampling stations was in the range of 45.45-50 with an average value of 47.73 at Vadinar. The average relative abundance is found in range of 0.15, thus the studied species can be stated as neither highly dominant nor rare.
- The **Species Evenness** is observed in the range of 0.85 to 0.97 for all the eight-monitoring station, with an average value of 0.91 at Kandla and Vadinar indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species.



**Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla for April-May 2023**

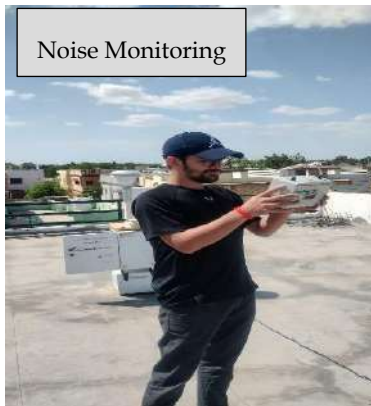
Ambient Air Monitoring



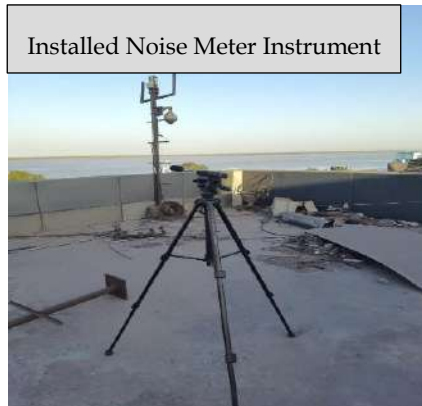
Meteorological Monitoring



Noise Monitoring



Installed Noise Meter Instrument



Soil Monitoring



Drinking water Monitoring



STP Monitoring



Marine (water, sediment & ecology) Monitoring





**Annexure 1: Photographs of the Environmental Monitoring conducted at Vadinar for April-May 2023**

Ambient Air Monitoring



Meteorological Monitoring



Noise Monitoring



Soil Monitoring



Drinking water Monitoring



Preservation at site



STP Monitoring



Marine (water, sediment & ecology) Monitoring



Source: GEMI



## **Gujarat Environment Management Institute (GEMI)**

(An Autonomous Institute of Government of Gujarat)

'An ISO 9001:2015, ISO 14001:2015 & ISO 45001:2018 Certified Institute'

### **Head Office**

Plot No. B 246 & 247, G.I.D.C. Electronic Estate,  
Sector-25, Gandhinagar-382024

### **Laboratory**

Plot No. B-64, G.I.D.C. Electronic Estate,  
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Tel: (+91) 79-23240964 (O), T: (+91) 79-23287758 (Lab), F: (+91) 79-23240965

E-mail: [info-gemi@gujarat.gov.in](mailto:info-gemi@gujarat.gov.in) | Website: [www.gemi.gujarat.gov.in](http://www.gemi.gujarat.gov.in)

*"We Provide Environmental Solutions"*

# **Annexure -V**

## **Annexure V**

**Subject:** Compliance of mitigation measures suggested in EIA report of the project “**Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Trust (Erstwhile: Kandla Port Trust) at Gandhidham, Kutch, Gujarat**”.

**Reference:** Specific Condition no. XXXII of Environmental and CRZ Clearance granted by MoEF&CC, GoI vide letter vide file no. 10-9/2017-IA-III dated 18/2/2020.

<b>S.No.</b>	<b>Particulars</b>	<b>Location</b>	<b>Quantification</b>	<b>Proposed Measures</b>	<b>Compliance</b>
1.	Generation of Particulates	Applicable to the proposed projects and surrounding	Not quantified	Spraying of water  Reducing speed of vehicles  Deploying vehicles with PUC certificate	DPA has installed Mist Canon at the Port area to minimize the dust.  Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done.  DPA has issued Circular No. TF/SH/Circulars/2022/1341 dated 04/11/2022 considering the safety norms provided for smooth and continuous operation.  DPA has issued Circular regarding Implementation of RFID enabled access control system (e-Drishti); wherein, PUC certificate has been made mandatory for vehicle registration in e-Drishti portal to obtain valid permit for entry in the port premises.
2	Generation Noise	Along proposed projects	Not quantified	Restricted operation in the night time	DPA has issued Circular No. TF/SH/Circulars/2022/1341 dated 04/11/2022 considering the safety norms provided for smooth and continuous

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
				<p>Selection of machinery generating noise less than 72 db(A)</p> <p>Fitting on noise attenuation devices</p>	<p>operation.</p> <p>For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&amp;CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is enclosed with the EC compliance.</p> <p>Further, routine maintenance is being carried out to keep check on the efficiency and noise.</p>
Soil & Geology					
3	Soil erosion	Applicable to the proposed projects	Not quantified; initiates a chain of impacts	<p>Water bars; stabilization of slopes</p> <p>Controlled discharge of water</p> <p>Conducting construction activities in non-monsoon season</p> <p>Oil spill prevention measures</p>	<p>Topography at the site location is generally flat with average ground level of about 6.5 m CD with marshy topsoil. Kindly refer Section 3.4.1 Topography of the EIA report.</p> <p>Point noted</p> <p>The area falls under arid/semi-arid region, thus the rainfall is very scanty.</p> <p>DPA has Oil Spill Contingency Plan in place. Copy of the same is attached with the EC compliance report.</p>

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
Hydrology					
4	Surface water contamination	At the proposed projects Soil erosion prone area	Not quantified	<p>Soil erosion control measures</p> <p>Waste management and spill control</p>	<p>For mitigating soil erosion, DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed.</p> <p>DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005. The copy of the details has already been communicated with the earlier compliance reports submitted.</p> <p>For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&amp;CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is enclosed with the EC compliance.</p> <p>For waste management, companies authorized by State Pollution Control Board (SPCB) have been awarded the work of collection, transporting and disposal of solid waste by the DPA.</p> <p>Further, DPA has assigned M/s Gujarat Environment Management Institute (GEMI)</p>



S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
	Spillage and sanitary wastes				vide letter EG/WK/4751/Waste Management-1/217 dated 24/01/2023 for "Preparation of Plan for Management of Plastic Waste, Solid Waste, C&D Waste, E-waste, Hazardous Waste including Bio-medical Waste and Non-hazardous waste in the Deendayal Port Authority Area". The work is in progress.  DPA has Oil Spill Contingency Plan in place. Copy of the same has been communicated with the last compliance report submitted.
5	Ground water contamination	Not expected			---
Land Use and Aesthetics					
6	Land use and Aesthetics	At project site At campsites  At other utilities like scraper stations	Not quantifiable	Contouring of the affected areas   Cleaning the stretch immediately after the construction activities are over   Restoration and re-vegetation to the best possible	Topography at the site location is generally flat with average ground level of about 6.5 m CD with marshy topsoil. Kindly refer Section 3.4.1 Topography of the EIA report.  DPA has included clause in tender/ Concession agreement for the contractor to undertake Clearance of site on completion and environmental protection measures. Copy of the relevant page of the tender has already been communicated with the last compliance report submitted.  DPA entrusted work of green belt development in and around the Port area to the Forest

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
				extent	<p>Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed.</p> <p>Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The final report submitted by GUIDE, Bhuj is attached with the EC compliance report. Further, DPA assigned work to GUIDE, Bhuj vide work order dated 23/06/2023 for "Green belt development in Deendayal Port Authority and its Surrounding Areas(Phase II) (10000 plants). The work is in progress.</p> <p>DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005. The copy of the details has already been communicated with the earlier compliance reports submitted.</p>
Biological Environment: Flora and Vegetation					
7	Due to dusting on floral cover	At project site & approach road	Limited	Sprinkling of water for dust suppression.	<p>–DPA has installed Mist Canon at the Port area to minimize the dust.</p> <p>–Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done.</p>
8	Removal of vegetation	At project site	Limited	Restoration and re-vegetation and plantation;	DPA entrusted work of green belt development in and around the Port area to

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
				Compensatory vegetation	<p>the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed.</p> <p>Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The final report submitted by GUIDE, Bhuj is attached with the EC compliance report. Further, DPA assigned work to GUIDE, Bhuj vide work order dated 23/06/2023 for "Green belt development in Deendayal Port Authority and its Surrounding Areas(Phase II) (10000 plants). The work is in progress.</p> <p>DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005. The copy of the details has already been communicated with the earlier compliance reports submitted.</p>
9	Due to Piling activity	At project site	Limited	Piling should be done in closed vessels to minimize the impact.	DPA has included clause in tender/ Concession agreement for the contractor to undertake piling installation in accordance with IS 2911. Copy of the relevant page of the tender has already been communicated with the last compliance report submitted.
10	Due to dredging	At project site in Sea	Not quantified	Silt curtain should be used to minimize the impact.	The possibility of providing silt curtains to minimize the impacts while dredging activities

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
					in a study for "Comprehensive study for the Deepening of Navigational channel to increase the draught of Navigational channel at Deendayal Port Trust including Capital & Maintenance dredging requirements and Preparation of Technical & Commercial Feasibility Report" has been awarded to IIT, Madras.
11	Oil spillage & waste disposal from ships	Sea & creeks	Unlimited	Oily wastes and sewage should not be discharged directly; MARPOL norms should be followed.	DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars in line with MARPOL norm regarding the reception facilities at Swachh Sagar portal.
12	Fishes & Fishery	In project area	Limited	No legal fishery is in study area, major fish landing site is far from project site.	Since Kandla Port is one of the major port in India and major portion of the study area is occupied by the Kandla port, and other industrial activities, fishing activities are very limited in the study area. Kindly refer Section 3.7.4 Fisheries of the EIA report.
Fauna and Wildlife					
13	Loss of wildlife	No wildlife habitation in proximity	Not applicable	Strictly prohibiting hunting and similar activities	It is a custom bonded area, therefore, no hunting or similar activities are permitted in the port area. In the study area of the KPT no National park, wildlife sanctuary or biosphere reserve is present. Kindly refer Section 3.5.5.4

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
				<p>Restricting the speed of movement of vehicles</p> <p>Keeping "trench plugs" at strategic locations</p> <p>Shifting the nests, wherever possible</p>	<p>Occurrence of National Park/Sanctuary/ Biosphere Reserve etc. of the EIA report.</p> <p>DPA has issued Circular No. TF/SH/Circulars/2022/1341 dated 04/11/2022 considering the safety norms provided for smooth and continuous operation.</p> <p>Point noted</p> <p>There is no considerable habitat of fauna in vicinity of the project site. Kindly refer 3<sup>rd</sup> paragraph of Section 4.3.1. Noise generation during Construction Phase of the EIA report.</p>
Socio-Economic and Cultural Environmental					
14	Human habitations affected	No habitation falling within the project site	Not quantified, but critical locations are identified	Villagers in the proximity will kept informed on the project activities	DPA has already given advertisement regarding grant of Environmental & CRZ Clearance in two local newspapers viz. KUTCHMITRA (In Gujarati) dated 23/2/2020 and in the Indian Express (In English) dated 22/02/2020 and also forwarded to the Regional Office, MoEF&CC, Bhopal vide letter dated 27/2/2020.
15	Economic implications	Along the project site	Not quantified. The implications with regard to loss of seasonal crops and plantations	Compensation to the affected people; Employment, wherever possible, to the unskilled local people	The law of land will be followed by the BOT operator. The details of CSR Activities implemented as well as proposed are enclosed with EC compliance report.

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
			are identified		
16	Agriculture lands	At project site	No agriculture land involved	Restoration of the land; Management of topsoil	<p>No agriculture land is involved.</p> <p>For topsoil management, DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed.</p> <p>Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. Copy of the final report submitted by GUIDE, Bhuj is attached with the EC compliance report. Further, DPA assigned work to GUIDE, Bhuj vide work order dated 23/06/2023 for "Green belt development in Deendayal Port Authority and its Surrounding Areas(Phase II) (10000 plants). The work is in progress.</p>
17	Infrastructure	Near human habitations; Road and railway crossings	Not quantified	Rehabilitation of the affected infrastructure components; Leaving behind the infrastructure facilities like approach roads and facilities at the campsites for the local inhabitants	N/A
18	Social conflicts	Surrounding the proposed project.	Not quantifiable	Keeping good relationship with the local people; Keeping them informed on the project and project development.	The details of CSR Activities implemented as well as proposed are enclosed with EC compliance report.



S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
					DPA has already given advertisement regarding grant of Environmental & CRZ Clearance in two local newspapers viz. KUTCHMITRA (In Gujarati) dated 23/2/2020 and in the Indian Express (In English) dated 22/02/2020 and also forwarded to the Regional Office, MoEF&CC, Bhopal vide letter dated 27/2/2020.
19	Political conflicts	-	Not quantifiable	Keeping the key players informed on the pros and cons of the project.	The key players shall be informed on the pros and cons of the project.
20	Historic and archaeological importance	Surrounding the 15.0 Km. radius from the proposed project.	No structure on the surface possibilities are there of sub-surface structure	Inform the concerned authority in case of coming across any structure of archaeological significance.	Point noted

# **Annexure -VI**



# DEENDAYAL PORT AUTHORITY (Erstwhile: DEENDAYAL PORT TRUST)

Administrative Office Building  
Post Box NO. 50  
GANDHIDHAM (Kutch).  
Gujarat: 370 201.  
Fax: (02836) 220050  
Ph.: (02836) 220038

[www.deendayalport.gov.in](http://www.deendayalport.gov.in)

Date: 19/06/2023

EG/WK/4751 (CCA Renewal)/ 326

To,  
The Member Secretary  
Gujarat Pollution Control Board  
Paryavaran Bhavan,  
Sector 10A, Gandhinagar - 382010

**Sub:** Submission of Environmental statement in format form V for the financial year 2022-23 reg.

- Ref.:** 1) KPT letter no. MR/GN/1527(Part I)/535 dated 16/6/2012  
2) KPT letter no. MR/GN/1527(Part I)/2011 dated 20/5/2013  
3) KPT letter no. MR/GN/1527(Part I)/337 dated 17/05/2014  
4) KPT letter no. MR/GN/1527/ (Part I)/dated 27/04/2015  
5) KPT letter no. EG/WK/EMC/CCA (Part II)/218 dated 27/6/2016  
6) KPT letter no. EG/WK/EMC/CCA (Part II)/214 dated 19/6/2017  
7) DPT letter no. EG/WK/EMC/CCA (Part II)/294 dated 13/6/2018  
8) DPT letter no. EG/WK/EMC/CCA (Part II) dated 27/5/2019  
9) DPT letter no. EG/WK/4751 (CCA Renewal) dated 22/5/2020  
10) DPT letter no. EG/WK/4751 (CCA Renewal)/14 dated (30)04/(4)5/2021  
11) DPA letter no. EG/WK/4751 (CCA Renewal)/132 dated 06/07/2022

Sir,

It is requested to kindly refer above cited references for the said subject.

In this connection, it is to state that, the GPCB has renewed the consolidated consent & Authorization granted to Deendayal Port Authority (Erstwhile Deendayal Port Trust) and issued CCA order no. AWH-110594 vide PC/CA-KUTCH-812 (5)/GPCB ID 28494/581914 dated 21/01/2021 valid upto 21/07/2025

In this regard, as per statutory requirement, the DPA has regularly submitted Annual Returns (as mentioned in reference above) in format Form V to the GPCB.

Now please find the enclosed herewith Environmental Statement in Form V for the year 2022-23

This is for kind information and record please.

Encl : As above

Yours faithfully  
  
Manager (Environment)  
Deendayal Port Authority

**Enclosure – A**

Environmental Statement (Form V)  
For Deendayal Port Authority, Kandla  
For the FY @ 2022-2023

**"FORM-V"**  
(See rule -14)

From:

**Deendayal Port Authority,**  
Administrative Office Building,  
Post Box No.: 50, Gandhidham,  
Dist.: Kutch – 370 207. Gujarat State.  
Tel No.: O: 02836-220038  
Fax No.: 02836-220050

To,

The Member Secretary,  
**Gujarat Pollution Control Board,**  
Paryavaran Bhavan, Sector - 10A,  
Gandhinagar – 382043

**Environmental statement for the financial year ending the 31<sup>st</sup> March, 2023**

**"PART-A"**

1) Name and Address of the owner/occupier of the industry or process		
➤ NAME	:	Mr. Raveendra Reddy Chief Engineer
➤ ADDRESS	:	<b>Deendayal Port Authority</b> Administrative Office Building, Post Box No.: 50, Gandhidham, Dist.: Kutch – 370 207. Gujarat State. Tel No.: O: 02836-220038 Fax No.: 02836-220050
➤ Industry Category Primary – (STC code) Secondary – (STC code)	:	Major port Authority under the administrative control of Ministry of Ministry of Ports, Shipping and waterways, GOI
➤ Year of Establishment	:	8th April 1955
➤ Date of the last Environment audit report submitted	:	27 <sup>th</sup> June, 2016

**"PART-B"**

**WATER AND RAW MATERIAL CONSUMPTION**

Sr.No.	WATER CONSUMPTION	(M³/Day)
1.	Process	652676.55
2.	Cooling	
3.	Domestic Purpose	
Total water consumption for the period from April 2022 to March 2023 was KL hence, average water consumption for per day – 1788 M³/day		

**I. Water Consumption**

Sr. No.	Name of Products	Process Water Consumption per unit of products output	
		During the current financial year 2021-22	During the current financial year 2022-23
01.	Dry Cargo Handling	127.10 MT	137.5 MT
02.	Liquid Cargo Handling		
Deendayal Port Authority has only loading & unloading activities for dry cargo and liquid cargo. Hence consumption of process water consumption per unit of output with respective to production is not applicable.			
During FY 2022-23 Total Cargo Handled is 137.5 MMTPA			
However, Details of the Domestic water consumption for the financial year 2022-23 please refer Annexure-1			

**II. Raw material Consumption**

<b>Sr.No.</b>	<b>Name of Raw Material</b>	<b>Name of Products</b>	<b>Consumption of Raw material per unit of output</b>	
			<b>During the current financial year 2021-22</b>	<b>During the current financial year 2022-23</b>
1.	Deendayal Port Authority has only loading & unloading activities for dry cargo and liquid cargo. Hence consumption of raw material per unit of output with respective to production is not applicable			



**"PART-C"**

**POLLUTION DISCHARGED TO ENVIRONMENT/UNIT OF OUTPUT  
(PARAMETERS AS SPECIFIED IN THE CONSENT)**

<b>Pollutant</b>	<b>Quantity of Pollutant Discharged (mass/day)</b>	<b>Concentration of Pollution in Discharge (mass/volume)</b>	<b>% of Variation from prescribed standard with reasons</b>
Please Refer <b>Annexure -II</b> for Environmental Monitoring Reports of <ul style="list-style-type: none"><li>• Ambient Air Quality Monitoring</li><li>• Drinking Water Quality Monitoring</li><li>• Marine Water Monitoring</li><li>• Noise Level Monitoring</li></ul>			

**"PART-D"**

**HAZARDOUS WASTE  
[AS SPECIFIED UNDER HAZARDOUS WASTE (MANAGEMENT AND HANDLING) RULES -1989 & AMENDMENT RULES -2008]**

<b>Sr.No.</b>	<b>Hazardous Waste</b>	<b>Total Quantity in MT/Year</b>	
		<b>During the current financial year 2021-22</b>	<b>During the current financial year 2022-23</b>
1.	5.1- Used Spent Oil	3195.28	4578.79
2.	5.2- Waste Residue Containing Oil	6390.57	9157.58
<ul style="list-style-type: none"><li>• Details of Hazardous Waste generated during the financial year 2022-23 please refer <b>Annexure-III</b></li></ul>			
a. From Process: NA			
b. From Pollution Control facility: NA			

**"PART-E"**  
**SOLID WASTE**

Sr.No.	Solid Waste	Total Quantity in MT/year	
		During the current financial year 2021-22	During the current financial year 2022-23
1.	From Process	Nil	Nil
2.	From pollution Control Facility	Nil	Nil
a.	Quantity Recycled or Reutilized within the unit	Nil	Nil
b.	Sold	Nil	Nil
c.	Disposed Off	<b>1724.08 MT</b>	<b>2473.19 MT</b>
Details of Solid Waste (Non-Hazardous Waste) generated during the financial year 2022-23 please refer <b>Annexure-IV</b>			

## **"PART-F"**

**PLEASE SPECIFY THE CHARACTERISTICS (IN TERMS OF CONCENTRATION AND QUANTUM) OF HAZARDOUS AS WELL AS SOLID WASTES AND INDICATE DISPOSAL PRACTICE ADOPTED FOR BOTH THESE CATEGORIES OF WASTES.**

### **Hazardous Waste:**

Companies authorized by Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) have been awarded the work of collection, transporting and disposal of hazardous Waste by the Deendayal Port Authority. The same will be hand over to authorize parties for further Treatment & disposal.

### **Solid Waste:**

Garbage facility is provided as per MARPOL Act 73/78 to the vessel berthed at Deendayal Port Authority. Companies authorized by Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) have been awarded the work of collection, transporting and disposal of solid waste by the Deendayal Port Authority. The same will be hand over to authorize parties for further treatment and disposal.

## **"PART-G"**

### **IMPACT OF THE POLLUTION ABATEMENT MEASURES TAKEN ON CONSERVATION OF NATURAL RESOURCES AND ON THE COST OF PRODUCTION.**

DPA has awarded the work of "Preparing and Monitoring of Environmental monitoring and management plan for Deendayal Port Authority Kandla and Vadar to Gujarat Environment Management Institute (GEMI), Gandhinagar (An autonomous Institute of Government of Gujarat).

Further for Pollution Abatement measures taken for Conservation of Natural Resources DPA appointed renowned agency i.e M/s. GUIDE, Bhuj for the following work.

1. Regular Monitoring of Mangrove Plantation.
2. Preparation of detailed marine Biodiversity management plan for the impact of the project activities as per the requirement of EC & CRZ Clearance accorded by the MoEF&CC, GOI for the project "Creation of water front facilities (Oil jetties 8,9,10,11) and development of land of area 554 acres for associated facilities for storage at old Kandla, Gandhidham, kutch, Gujarat by M/s Deendayal Port Authority"
3. Regular monitoring of marine ecology in and around the Deendayal Port Authority area and continuous monitoring programme covering all season on various aspects of the coastal environ covering physico-chemical parameters of marine sediments samples coupled with biological indices, as per the requirement of EC & CRZ clearance accorded by the MoEF&CC,GOI to the various projects of the Deendayal port Authority.
4. Study on dredged material for presence of contaminant as per EC and CRZ clearance accorded by the MoEF&CC, GOI dated 19/12/2016 – specific condition vii

## **"PART-H"**

### **ADDITIONAL MEASURES / INVESTMENT PROPOSAL FOR ENVIRONMENTAL PROTECTION INCLUDING ABATEMENT OF POLLUTION, PREVENTION OF POLLUTION**

The allocation made under the scheme of "Environmental Services & Clearance there of other related Expenditure" during BE 2023-2024 is Rs. 274 Lakhs

## **"PART-I"**

### **ANY OTHER PARTICULAR FOR IMPROVING THE QUALITY OF THE ENVIRONMENT**

1. DPA is ISO 14001:2015 certified port for "Providing port facility and related maritime services for vessel and Cargo handling including storage
2. DPA has appointed M/s GEMI, Gandhinagar for the work "Making Deendayal Port a Green Port- Intended Sustainable Development under the Green Port Initiatives". M/s GEMI, Gandhinagar had submitted the Final Report on 10/03/2021
3. DPA has accorded the work of Afforestation project in Deendayal Port Area to Forest Department, GoG which includes plantation and maintenance work of 1100 plants per ha.
4. DPA has accorded the work of green belt development in Deendayal port Authority and its Surrounding areas charcoal site to GUIDE for the plantation of 5000 saplings of suitable species.
5. DPA has planted 7500 trees in Deendayal port trust area during the year 2014-15 6000 trees during financial year 2016-17 and the same has been regularly maintained.
6. DPA has planted 4000 trees at A.O building, Gopalpuri residential colony and along the road side at Kandla. Further, approximately 885 no. of trees have been planted since September 2015 onwards.
7. Continuous water sprinkling has been carried out on the top of the heap of coal, at regular intervals to prevent dusting, fire and smoke. DPA already installed sprinkling system inside Cargo Jetty area for coal dust suppression in coal yard (40 Ha. Area) at the cost of Rs. 14.44 crores.
8. DPA has installed Mist Canon at the Port area to minimize the coal dust.
9. Deendayal port Authority (traffic department) issued a Circular (SOP) to the trade with regard to control of dust pollution arising out of coal handling and ensuring safety in coal handling. In case of any violations of SOP, provision of impose of penalty of Rs. 10000/- has been made and if violation is repeated thrice, the same will lead to ban of concerned party into port area. The DPA is taking all the measures to reduce coal dust by implementing the coal handling guidelines through port users.

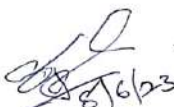
10. All trucks before leaving the storage yard have been covered with tarpaulin and also trucks are also not over loaded as well as there is no spillage during transportation and there is adequate space for movement of vehicles at the surrounding area.
11. DPA has constantly improving the house keeping in the dry cargo storage yard and nearby approved areas leading to roads. Adequate steps under the provisions of air prevention and control of pollution Act 1981, Environmental Protection Act 1986 are taken.
12. DPA commissioned STP of capacity 1.5 MLD for treatment of domestic waste water for entire DPA area. (Details of domestic waste water generation is attached herewith as **Annexure V**)
13. Deendayal Port Authority had carried out mangrove plantation in an area of 1500 ha. through various government agencies like Gujarat Ecology Commission, State Forest Department.
14. It is also relevant to mention here that, DPA entrusted work to Forest Department, GoG (Social Forestry Division, Bhuj) during August, 2019 for green belt development in and around port area 31.942 hectares (approx. 35200 plants at various locations) at a cost of Rs. 352.32 lakhs.
15. DPA is involved in various CER activities like providing the proper sanitation and development of better roads for connectivity
16. DPA is managing its plastic waste as per Plastic Waste Management Rules – 2016 and amendments made therein. In order to strictly implement the said rules, DPT had issued a circular regarding plastic waste minimization, source segregation, recycling etc. vide its Circular no. EG/WK/4751/Part 243(A) dated 03/09/2021
17. DPA has entrusted the work to GEMI, Gandhinagar for "Preparation of Plan for Management of Plastic Waste, Solid Waste, C&D Waste, E-waste, Hazardous Waste including Bio-medical Waste and Non-hazardous waste in the Deendayal Port Authority Area
18. DPA has assigned the work to TERI, New Delhi for "Transition of Business Operations to Water Neutrality – Water Neutrality of Deendayal Port, Kandla (Phase I- Study and assessment)
19. Recently, DPA has entrusted the work to GEMI, Gandhinagar for "Study of CO<sub>2</sub> Emission Estimation and Reduction Strategy under Maritime India Vision 2030.
20. Initiative for Installation of Continuous Ambient Air Quality Monitoring System (CAAQMS) for monitoring of Air quality is under process.

# **ANNEXURE - 1**



**Statement Showing the quantity of water consumed from GWSSB from April 2022 to March 2023**

<b>Sr.No.</b>	<b>Month</b>	<b>Total Quantity Consumed in KL</b>
1.	April 2022	49710
2.	May 2022	58030
3.	June 2022	61630
4.	July 2022	60580
5.	August 2022	61320
6.	September 2022	58230
7.	October 2022	55339
8.	November 2022	47983
9.	December 2022	56388
10.	January 2023	50360
11.	February 2023	44186
12.	March 2023	48920.55
		<b>652676.55</b>

  
**SE (PL) and EMC (I/C)**



# **ANNEXURE - IA**

**Statement Showing the quantity of Domestic Waste Water Generation  
(STP – Kandla) for the period from April 2022 to March 2023**

<b>Sr. No.</b>	<b>Month</b>	<b>Average Quantity of Domestic Waste Water Generation (KLD)</b>
1.	April 2022	269.86
2.	May 2022	200
3.	June 2022	263.78
4.	July 2022	328.66
5.	August 2022	290.16
6.	September 2022	244.72
7.	October 2022	231.93
8.	November 2022	143.03
9.	December 2022	124.52
10.	January 2023	124.5
11.	February 2023	163.75
12.	March 20223	138.21
<b>Average</b>		<b>210.26</b>

  
**XEN (Road)**

**DEENDAYAL PORT AUTHORITY**

# **ANNEXURE - II**

## ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT TRUST



<b>REPORT</b>	<b>:</b>	<b>DCPL/DPT/20-21/21</b>
<b>Mont</b>	<b>:</b>	<b>January</b>
<b>Issue</b>	<b>:</b>	<b>01</b>
<b>Revision</b>	<b>:</b>	<b>00</b>
<b>Prepare</b>	<b>:</b>	<b>DETOX CORPORATION PVT. LTD., SURAT</b>

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## **Introduction**

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF to identify non conformity in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.

## **1. Ambient Air Quality Monitoring**

As per the Environmental Monitoring Plan of Deendayal Port Trust, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

### **1.1 Air Quality Monitoring Methodology**

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub> & Benzene, and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours of the sampler, the reagents were replaced to obtain 3 samples per day for each parameter namely, SO<sub>2</sub>, NO<sub>x</sub>. The EPM 2000 filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected twice a week from all the eight locations as per the EMP.

### **1.2 Results**

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of January 2022 are given in Tables 1A to 6B. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 7A to 8B.

# **Ambient Air Quality Monitoring**

## Environmental Monitoring Report Of Deendayal Port Trust, JANUARY-2022

### Location 1: Marine Bhavan (AL1)

Location 1: Marine Bhavan (AL1)Table 1 : Results of Air Pollutant Concentration at Marine Bhavan										
Parameter	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL1 - 1	04.01.2022	314	209	84	6.00	6.43	20.30	20.30	11.74	11.74
					6.43		19.60		11.60	
					6.86		21.00		11.88	
AL1 - 2	07.01.2022	378	198	87	4.84	5.42	15.88	17.78	8.42	10.55
					5.28		18.42		10.98	
					6.15		19.05		12.25	
AL1 - 3	11.01.2022	463	204	96	4.84	3.66	26.04	19.48	7.66	7.23
					3.96		16.51		7.15	
					2.20		15.88		6.89	
AL1 - 4	12.01.2022	466	247	100	3.52	2.34	15.88	15.24	12.76	11.66
					2.20		14.61		11.74	
					1.32		15.24		10.47	
AL1 - 5	19.01.2022	434	239	98	3.08	3.96	19.05	16.73	7.40	7.57
					4.84		17.78		7.91	
					3.96		13.34		7.40	
AL1 - 6	21.01.2022	485	286	101	2.64	2.93	14.61	15.46	10.21	8.93
					3.52		19.69		9.19	
					2.64		12.07		7.40	
AL1 - 7	24.01.2022	396	217	98	3.52	3.08	14.61	17.15	12.76	11.49
					3.96		19.69		11.49	
					1.76		17.15		10.21	
AL1 - 8	28.01.2022	398	221	96	5.28	4.84	22.23	19.90	10.47	10.47
					5.71		19.05		10.98	
					3.52		18.42		9.96	
Monthly Average		417	227	95		4.08		17.75		9.96
Standard Deviation		57	29	6		1.38		1.97		1.82

NS -Not Specified

**DCPL/DPT/20-21/21 - JANUARY -2022**

**Detox Corporation Pvt.Ltd.,Surat**

<b>Table 1 : Results of Air Pollutant Concentration at Marine Bhavan</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL1 - 1	04.01.2022	1	BQL	1.8	506
AL1 - 2	07.01.2022	1.15	BQL	1.8	1005
AL1 - 3	11.01.2022	1.39	BQL	1.8	568
AL1 - 4	12.01.2022	1.19	BQL	1.9	579
AL1 - 5	19.01.2022	1.24	BQL	1.8	652
AL1 - 6	21.01.2022	1.154	BQL	1.82	587
AL1 - 7	24.01.2022	1.163	BQL	1.83	665
AL1 - 8	28.01.2022	1.171	BQL	1.96	665
<b>Monthly Average</b>		<b>1.18</b>	<b>-</b>	<b>1.84</b>	<b>653</b>
<b>Standard Deviation</b>		<b>0.11</b>	<b>-</b>	<b>0.06</b>	<b>153</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS -Not Specified

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 417µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 227.0 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean 95.0 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.08 µg/ m<sup>3</sup>, 17.75 µg/ m<sup>3</sup> & 9.96 µg/ m<sup>3</sup> respectively. These were within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.18 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.84 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 2: Oil Jetty (AL2)**

**Table 2 : Results of Air Pollutant Concentration at Oil Jetty**

Table 2 : Results of Air Pollutant Concentration at Oil Jetty										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 µg/m3	60 µg/m3	-	80 µg/m3	-	80 µg/m3	-	400 µg/m3
AL2 - 1	04.01.2022	378	121	78	2.64	3.96	13.34	14.61	6.38	9.79
					4.40		12.07		10.21	
					4.84		18.42		12.76	
AL2 - 2	07.01.2022	551	283	101	1.32	3.08	12.70	13.13	8.93	7.83
					3.52		12.07		7.40	
					4.40		14.61		7.15	
AL2 - 3	11.01.2022	486	261	89	6.59	5.86	19.69	20.11	10.21	9.62
					5.28		18.42		9.96	
					5.71		22.23		8.68	
AL2 - 4	12.01.2022	557	300	108	5.28	4.98	13.97	16.09	6.13	8.42
					5.71		14.61		10.21	
					3.96		19.69		8.93	
AL2 - 5	19.01.2022	300	185	89	3.96	2.78	19.69	21.17	7.15	8.34
					1.76		22.87		9.19	
					2.64		20.96		8.68	
AL2 - 6	21.01.2022	362	249	92	6.59	4.98	18.42	15.24	6.64	8.76
					4.40		10.16		9.19	
					3.96		17.15		10.47	
AL2 - 7	24.01.2022	392	200	84	1.32	1.76	19.69	18.63	10.21	10.72
					1.76		15.24		11.49	
					2.20		20.96		10.47	
AL2 - 8	28.01.2022	474	253	100	2.64	2.93	13.34	15.24	6.89	8.25
					2.20		20.33		7.66	
					3.96		12.07		10.21	
Monthly Average		480	437	232	93		3.79		16.78	8.97
Standard Deviation		96	93	59	10		1.39		2.86	0.98

NS: Not Specified

**DCPL/DPT/20-21/21 - JANUARY -2022**

**Detox Corporation Pvt.Ltd.,Surat**

<b>Table 2B : Results of Air Pollutant Concentration at Oil Jetty</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL2 -1	04.01.2022	1.17	BQL	1.8	451
AL2 -2	07.01.2022	1.23	BQL	1.7	1020
AL2 -3	11.01.2022	1.08	BQL	1.8	552
AL2 -4	12.01.2022	1.26	BQL	2	648
AL2 - 5	19.01.2022	1.06	BQL	1.9	550
AL2 - 6	21.01.2022	1.26	BQL	1.76	530
AL2 -7	24.01.2022	1.18	BQL	1.89	677
AL2 - 8	28.01.2022	1.26	BQL	1.75	661
<b>Monthly Average</b>		<b>1.19</b>	<b>-</b>	<b>1.83</b>	<b>636</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.10</b>	<b>173</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS- Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Oil Jetty area was mainly by motor vehicle emission produced from various types of vehicles Oil Jetty Area. The mean TSPM values at Oil Jetty were 480 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 437 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 232 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit, The mean concentration of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.79 µg/m<sup>3</sup>, 16.78 µg/m<sup>3</sup> and 8.97 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.19 µg/m<sup>3</sup>. Well below the permissible limit of 5.0 µg/m<sup>3</sup>. , HC's were below the detectable limit and Carbon Monoxide concentration was 1.83 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



**Location 3: Kandla Colony - Estate Office (AL-3)**

Table 3 : Results of Air Pollutant Concentration at Estate Office										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 µg/m3	60 µg/m3	-	80 µg/m3	-	80 µg/m3	-	400 µg/m3
AL3 - 1	04.01.2022	259	141	85	1.76	2.93	22.23	20.33	8.93	10.21
					3.08		20.96		10.72	
					3.96		17.78		10.98	
AL3 - 2	07.01.2022	457	230	100	3.52	2.64	13.34	14.61	10.21	10.64
					2.64		13.97		10.72	
					1.76		16.51		10.98	
AL3 - 3	11.01.2022	413	180	98	4.84	4.10	13.34	18.00	8.93	7.49
					4.40		18.42		8.68	
					3.08		22.23		4.85	
AL3 - 4	12.01.2022	552	298	104	3.08	4.10	13.34	11.86	8.93	8.68
					4.40		12.07		9.70	
					4.84		10.16		7.40	
AL3 - 5	19.01.2022	440	220	99	4.40	4.84	22.23	18.21	10.47	8.68
					4.84		17.78		8.17	
					5.28		14.61		7.40	
AL3 - 6	21.01.2022	446	260	105	3.96	4.69	18.42	18.21	10.21	8.51
					4.84		15.24		7.91	
					5.28		20.96		7.40	
AL3 - 7	24.01.2022	395	193	96	3.52	4.25	12.70	15.03	10.47	10.64
					4.40		13.34		11.49	
					4.84		19.05		9.96	
AL3 - 8	28.01.2022	371	211	108	3.08	3.37	14.61	17.78	10.21	8.85
					4.84		19.05		8.93	
					2.20		19.69		7.40	
Monthly Average		417	217	99		3.86		16.75		9.21
Standard Deviation		84	48	7		0.80		2.70		1.15

NS: Not Specified

<b>Table 3B : Results of Air Pollutant Concentration at Kandla Port Colony</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC*</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL3 -1	04.01.2022	1.13	BQL	1.6	487
AL3 -2	07.01.2022	1.05	BQL	1.5	1560
AL3 -3	11.01.2022	1.01	BQL	1.7	683
AL3 -4	12.01.2022	1.23	BQL	1.89	576
AL3 - 5	19.01.2022	1.07	BQL	1.9	614
AL3 - 6	21.01.2022	1.019	BQL	2	540
AL3 - 7	24.01.2022	1.127	BQL	1.89	670
AL3 - 8	28.01.2022	1	BQL	2.03	621
<b>Monthly Average</b>		<b>1.08</b>	<b>-</b>	<b>1.81</b>	<b>719</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.19</b>	<b>346</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS- Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Kandla Port Colony was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Oil Jetty were 417µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 217 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 99.0 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.86µg/m<sup>3</sup>, 16.75 µg/m<sup>3</sup> and 9.21µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.08 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.81 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 4: Gopalpuri Hospital (AL-4)**

**Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital**

Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
Parameter	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 µg/m3	60 µg/m3	-	80 µg/m3	-	80 µg/m3	-	400 µg/m3
AL4 -1	04.01.2022	154	87	55	2.20	2.34	11.43	12.91	9.19	8.17
					1.76		12.07		7.91	
					3.08		13.34		7.40	
AL4 -2	07.01.2022	319	182	90	2.64	2.64	9.53	12.07	10.21	9.19
					2.20		11.43		8.93	
					3.08		10.16		8.42	
AL4 -3	11.01.2022	333	197	89	2.20	2.20	12.07	9.53	5.36	6.64
					3.08		8.26		6.64	
					1.32		9.53		7.91	
AL4 -4	12.01.2022	315	197	88	3.52	2.64	13.34	11.01	7.66	6.55
					2.64		12.07		6.64	
					1.76		8.26		5.36	
AL4 - 5	19.01.2022	220	124	80	2.64	2.78	14.61	14.61	7.91	7.15
					3.52		12.70		7.40	
					2.20		15.88		6.13	
AL4 - 6	21.01.2022	217	153	62	3.08	2.64	12.07	13.97	7.40	8.51
					2.64		9.53		7.66	
					2.20		13.34		10.47	
AL4 - 7	24.01.2022	182	97	79	3.96	3.08	19.69	17.36	7.91	7.74
					3.08		17.78		8.68	
					2.20		16.51		6.64	
AL4 - 8	28.01.2022	267	165	95	2.20	3.22	13.34	13.34	7.40	8.00
					3.52		15.24		8.68	
					3.96		12.07		7.91	
Monthly Average		251	142	87.0		2.69		12.68		7.74
Standard Deviation		54	48	2		0.34		2.62		0.92

NS: Not Specified

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<b>Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC*</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL4 -1	04.01.2022	1.16	BQL	1.72	588
AL4 -2	07.01.2022	1.14	BQL	1.63	998
AL4 -3	11.01.2022	1.28	BQL	1.8	640
AL4 -4	12.01.2022	1.12	BQL	1.81	581
AL4 - 5	19.01.2022	1.13	BQL	1.7	552
AL4 - 6	21.01.2022	1.04	BQL	1.66	604
AL4 - 7	24.01.2022	1.27	BQL	1.67	706
AL4 - 8	28.01.2022	1.05	BQL	1.58	632
<b>Monthly Average</b>		<b>1.15</b>	<b>-</b>	<b>1.70</b>	<b>663</b>
<b>Standard Deviation</b>		<b>0.09</b>	<b>-</b>	<b>0.08</b>	<b>143</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS-Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Oil Jetty were 251µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 142 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean= 87.0 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 2.69µg/m<sup>3</sup>, 12.68 µg/m<sup>3</sup> and 7.74 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.16 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.91 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

### Location 5: Coal Storage Area (AL-5)

**Table 5 : Results of Air Pollutant Concentration at Coal Storage Area**

Table 5 : Results of Air Pollutant Concentration at Coal Storage Area										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period	-	24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit	-	NS	100 µg/m3	60 µg/m3	-	80 µg/m3	-	80 µg/m3	-	400 µg/m3
AL5 - 1	04.01.2022	456	297	124	8.15	18.84	18.20	18.90	25.28	25.42
					8.58		18.90		25.42	
					9.00		19.60		25.55	
AL5 - 2	07.01.2022	424	225	108	3.96	3.81	19.69	19.90	11.49	11.49
					4.40		22.23		10.21	
					3.08		17.78		12.76	
AL5 - 3	11.01.2022	566	280	112	3.96	3.52	19.05	20.11	5.87	7.40
					3.52		19.69		6.13	
					3.08		21.60		10.21	
AL5 - 4	12.01.2022	599	256	109	2.20	3.22	16.51	18.84	9.96	10.38
					3.96		19.05		10.21	
					3.52		20.96		10.98	
AL5 - 5	19.01.2022	433	251	108	5.28	4.54	12.07	14.61	10.21	10.55
					5.71		12.70		10.47	
					2.64		19.05		10.98	
AL5 - 6	21.01.2022	502	277	123	3.52	2.93	13.34	16.09	10.72	11.49
					3.08		15.88		10.98	
					2.20		19.05		12.76	
AL5 - 7	24.01.2022	403	236	103	3.52	4.25	16.51	16.30	9.96	9.02
					4.84		19.05		9.19	
					4.40		13.34		7.91	
AL5 - 8	28.01.2022	487	293	104	3.08	3.81	16.51	13.34	10.21	11.15
					3.96		12.07		11.49	
					4.40		11.43		11.74	
Monthly Average		484	264	111		5.62		17.26		12.11
Standard Deviation		70	26	8		5.37		2.54		5.55

NS: Not Specified

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<b>Table 6 : Results of Air Pollutant Concentration at Coal Storage Area</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC*</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL5 - 1	04.01.2022	1.21	BQL	1.8	360
AL5 - 2	07.01.2022	1.21	BQL	1.6	1024
AL5 - 3	11.01.2022	1.23	BQL	1.9	586
AL5 - 4	12.01.2022	1.1	BQL	1.80	572
AL5 - 5	19.01.2022	1.2	BQL	1.9	556
AL5 - 6	21.01.2022	1.19	BQL	1.82	499
AL5 - 7	24.01.2022	1.2	BQL	1.77	739
AL5 - 8	28.01.2022	1.22	BQL	1.4	618
<b>Monthly Average</b>		<b>1.19</b>	<b>-</b>	<b>1.75</b>	<b>619</b>
<b>Standard Deviation</b>		<b>0.04</b>	<b>-</b>	<b>0.17</b>	<b>195</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS-Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 484 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 264 µg/m<sup>3</sup>, which is well above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 111 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 5.62 µg/m<sup>3</sup>, 17.26 µg/m<sup>3</sup> and 12.11 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.19 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.75 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



**Location 6: Tuna Port (AL-6)**

Table 6 : Results of Air Pollutant Concentration at Tuna Port										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 µg/m3	60 µg/m3	-	80 µg/m3	-	80 µg/m3	-	400 µg/m3
AL6 -1	04.01.2022	283	132	57	2.64	2.93	15.88	15.88	10.21	9.62
					3.52		15.24		10.47	
					2.64		16.51		8.17	
AL6 - 2	07.01.2022	335	174	67	3.96	3.81	19.69	19.90	11.49	11.49
					4.40		22.23		10.21	
					3.08		17.78		12.76	
AL6 - 3	11.01.2022	338	161	72	3.96	3.52	19.05	20.11	5.87	7.40
					3.52		19.69		6.13	
					3.08		21.60		10.21	
AL6 - 4	12.01.2022	454	248	105	2.20	3.22	16.51	18.84	9.96	10.38
					3.96		19.05		10.21	
					3.52		20.96		10.98	
AL6 - 5	19.01.2022	362	204	98	5.28	4.54	12.07	14.61	10.21	10.55
					5.71		12.70		10.47	
					2.64		19.05		10.98	
AL6 - 6	21.01.2022	304	166	80	3.52	2.93	13.34	16.09	10.72	11.49
					3.08		15.88		10.98	
					2.20		19.05		12.76	
AL6 - 7	24.01.2022	310	150	62	3.52	4.25	16.51	16.30	9.96	9.02
					4.84		19.05		9.19	
					4.40		13.34		7.91	
AL6 - 8	28.01.2022	400	237	92	3.08	3.81	16.51	13.34	10.21	11.15
					3.96		12.07		11.49	
					4.40		11.43		11.74	
Monthly Average		348	184	79		3.63		16.88		10.14
Standard Deviation		70	32	9		0.59		2.48		1.41

NS: Not Specified

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<b>Table 6B : Results of Air Pollutant Concentration at Tuna Port</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC*</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL6 -1	04.01.2022	1.1	BQL	1.72	590
AL6 -1	04.01.2022	1.1	BQL	1.72	590
AL6 -2	07.01.2022	1.03	BQL	1.8	1063
AL6 -3	11.01.2022	BQL	BQL	1.9	569
AL6 -4	12.01.2022	1.17	BQL	1.9	574
AL6 -5	19.01.2022	1.08	BQL	1.81	542
AL6 -6	21.01.2022	1.13	BQL	1.9	669
AL6 -7	24.01.2022	1.16	BQL	1.69	759
AL6 -8	28.01.2022	1.11	BQL	1.53	670
<b>Monthly Average</b>		<b>1.11</b>	<b>-</b>	<b>1.78</b>	<b>680</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.13</b>	<b>171</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS- Not Specified

The mean TSPM values at Tuna Port were 348µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 184 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 79 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.63 µg/m<sup>3</sup>, 16.88 µg/m<sup>3</sup> and 10.14 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.11 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.78 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 7: Signal Building (Vadinar) (AL-7)**

**Table 7 : Results of Air Pollutant Concentration at Signal Building**

Table 7 : Results of Air Pollutant Concentration at Signal Building										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 µg/m3	60 µg/m3	-	80 µg/m3	-	80 µg/m3	-	400 µg/m3
AL7 -1	04.01.2022	130	82	47	5.28	3.81	19.69	18.84	7.91	7.74
					2.20		20.96		8.42	
					3.96		15.88		6.89	
AL7 -2	07.01.2022	202	111	84	1.76	2.49	19.69	19.05	9.19	9.10
					2.64		20.96		10.21	
					3.08		16.51		7.91	
AL7 -3	11.01.2022	174	91	73	3.96	2.64	13.34	14.82	5.11	6.21
					1.76		20.96		5.87	
					2.20		10.16		7.66	
AL7 -4	12.01.2022	154	84	65	3.52	3.08	14.61	12.28	7.66	7.32
					3.08		12.07		10.21	
					2.64		10.16		4.08	
AL7 -5	19.01.2022	122	72	47	4.40	2.93	12.07	11.01	5.36	7.23
					2.64		10.16		7.91	
					1.76		10.80		8.42	
AL7 -6	21.01.2022	210	120	85	5.28	5.86	16.51	17.15	8.42	8.00
					5.71		15.24		8.17	
					6.59		19.69		7.40	
AL7 -7	24.01.2022	151	81	66	3.52	3.08	12.07	15.67	9.19	8.76
					3.08		17.15		9.96	
					2.64		17.78		7.15	
AL7 -8	28.01.2022	173	100	61	1.76	2.49	12.07	14.82	5.62	5.36
					2.64		20.96		4.60	
					3.08		11.43		5.87	
Monthly Average		164	93	66		3		15		7
Standard Deviation		31	16	15		1		3		1

NS: Not Specified

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<b>Table 7B : Results of Air Pollutant Concentration at Signal Building</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC*</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL7 -1	04.01.2022	1.46	BQL	1.66	403
AL7 - 2	07.01.2022	1.12	BQL	1.72	224
AL7 - 3	11.01.2022	1.26	BQL	1.57	369
AL7 - 4	12.01.2022	1.13	BQL	2.12	551
AL7 - 5	19.01.2022	1.12	BQL	2.02	607
AL7 - 6	21.01.2022	1.03	BQL	1.66	314
AL7 - 7	24.01.2022	1.03	BQL	1.77	326
AL7 - 8	28.01.2022	1.18	BQL	1.82	365
<b>Monthly Average</b>		<b>1.17</b>	<b>-</b>	<b>1.79</b>	<b>395</b>
<b>Standard Deviation</b>		<b>0.14</b>	<b>-</b>	<b>0.19</b>	<b>126</b>

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS Not Specified

The mean TSPM values at Vadinar Port were 164 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 93 µg/m<sup>3</sup>, which is below the permissible limit. PM<sub>2.5</sub> values were also within the permissible limit (mean = 66 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.0 µg/m<sup>3</sup>, 15.0 µg/m<sup>3</sup> and 7.0 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.17 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.79 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 8: Admin Building (Vadinar) (AL-8)

Table 8 : Results of Air Pollutant Concentration at Admin Building										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 µg/m3	60 µg/m3	-	80 µg/m3	-	80 µg/m3	-	400 µg/m3
AL8 -1	04.01.2022	163	100	58	3.52	3.96	11.43	13.13	7.91	7.32
					3.96		13.34		6.64	
					4.40		14.61		7.40	
AL8 -2	07.01.2022	172	104	61	5.28	5.86	22.87	17.57	5.87	7.57
					5.71		17.78		7.91	
					6.59		12.07		8.93	
AL8 -3	11.01.2022	192	108	78	2.64	2.05	11.43	17.15	6.38	8.42
					2.20		22.87		10.4 7	
					1.32		17.15		8.42	
AL8 -4	12.01.2022	153	92	54	3.52	4.54	19.69	15.24	7.91	5.79
					4.84		14.61		4.08	
					5.28		11.43		5.36	
AL8 -5	19.01.2022	144	95	46	5.71	3.66	13.34	15.67	7.91	8.17
					2.20		19.69		9.19	
					3.08		13.97		7.40	
AL8 -6	21.01.2022	162	97	55	3.08	3.52	13.34	15.03	5.36	5.36
					2.64		12.70		4.85	
					4.84		19.05		5.87	
AL8 -5	24.01.2022	186	101	76	1.76	3.52	14.61	17.36	10.2 1	9.45
					2.64		16.51		10.4 7	
					6.15		20.96		7.66	
AL8-6	28.01.2022	138	83	47	3.52	2.34	19.05	19.05	7.40	6.21
					2.20		19.69		6.38	
					1.32		18.42		4.85	
Monthly Average		164	97	60		4		16		7
Standard Deviation		19	8	12		1		2		1

NS: Not Specified

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<b>Table 8B : Results of Air Pollutant Concentration at Admin Building</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC*</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL8 -1	04.01.2022	1.63	BQL	1.68	452
AL8-2	07.01.2022	1.17	BQL	1.71	337
AL8 -3	11.01.2022	1.23	BQL	1.6	391
AL8-4	12.01.2022	1.01	BQL	1.94	542
AL8 -5	19.01.2022	1.23	BQL	2	530
AL8-6	21.01.2022	1.02	BQL	1.59	305
AL8-7	24.01.2022	1.14	BQL	1.91	344
AL8-8	28.01.2022	1.18	BQL	1.86	356
<b>Monthly Average</b>		<b>1.20</b>	<b>-</b>	<b>1.79</b>	<b>407</b>
<b>Standard Deviation</b>		<b>0.19</b>	<b>-</b>	<b>0.16</b>	<b>91</b>

\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

NS-Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Admin Building Vadinar was comparatively low among all the locations of Air Quality monitoring in Kandla Port and Vadinar Port. The mean TSPM values at Vadinar Port were 164 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 97 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 60.0 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.0µg/m<sup>3</sup>, 16.0µg/m<sup>3</sup> and 7.0µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Admin Building, Vadinar Port. The mean Benzene concentration was 1.20 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.79 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



#### **1.4 Observations and Conclusion**

During the monitoring period, the overall Ambient Air Quality of the port area was found to be well within the desired levels for various gaseous pollutants. However, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan, Estate Office, Tuna Port and Oil Jetty area.

# **Drinking Water Monitoring**

## **2. Drinking Water Quality Monitoring**

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

### **2.1 Drinking Water Monitoring Methodology**

Drinking water samples were collected from 20 locations as prescribed in the tender document. Samples for physico-chemical analysis were collected in 1 liter carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling and Analysis was done as per standard methods - IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate , Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (cfu) .

### **2.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 9 to Table No. 15

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**Table 9: Drinking Water Quality Monitoring Parameters for Nirman Building 1, P & C building & Main Gate (North) at Kandla**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C building	Main Gate North	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.3	7.4	7.5	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1050	1070	1020	500	2000
3	Turbidity	NTU	0	1	1	1.0	5.0
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	Hazen Units	Colorless	Colorless	Colorless	5.0	15.0
6	Conductivity	µs/cm	1920	1956	1895	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	481.07	466.04	516.15	250.0	1000.0
9	Ca as Ca	mg/l	60.12	56.11	52.10	75.0	200.0
10	Mg as Mg	mg/l	75.33	70.47	77.76	30.0	100.0
11	Total Hardness	mg/l	460	430	450	200.0	600.0
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.42	0.49	0.35	1.0	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	265.2	273.6	277.2	200.0	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	6.90	8.52	8.87	45.0	No Relaxation
17	Salinity	%	0.87	0.84	0.93	NS*	NS*
18	Sodium as Na	mg/l	302	294	302	NS*	NS*
19	Potassium as K	mg/l	4.40	4.03	4.68	NS*	NS*
20	Manganese	mg/l	<0.04	<0.04	<0.04	0.1	0.3
21	Hexavalent Chromium	mg/l	<0.03	<0.03	<0.03	NS*	NS*
22	Copper	mg/l	<0.05	<0.05	<0.05	0.05	1.5
23	Cadmium	mg/l	<0.002	<0.002	<0.002	0.003	0.003
24	Arsenic	mg/l	<0.01	<0.01	<0.01	0.01	0.05
25	Mercury	mg/l	<0.001	<0.001	<0.001	0.001	0.001
26	Lead	mg/l	<0.01	<0.01	<0.01	0.01	0.01
27	Zinc	mg/l	<0.1	<0.1	<0.1	5.0	15.0
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BODZinc-0.02-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 10: Drinking Water Quality Monitoring Parameters for Canteen, West Gate - I & Wharf Area at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate - I	Wharf Area	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.1	7.4	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1120	950	1020	500	2000
3	Turbidity	NTU	0	1	1	1.0	5.0
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	Hazen Units	Colorless	Colorless	Colorless	5.0	15.0
6	Conductivity	µs/cm	2120	1723	1562	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	526.17	491.09	486.08	250.0	1000.0
9	Ca as Ca	mg/l	48.10	60.12	56.11	75.0	200.0
10	Mg as Mg	mg/l	72.90	63.18	72.90	30.0	100.0
11	Total Hardness	mg/l	420	410	440	200.0	600.0
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.28	0.34	0.56	1.0	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	222.0	235.2	252.0	200.0	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	9.50	10.28	8.73	45.0	No Relaxation
17	Salinity	%	0.95	0.89	0.88	NS*	NS*
18	Sodium as Na	mg/l	281	293	308	NS*	NS*
19	Potassium as K	mg/l	5.15	5.04	5.49	NS*	NS*
20	Manganese	mg/l	<0.04	<0.04	<0.04	0.1	0.3
21	Hexavalent Chromium	mg/l	<0.03	<0.03	<0.03	NS*	NS*
22	Copper	mg/l	<0.05	<0.05	<0.05	0.05	1.5
23	Cadmium	mg/l	<0.002	<0.002	<0.002	0.003	0.003
24	Arsenic	mg/l	<0.01	<0.01	<0.01	0.01	0.05
25	Mercury	mg/l	<0.001	<0.001	<0.001	0.001	0.001
26	Lead	mg/l	<0.01	<0.01	<0.01	0.01	0.01
27	Zinc	mg/l	<0.1	<0.1	<0.1	5.0	15.0
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 11: Drinking Water Quality Monitoring Parameters for Sewa sadan - 3, Workshop I & Custom Building at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan - 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.4	7.2	7.4	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1010	1120	1910	500	2000
3	Turbidity	NTU	0	0	1	1.0	5.0
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	Hazen Units	Colorless	Colorless	Colorless	5.0	15.0
6	Conductivity	µs/cm	1498	2050	2630	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	541.20	556.24	521.16	250.0	1000.0
9	Ca as Ca	mg/l	64.13	72.14	76.15	75.0	200.0
10	Mg as Mg	mg/l	70.47	70.47	70.47	30.0	100.0
11	Total Hardness	mg/l	450	470	480	200.0	600.0
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.67	0.78	0.52	1.0	1.5
14	Sulphate	mg/l	255.6	262.8	211.2	200.0	400
15	Nitrite	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate	mg/l	12.32	11.40	12.74	45.0	No Relaxation
17	Salinity	%	0.98	1.00	0.94	NS*	NS*
18	Sodium as Na	mg/l	297	319	318	NS*	NS*
19	Potassium as K	mg/l	4.28	2.53	5.78	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5.0	15.0
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



**Table 12: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla & A.O. Building at Gandhidham**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.6	7.3	7.4	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1020	940	950	500	2000
3	Turbidity	NTU	0	1	1	1.0	5.0
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	Hazen Units	Colorless	Colorless	Colorless	5.0	15.0
6	Conductivity	µs/cm	1920	1730	1689	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	511.14	496.10	526.17	250.0	1000.0
9	Ca as Ca	mg/l	64.13	48.10	52.10	75.0	200.0
10	Mg as Mg	mg/l	70.47	75.33	68.04	30.0	100.0
11	Total Hardness	mg/l	450	430	410	200.0	600.0
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.57	0.72	0.81	1.0	1.5
14	Sulphate	mg/l	219.6	231.6	283.2	200.0	400
15	Nitrite	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate	mg/l	12.60	13.52	10.28	45.0	No Relaxation
17	Salinity	%	0.92	0.90	0.95	NS*	NS*
18	Sodium as Na	mg/l	293	301	290	NS*	NS*
19	Potassium as K	mg/l	4.30	5.13	4.68	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5.0	15.0
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 13: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House & E - Type Quarter at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	School Gopalpuri	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.6	7.5	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1000	1390	1410	500	2000
3	Turbidity	NTU	0	0	0	1.0	5.0
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	Hazen Units	Colorless	Colorless	Colorless	5.0	15.0
6	Conductivity	µs/cm	1860	2550	2710	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	536.19	491.09	561.25	250.0	1000.0
9	Ca as Ca	mg/l	56.11	60.12	64.13	75.0	200.0
10	Mg as Mg	mg/l	68.04	58.32	65.61	30.0	100.0
11	Total Hardness	mg/l	420	390	430	200.0	600.0
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.75	0.65	0.63	1.0	1.5
14	Sulphate	mg/l	268.8	289.2	219.6	200.0	400
15	Nitrite	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate	mg/l	10.63	12.04	11.62	45.0	No Relaxation
17	Salinity	%	0.97	0.89	1.01	NS*	NS*
18	Sodium as Na	mg/l	294	284	197	NS*	NS*
19	Potassium as K	mg/l	4.98	4.76	1.49	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5.0	15.0
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 14: Drinking Water Quality Monitoring Parameters for F - Type Quarter, Hospital Gopalpuri & Tuna Port**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.7	7.5	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1100	1200	760	500	2000
3	Turbidity	NTU	0	1	0	1.0	5.0
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	Hazen Unit	Colorless	Colorless	Colorless	5.0	15.0
6	Conductivity	µs/cm	2130	2270	1350	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	516.15	571.27	546.21426	250.0	1000.0
9	Ca as Ca	mg/l	68.14	56.11	52.10	75.0	200.0
10	Mg as Mg	mg/l	58.32	72.90	70.47	30.0	100.0
11	Total Hardness	mg/l	410	440	420	200.0	600.0
12	Iron as Fe+3	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.56	0.79	0.84	1.0	1.5
14	Sulphate	mg/l	230.4	211.2	259.2	200.0	400
15	Nitrite	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate	mg/l	10.21	9.22	11.33	45.0	No Relaxation
17	Salinity	%	0.93	1.03	0.99	NS*	NS*
18	Sodium as Na	mg/l	294	302	292	NS*	NS*
19	Potassium as K	mg/l	4.28	4.79	4.82	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5.0	15.0
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 15: Drinking Water Quality Monitoring Parameters for Vadinar Jetty & Port Colony at Vadinar**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.2	7.4	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	940	980	500	2000
3	Turbidity	NTU	0.00	1.00	1.0	5.0
4	Odor	-	Odorless	Odorless	Agreeable	Agreeable
5	Color	Hazen Units	Colorless	Colorless	5.0	15.0
6	Conductivity	µs/cm	1730	1690	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride	mg/l	471.05	481.07	250.0	1000.0
9	Ca as Ca	mg/l	64.13	60.12	75.0	200.0
10	Mg as Mg	mg/l	72.90	72.90	30.0	100.0
11	Total Hardness	mg/l	460	450	200.0	600.0
12	Iron as Fe+3	mg/l	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.86	0.92	1.0	1.5
14	Sulphate	mg/l	26.76	25.32	200.0	400
15	Nitrite	mg/l	BQL	BQL	NS*	NS*
16	Nitrate	mg/l	9.22	9.99	45.0	No Relaxation
17	Salinity	%	0.85	0.87	NS*	NS*
18	Sodium as Na	mg/l	54.6	42.2	NS*	NS*
19	Potassium as K	mg/l	3.2	2.8	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	5.0	15.0
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,  
BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **2.3 Results & Discussion**

The colour of all drinking water samples was <5 Hazen unit and odour of the samples was also agreeable. All parameters are found to be within the specified limit of the Drinking water Standard.

#### **pH**

The limit of pH value for drinking water is specified as 6.5 to 8.5. pH value in the studied area varied from 7.3 to 7.8 pH unit. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Total Dissolved Solids (TDS)**

TDS values in the studied area varied between 1020 -1850 mg/l. None of the sampling points showed higher TDS values than the prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of January ranged from 2000-3670  $\mu\text{S}/\text{cm}$ . Electrical conductivity standards do not appear in BIS standards for drinking water.

#### **BOD**

BOD value in the studied area was found Below Quantification Limit (2.0 mg/l). Indian standards does not show any standard values for BOD in drinking water.

#### **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. Chloride value in the studied area varied between 320.7-821.8 mg/l and is found to be within the Permissible limit of the Drinking Water Standard.

### **Calcium**

Calcium value in the studied area varied between 40.08 - 80.1 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. If calcium is present beyond the maximum acceptable limit, it causes incrustation of pipes.

### **Magnesium**

Magnesium value in the studied area varied between 60.75-99.63 mg/l. All the locations had Magnesium within the prescribed limits of 30-100 mg/L.

### **Total Hardness**

Hardness value in the studied area varied between 260-410 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. The prescribed limit by Indian Standards is 200-600 mg/L.

### **Iron**

Iron value in the studied area was found Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards is 0.3 mg/L. The excess amount of iron causes slight toxicity; gives stringent taste to water.

### **Fluoride**

Fluoride value in the studied area varied between 0.1 - 0.8 mg/l and hence well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphates**

Sulphate value in the studied area varied between 164.4 - 336 mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

Nitrite values in all the water samples were found Below Quantification Limit (0.1 mg/l). There are no specified standard values for Nitrites in Drinking water. The minimum Nitrate value in drinking water of KPT was 0.0038 mg/l which is well within the permissible limit of the Drinking water Standard.



### **Salinity**

Salinity in drinking water in the present samples collected ranged from 0.5 to 1.4%. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected ranged from 162 - 301 mg/l and Potassium salts ranged from 2.18 to 4.23 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter at all location shows that Bacteria is not present and hence Bacterial count is in line with the permissible limit of drinking water. This shows that all the drinking water samples were safe from any bacteriological contamination.

## **2.4 Conclusions**

These results are compared with acceptable limits as prescribed in IS 10500:2012 - Drinking Water Specification. It is seen from the analysis data that during the study period the water was safe for human consumption at all drinking water monitoring stations.

# Noise Quality Monitoring

### 3. Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

#### 3.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

#### 3.2 Results

Table 16: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	6:00 am to 10:00 PM	10:00PM to 6:00 AM
1	Marine Bhavan	70.6	67.7
2	Nirman Building 1	57.2	61.6
3	Tuna Port	65.5	55.0
4	Main Gate North	58.2	61.4
5	West Gate I	68.9	64.1
6	Canteen Area	57	60.5
7	Main Road	64.2	61.3
8	ATM Building	69.5	69.7
9	Wharf Area /Jetty Area	71.6	71.6
10	Port & Custom Office	74.3	59.3

#### Vadinar Port

11	Entrance Gate of Vadinar Port	48.6	48.5
12	Nr. Port Colony, Vadinar	55.1	54.3
13	Nr. Vadinar Jetty	58.0	57.4

### **3.3 Conclusions**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Average Noise Level (SPL) in all 13 locations at Deendayal Port ranged from 48.6 dB(A) to 74.3 dB(A) and it was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from 48.5 dB to 71.6 dB(A) and it was within the permissible limits of 70 dB(A) for the industrial area for the night time.

# **Soil Quality Monitoring**

#### **4. Soil Monitoring**

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

##### **4.1 Methodology**

The soil samples were collected in the month of January 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.



## 4.2 Results

**Table-17: Chemical Characteristics of Soil in the Study Area**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	KPT Admin Site	KPT Colony
			Near main gate of Port	10 m away from main gate	Sand from creek at low tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	7.46	8.23	8.92	8.71	7.97	7.58
3	Electrical Conductivity	µs/cm	12,520.0	18,150.0	14,555.0	15,330.0	209.0	341.0
4	Moisture	%	14.27	24.86	16.34	23.84	7.24	3.24
5	Total Organic Carbon	%	0.44	1.11	0.54	1.15	0.48	0.94
6	Alkalinity	mg/kg	40.04	60.06	60.06	100.10	60.06	60.06
7	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
8	Chloride	mg/kg	1,404.0	450.0	494.0	578.0	17.0	25.5
9	Sulphate	mg/kg	1,808.0	2,294.0	7,317.0	1,106.0	20.22	19.5
10	Phosphorus	mg/kg	50.25	15.69	8.49	9.11	5.17	6.45
11	Potassium	mg/kg	154.0	139.0	149.0	107.0	5.9	22.2
12	Sodium	mg/kg	2,201.0	1,248.0	1,094.0	809.0	13.5	24.4
13	Calcium	mg/kg	153.00	139.00	149.00	106.00	941.88	180.36
14	Copper as Cu	mg/kg	20.90	45.10	21.60	64.60	78.9	51.1
15	Lead as Pb	mg/kg	8.80	23.50	9.00	23.80	BQL	7.10
16	Nickel as Ni	mg/kg	41.90	18.10	41.50	39.80	37.9	22.50
17	Zinc as Zn	mg/kg	50.30	191.60	49.8	100.00	46.50	50.00
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg).

#### **4.3 Discussion**

The data shows that value of pH ranges from 7.46 at IFFCO Plant to 8.92 at Khori Creek indicating that all soil samples are neutral to slight basic. Iffco Plant samples showed maximum conductivity of 18150.0  $\mu\text{mhos/cm}$ , while Tuna Port location showed minimum conductivity of 12520.0  $\mu\text{mhos/cm}$ . Conductivity at Vadinar Port was 209.0 and 341.0  $\mu\text{mhos/cm}$  at Admin site and Vadinar Port colony respectively.

Total organic Carbon ranged from 0.44 % to 1.15 at Deendayal Port. At Vadinar Port, organic carbon content ranged from 0.48 % to 0.94 %.

The concentration of Phosphorus and Potassium in the soil samples varies from 8.49 to 50.25 mg/kg and 107 to 154 mg/kg respectively at Deendayal Port. The mean concentration of Phosphorous at Vadinar site was 5.81 mg/kg and mean concentration of Potassium at Vadinar site was 14.04 mg/kg.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) are of saline nature as they are coastal soil; where as other locations are inland locations and have different chemical properties.

#### **Heavy Metals in the Soil**

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

#### **4.4 Conclusion**

The soils of Deendayal Port and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

# **Sewage Treatment Quality Monitoring**

## 5. Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guide lines of State Pollution Control Board and other statutory bodies.

### 5.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

### 5.2 Results

#### Kandla STP

**Table 18: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

Date of Sampling		02.01.2022		
Sr. No.	Parameters	Unit	Results	
			KPT STP I/L	KPT STP O/L
1	pH	pH unit	7.7	7.5
2	Total Suspended Solids	mg/l	177.8	57.9
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	404.0	132.0
5	BOD @ 27 °C	mg/l	132.0	38.0
6.	Fecal Coliform	MPN Index / 100 ml	-	540.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	27.0	
8.	MLVSS	%	84.0	

**Table 19: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

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<b>Date of Sampling</b>	11.01.2022
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Sr. No.	Parameters	Unit	Results	
			KPT STP I/L	KPT STP O/L
1	pH	pH unit	7.68	7.46
2	Total Suspended Solids	mg/l	154.2	81.5
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	404	102.0
5	BOD @ 27 °C	mg/l	130.0	30.0
6.	Fecal Coliform	MPN Index / 100 ml	-	26.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	439.0	
8.	MLVSS	%	ND	

**Table 20: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	19.01.2022
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Sr. No.	Parameters	Unit	Results	
			KPT STP I/L	KPT STP O/L
1	pH	pH unit	7.54	7.31
2	Total Suspended Solids	mg/l	162.4	76.5
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	353.5	212.1
5	BOD @ 27 °C	mg/l	60.0	20.0
6.	Fecal Coliform	MPN Index / 100 ml	-	63.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	374.0	
8.	MLVSS	%	ND	

**Table 21: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

Date of Sampling		24.01.2022		
Sr. No.	Parameters	Unit	Results	
			KPT STP I/L	KPT STP O/L
1	pH	pH unit	7.6	7.4
2	Total Suspended Solids	mg/l	195.4	99.6
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	232.3	101
5	BOD @ 27 °C	mg/l	77.0	28.0
6.	Fecal Coliform	MPN Index / 100 ml	-	110.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	238.0	
8	MLVSS	%	ND	

### Gopalpuri Colony STP

**Table 22: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

Date of Sampling		02.01.2022		
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Sr. No.	Parameters	Unit	Results	
			Gopalpuri STP I/L	Gopalpuri STP O/L
1	pH	pH unit	7.76	7.34
2	Total Suspended Solids	mg/l	212.4	82.8
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	434.0	152.0
5	BOD @ 27 °C	mg/l	138.0	48.0
6.	Fecal Coliform	MPN Index / 100 ml	-	79.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	37.0	
8	MLVSS	%	87.0	



**Table 23: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	11.01.2022
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Sr. No.	Parameters	Unit	Results	
			Gopalpuri STP I/L	Gopalpuri STP O/L
1	pH	pH unit	7.5	7.3
2	Total Suspended Solids	mg/l	220.4	95.1
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	383.8	102
5	BOD @ 27 °C	mg/l	126.0	32.0
6.	Fecal Coliform	MPN Index / 100 ml	-	21.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	32.0	
8	MLVSS	%	84.0	

**Table 24: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	19.01.2022
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Sr. No.	Parameters	Unit	Results	
			Gopalpuri STP I/L	Gopalpuri STP O/L
1	pH	pH unit	7.46	7.21
2	Total Suspended Solids	mg/l	184.8	86.1
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	373.7	110
5	BOD @ 27 °C	mg/l	120.0	28.0
6.	Fecal Coliform	MPN Index / 100 ml	-	70.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	9.0	
8	MLVSS	%	86.0	

**Table 25: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	24.01.2022
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Sr. No.	Parameters	Unit	Results	
			Gopalpuri STP I/L	Gopalpuri STP O/L
1	pH	pH unit	7.51	7.36
2	Total Suspended Solids	mg/l	264.2	90.1
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	202	111.1
5	BOD @ 27 °C	mg/l	58.0	30.0
6.	Fecal Coliform	MPN Index / 100 ml	-	220.0
<b>Aeration Tank</b>				
7.	MLSS	mg/l	22.0	
8.	MLVSS	%	ND	

### **Vadinar STP**

**Table 26: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	02.01.2022
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Sr. No.	Parameters	Unit	Results	
			Vadinar STP I/L	Vadinar O/L
1	pH	pH unit	7.4	7.2
2	Total Suspended Solids	mg/l	110.5	61.1
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	353.5	101
5	BOD @ 27 °C	mg/l	110.0	28.0

**Table 27: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>		11.01.2022		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>Vadinar STP I/L</b>	<b>Vadinar O/L</b>
1	pH	pH unit	7.46	7.32
2	Total Suspended Solids	mg/l	110	59.3
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	364.0	112.0
5	BOD @ 27 °C	mg/l	120.0	30.0

**Table 28: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>		19.01.2022		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>Vadinar STP I/L</b>	<b>Vadinar O/L</b>
1	pH	pH unit	7.7	7.5
2	Total Suspended Solids	mg/l	105	38
3	Residual Chlorine	mg/l		<0.5
4	COD	mg/l	161.6	70.7
5	BOD @ 27 °C	mg/l	52.0	18.0

**Table 29: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

Date of Sampling		24.01.2022		
Sr. No.	Parameters	Unit	Results	
			Vadinar STP I/L	Vadinar O/L
1	pH	pH unit	7.71	7.43
2	Total Suspended Solids	mg/l	102.9	42.5
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	152	61
5	BOD @ 27 °C	mg/l	48.0	18.0

**5.3 Conclusions:**

The GPCB standards of BOD, TSS and Residual Chlorine for STP outlet are 20 mg/lit, 30 mg/lit & 0.5 mg/lit respectively. It is suggested to do treatment on regular basis to avoid flow of contaminated/polluted water into the sea.

# **Marine Water Quality Monitoring**

## **Marine Water Monitoring**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of 'green thinking'. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A(g) states that the "fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures".

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at "integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources." The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

## **Marine Environment**

On national and state levels, we have several policies and regulation like Water (Prevention and Control of Pollution) Act, 1974, to regulate pollution discharges and restore water quality of our aquatic resources including the prescription of monitoring activities. One of the important provisions of the Water Act, 1974, is to maintain and restore the 'wholesomeness' of our aquatic resources. Water quality monitoring is one of the first steps required in the rational development and management of water resources. In the field of water quality management, there has been a steady evolution in procedures for designing system to obtain information on the changes of water quality. The monitoring comprises all activities to obtain 'information' with respect to the water system.



## **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 03<sup>rd</sup> & 04<sup>th</sup> January-2022 in harbor regions of KPT and on 03<sup>rd</sup> January-2022 at Vadinar during spring tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 10<sup>th</sup> & 11<sup>th</sup> January 2022 in harbor regions of KPT. 10<sup>th</sup> January -2022 in Vadinar during Neap tide period first quarter of Lunar Cycle..

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and two stations in Nakti creek and one station in Khori creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

## **Sampling Locations**

<b>Offshore monitoring requirement</b>	<b>Number of locations</b>
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khori creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### **5.4 Marine Water Quality**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality and Marine sediments are as below;

**Table 30: Marine Water Quality Monitoring Parameters for location near KPT colony**

Sr. No.	Parameters	Unit	Kandla Creek Near KPT colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.23	7.36	7.41	7.36
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.6	31.5	32.2	32.0
5	Turbidity	NTU	30	26	32	28
6	Total Dissolved Solids	mg/l	13377	15123	18967.0	20788.0
7	Total Suspended Solids	mg/l	560	709	602	670
8	Total Solids	mg/l	14110	15920	19620.0	21526.0
9	DO	mg/l	4.3	4.5	4.5	4.6
10	COD	mg/l	82.0	86.0	82.0	86.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.64	0.75	0.78	0.71
13	Phosphate	mg/l	0.24	0.20	0.22	0.22
14	Sulphate	mg/l	2652	2172	2544	2304
15	Nitrate	mg/l	2.89	3.38	2.75	2.89
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	601.20	521.04	561.12	601.2
18	Magnesium	mg/l	1652.4	1725.3	1749.6	1676.7
19	Sodium	mg/l	9468.0	8936.0	9525.0	8978.0
20	Potassium	mg/l	362.0	326.0	375.0	311.0
21	Iron	mg/l	1.09	BQL	0.66	3.41
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 31: Marine Water Quality Monitoring Parameters for location near passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2) 23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.29	7.31	7.51	7.46
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32.0	32.5	31.6	31.1
5	Turbidity	NTU	32	28	36	27
6	Total Dissolved Solids	mg/l	28697	11321	27998.0	14910.0
7	Total Suspended Solids	mg/l	610	757	563	679
8	Total Solids	mg/l	29350	12100	28642.0	15666.0
9	DO	mg/l	4.4	4.9	4.4	4.2
10	COD	mg/l	78.0	80.0	88.0	92.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.93	1.00	0.93	0.96
13	Phosphate	mg/l	0.18	0.19	0.19	0.20
14	Sulphate	mg/l	2544	1836	2232	2340
15	Nitrate	mg/l	2.75	2.46	3.17	3.38
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	561.12	480.96	521.04	480.96
18	Magnesium	mg/l	1628.1	1652.4	1701	1676.7
19	Sodium	mg/l	9249.0	8814.0	9634.0	8912.0
20	Potassium	mg/l	368.0	318.0	384.0	314.0
21	Iron	mg/l	BQL	BQL	1.94	0.11
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Nitrite: 0.05mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 32: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.40	7.45	7.3	7.26
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32.0	31.4	32.0	31.7
5	Turbidity	NTU	32	36	34	33
6	Total Dissolved Solids	mg/l	26387	32722	21814.0	31669.0
7	Total Suspended Solids	mg/l	570	744	599	790
8	Total Solids	mg/l	26980	33500	22496.0	32560.0
9	DO	mg/l	4.8	4.6	4.1	4
10	COD	mg/l	82.0	88.0	70.0	76.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.65	0.60	0.89	0.82
13	Phosphate	mg/l	0.17	0.17	0.18	0.18
14	Sulphate	mg/l	2772	2892	2148	2172
15	Nitrate	mg/l	3.59	3.94	3.94	4.29
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	641.28	681.36	641.28	681.36
18	Magnesium	mg/l	1676.7	1676.7	1555.2	1579.5
19	Sodium	mg/l	10204.0	8765.0	9168.0	8834.0
20	Potassium	mg/l	343.0	320.0	355.0	331.0
21	Iron	mg/l	4.03	0.34	0.51	1.15
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	0.41	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

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**Table 33: Marine Water Quality Monitoring Parameters for location  
Khori creek at Kandla**

Sr. No.	Parameters	Unit	KPT 4			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.38	7.41	7.31	7.42
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.2	31.0	31.2	31.1
5	Turbidity	NTU	40	42	39	45
6	Total Dissolved Solids	mg/l	30002	23361	29742.0	25668.0
7	Total Suspended Solids	mg/l	622	600	672	667
8	Total Solids	mg/l	30686	23978	30462.0	26410.0
9	DO	mg/l	4.3	4.5	4.6	4.5
10	COD	mg/l	85.0	89.0	78.0	80.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.75	0.82	0.65	0.56
13	Phosphate	mg/l	0.23	0.24	0.20	0.20
14	Sulphate	mg/l	1704	2292	2700	2640
15	Nitrate	mg/l	4.36	4.79	4.86	5.14
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	521.04	480.96	601.2	521.04
18	Magnesium	mg/l	1628.1	1628.1	1701	1822.5
19	Sodium	mg/l	9176.0	8836.0	9214.0	8878.0
20	Potassium	mg/l	340.0	317.0	356.0	323.0
21	Iron	mg/l	1.12	8.38	0.94	1.53
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	0.14	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	0.11	0.43	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 34: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.50	7.60	7.4	7.5
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32.1	32.5	32.3	32.1
5	Turbidity	NTU	35	46	36	48
6	Total Dissolved Solids	mg/l	21305	17027	19685.0	19345.0
7	Total Suspended Solids	mg/l	792	671	691	573
8	Total Solids	mg/l	22120	17780	20400.0	19210.0
9	DO	mg/l	4.4	4.6	4.8	4.7
10	COD	mg/l	96.0	92.0	98.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.87	0.91	0.96	0.89
13	Phosphate	mg/l	0.20	0.21	0.19	0.20
14	Sulphate	mg/l	2148	2772	2340	2268
15	Nitrate	mg/l	5.14	4.72	5.70	6.05
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	521.04	601.20	480.96	561.12
18	Magnesium	mg/l	1579.5	1603.8	1701	1579.5
19	Sodium	mg/l	10204.0	10310.0	10308.0	10263.0
20	Potassium	mg/l	398.0	399.0	401.0	390.0
21	Iron	mg/l	1.77	9.19	0.31	0.87
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	0.30	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

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**Table 35: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.52	Sampling not possible during Low Tide	7.52	Sampling not possible during Low Tide
2	Color	-	Colorless		Colorless	
3	Odor	-	Odourless		Odourless	
4	Salinity	ppt	31.4		31.6	
5	Turbidity	NTU	38		37	
6	Total Dissolved Solids	mg/l	37757		32690.0	
7	Total Suspended Solids	mg/l	691		710	
8	Total Solids	mg/l	38496		33480.0	
9	DO	mg/l	4.8		4.5	
10	COD	mg/l	96.0		98.0	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	0.95		0.98	
13	Phosphate	mg/l	0.22		0.24	
14	Sulphate	mg/l	2736		2520	
15	Nitrate	mg/l	4.29		5.35	
16	Nitrite	mg/l	BQL		BQL	
17	Calcium	mg/l	641.28		641.28	
18	Magnesium	mg/l	1603.8		1506.6	
19	Sodium	mg/l	10415.0		10530.0	
20	Potassium	mg/l	404.0		409.0	
21	Iron	mg/l	0.41		0.46	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		BQL	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

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**Table 36: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.40	7.60	7.4	7.5
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odourless	Odourless	Odourless	Odourless
4	Salinity	ppt	32.0	31.7	31.2	31.6
5	Turbidity	NTU	33	28	35	31
6	Total Dissolved Solids	mg/l	26259	23319	27011.0	22504.0
7	Total Suspended Solids	mg/l	507	485	517.1	486.5
8	Total Solids	mg/l	26800	23864	27589.0	23000.0
9	DO	mg/l	4.5	4.4	4.3	4.4
10	COD	mg/l	82.0	89.0	90.0	89.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.65	0.71	0.75	0.71
13	Phosphate	mg/l	0.19	0.18	0.22	0.23
14	Sulphate	mg/l	2520	2292	2580	2652
15	Nitrate	mg/l	5.14	4.86	4.44	4.29
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	561.12	521.04	561.12	521.04
18	Magnesium	mg/l	1676.7	1725.3	1676.7	1725.3
19	Sodium	mg/l	10518.0	10648.0	10809.0	10530.0
20	Potassium	mg/l	407.0	411.0	417.0	439.0
21	Iron	mg/l	0.52	1.27	1.52	1.16
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	0.17	BQL	0.22

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 36 (a): Marine Water Quality Monitoring Parameters for locations  
Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr.Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.51	7.46	7.46	7.36
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odourless	Odourless	Odourless	Odourless
4	Salinity	ppt	32.2	31.5	31.4	32.0
5	Turbidity	NTU	30	32	28	31
6	Total Dissolved Solids	mg/l	33237	35588	34869	30549
7	Total Suspended Solids	mg/l	605	705	705	709
8	Total Solids	mg/l	33894	36882	35610	31352
9	DO	mg/l	4.7	4.6	4.6	4.1
10	COD	mg/l	96.0	90.0	96.0	90.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.93	0.96	0.96	0.76
13	Phosphate	mg/l	0.20	0.21	0.21	0.21
14	Sulphate	mg/l	2712	2556	2556	2726
15	Nitrate	mg/l	3.73	3.94	4.15	3.94
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	601.20	561.12	561.12	601.20
18	Magnesium	mg/l	1579.5	1652.4	1652.4	1725
19	Sodium	mg/l	10768.0	10804.0	10880.0	10893.0
20	Potassium	mg/l	415.0	418.0	444.0	442.0
21	Iron	mg/l	4.66	4.63	0.76	2.28
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	0.17	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

# **Marine Sediment Quality Monitoring**

**5.4.1 Marine Sediments**

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

**5.5 Results**

The Sediment Quality results are given in below from table no. 34 A & 34 B.

**Table 34 A: Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	KPT - 1	KPT - 2	KPT - 3	KPT - 4	KPT - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	2.31	3.97	2.53	1.74	1.09	1.55	1.76
3	Organic Carbon	mg/kg	1.34	2.30	1.46	1.01	0.63	0.90	1.02
4	Inorganic Phosphate	mg/kg	122.00	120.00	123.00	128.00	130.00	110.00	128.00
5	Moisture	%	6.04	20.28	5.07	4.51	1.79	27.71	27.58
6	Aluminium	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	10.00	9.20	11.20	10.60	8.80	8.60	10.20
8	Phosphate	mg/kg	9.62	2.99	3.07	8.93	8.15	1.08	3.15
9	Sulphate	mg/kg	392.29	669.86	328.07	328.50	285.04	1060.86	1028.84
10	Nitrite	mg/kg	0.11	0.10	0.12	0.10	0.11	0.11	0.10
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	140.28	184.37	164.33	164.33	136.27	220.44	212.42
13	Magnesium	mg/kg	51.03	94.77	43.74	36.45	34.02	133.65	165.24
14	Sodium	mg/kg	503.72	1090.45	516.67	595.13	389.07	1302.15	1504.45
15	Potassium	mg/kg	36.74	88.91	52.15	50.66	24.93	184.44	236.62
16	Chromium	mg/kg	58.10	42.60	22.60	20.90	12.20	42.90	129.20
17	Nickel	mg/kg	46.40	34.30	18.50	13.90	5.60	32.50	186.70
18	Copper	mg/kg	21.10	14.20	6.70	290.60	3.10	40.80	87.60
19	Zinc	mg/kg	60.90	58.20	24.60	32.10	7.00	80.40	145.20
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	7.50	5.40	4.30	6.90	4.00	7.80	4.10
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg)

**DCPL/DPT/20-21/21 - JANUARY -2022**

**Detox Corporation Pvt.Ltd.,Surat**

**Table 34 B: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	KPT - 1	KPT - 2	KPT - 3	KPT - 4	KPT - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	2.95	3.08	32.40	2.43	3.04	3.07	3.20
3	Organic Carbon	mg/kg	1.71	1.78	1.88	1.41	1.76	1.78	1.86
4	Inorganic Phosphate	mg/kg	126.00	123.00	128.00	132.00	124.00	109.00	120.00
5	Moisture	%	11.46	17.83	19.99	17.06	21.27	23.14	28.30
6	Aluminium	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	10.00	9.20	11.20	10.60	8.80	8.60	10.20
8	Phosphate	mg/kg	3.28	BQL	BQL	BQL	1.03	BQL	1.03
9	Sulphate	mg/kg	829.31	1136.31	929.95	898.93	617.09	1032.9 2	1392.64
10	Nitrite	mg/kg	0.11	0.10	0.12	0.10	0.11	0.11	0.10
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	204.41	216.43	228.46	208.42	200.40	220.44	216.43
13	Magnesium	mg/kg	82.62	114.21	111.78	75.33	97.20	143.37	153.09
14	Sodium	mg/kg	1042.67	1226.30	1316.01	1045.17	985.75	1493.7 9	1368.34
15	Potassium	mg/kg	84.42	106.16	123.23	95.05	107.98	159.65	172.47
16	Chromium	mg/kg	50.70	44.20	56.20	54.10	40.10	60.20	68.10
17	Nickel	mg/kg	34.70	27.60	38.50	35.50	23.70	41.10	46.60
18	Copper	mg/kg	10.10	9.90	28.10	14.40	7.40	19.00	24.50
19	Zinc	mg/kg	55.60	35.70	55.20	49.90	29.70	57.00	58.00
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	6.30	5.40	59.00	6.60	5.40	8.80	11.20
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg,Cd: 1.0mg/kg,Hg: 1.0mg/kg, As: 1.0mg/kg)

**REPORT  
ON  
ECOLOGICAL MONITORING  
OF MARINE ENVIRONMENT  
IN  
DPT HARBOUR AREA, NEAR BY CREEKS  
AND  
VADINAR JETTY AND SPM  
FOR  
DEENDAYAL PORT TRUST  
January, 2022**



## **INTRODUCTION:**

### **Sampling Stations:**

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 04<sup>th</sup> January 2022 in harbour region of DPT at Kandla Creek, and on 05<sup>th</sup> January 2022 in creeks near by the port during spring tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 11<sup>th</sup> January 2022 in harbour region of DPT at Kandla Creek and on 10<sup>th</sup> January 2022 in creeks near by the port during neap tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and one stations in Nakti creek and one station in Khorī creek. Sampling at second sampling station of Nakti creek was possible only during high tide period. The same sampling schedule was repeated during consecutive Neap tide and spring tide in same month.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during neap tide on 04/01/2022 and spring tide period on 10/01/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

**TABLE #1 SAMPLING LOCATIONS**

<b>monitoring requirement</b>	<b>Number of locations</b>
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khorī Creek	1 in Khorī creek
Vadinar jetty	1 near Vadinar
SPM	Jetty 1 near 1 <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

### **Sampling methodology adopted:**

**A** marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample were taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with nilyobolt cloth of 20µm mesh size.

### **Samples Processing for chlorophyll estimation:**

Samples for the chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 1998).

### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is general term for organisms have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplankton is free floating organisms that are capable of photosynthesis and zooplankton is the various free floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, **plankton** and **nekton** (Lalli and Parsons, 1997). **Plankton** consists of all organisms drifting in the water and is unable to swim against water currents, whereas **Nekton** includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

#### **Phytoplankton in the marine environment:**

Phytoplankton is free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio purifier and bio indicators of the aquatic ecosystems of which diverse array of the life depends .They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae).The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; diatoms and dinoflagellates. Phytoplankton also include numerous and diverse

collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the

classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

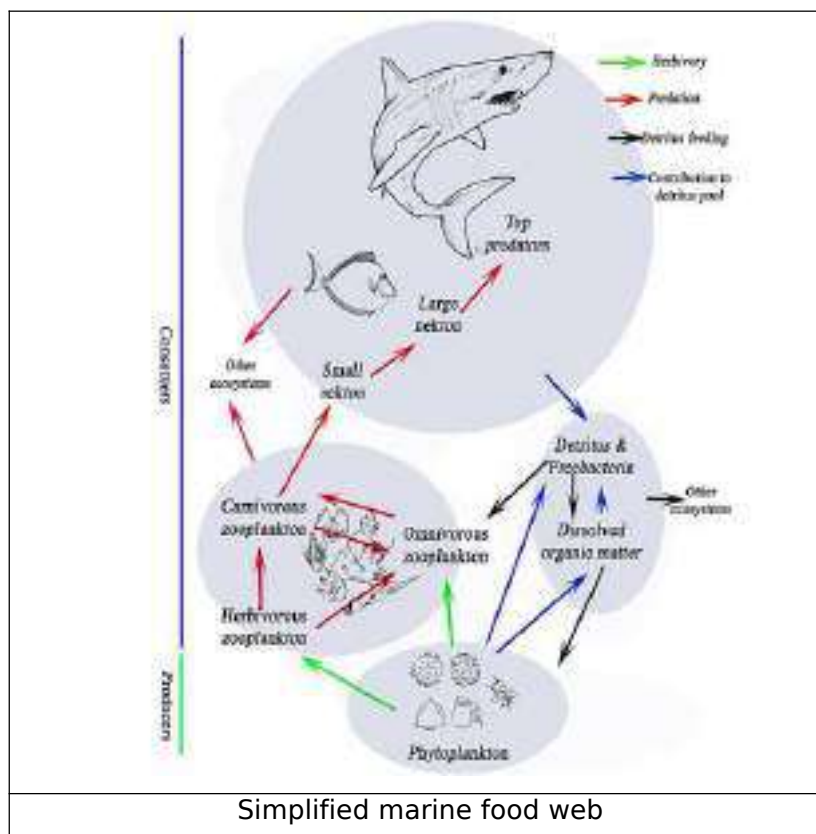
Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplankton is efficient grazers of the phytoplankton and is referred to as living machines transforming plant material

into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajbhiye, 2002).



### Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilometres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton may also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

**Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight .After the tow of about 15-30minutes, plankton net was pulled up and washed down to the tail and collected the plankton adhered to plankton net in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward. For quantitative evaluation 50 L water samples were collected from subsurface layer and filtered through 20µm mesh size net by using bucket and filtration assembly.

**Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

**Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

**Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of zooplankton that were encountered



***Cell counts by drop count method:***

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22x 60mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total number of plankton in the original volume of sample filtered was calculated as units/L.

**BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment-water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42 $\mu$  in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes

**SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

### **DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A. E. (1988)

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H.R. *eta/*. 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. The diversity measures that incorporate the two concepts may be termed heterogeneity measures (Magurran, 2004).

Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate species richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness (*S*) and evenness (*J*)

### **Simpson's diversity index**

Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present.. The Simpson index is one of the meaningful and robust biodiversity measures available.( Magurran ,2004).

The formula for calculating D is presented as:

$$D = \frac{n_i n_i}{N N} \frac{1}{1}$$

Where  $n_i$  = the total number of organisms of each individual species

$N$  = the total number of organisms of all species

The value of D ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When D increases diversity decreases. Simpson's index is therefore usually expressed as 1-D or 1/D. (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment
- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile
- complex food webs

$$H' = - \sum_{j=1}^S \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

to be  
whole

environmental change is less likely  
damaging to the ecosystem as a

### Species richness indices

The species richness (**S**) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness may be concomitant with severe or chronic human-induced perturbation (Fair weather 1990,) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness (**S**) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximised when all types are equally abundant (Rosenzweig, M. L. (1995).

### Shannon-Wiener's index:

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index (**H**), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index (**H**) reproduces community parameters to a single number by using an equation.

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the

range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

$$H' = - \sum_{j=1}^i \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

## **RESULTS:**

### **CHLOROPHYLL-a:**

Water Samples for the chlorophyll estimation were collected from sub surface layer during high tide and low tide period of the tidal cycle for each sampling locations and analysed for Chlorophyll -a and after acidification for Pheophytin -a. Chlorophyll- a value was used as algal biomass indicator (APHA,1998) Algal biomass was estimated by converting Chlorophyll value.

In the sub surface water chlorophyll-a was varying from 0.509- 0.850 mg/m<sup>3</sup> with an average value 0.714 mg/m<sup>3</sup> of in harbour region of DPT in Kandla Creek during sampling done in spring tide period of JANUARY 2022. In the nearby creeks chlorophyll-a was varying from 0.378 -1.038 mg/m<sup>3</sup>. with an average value 0.760 mg/m<sup>3</sup> Pheophytin -a level was below detectable limit- the all the sampling stations during spring tide.

In the sub surface water chlorophyll-a was varying from 0.512- 0.850 mg/m<sup>3</sup> with an average value 0.648 mg/m<sup>3</sup>.in harbour region of DPT in Kandla Creek during sampling done in neap tide period of January , 2021 . In the nearby creeks chlorophyll-a was varying from 0.378-0.835 mg/m<sup>3</sup> with an average value 0.658 mg/m<sup>3</sup>.Pheophytin -a level was below detectable limit- the all the sampling stations.

In the sub surface water chlorophyll-a was varying from 0.628-1.156 mg/m<sup>3</sup> with an average value 0.883 mg/m<sup>3</sup>. in harbour region of DPT OOT in path finder Creek during sampling done in spring tide period of JANUARY 2022. In the sub surface water chlorophyll-a was varying from 0.833 - 1.039 mg/m<sup>3</sup> with an average value 0.940 mg/m<sup>3</sup>.in harbour region of DPT OOT in path finder Creek during sampling done in Neap Tide period of JANUARY 2022

**TABLE #2 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING SPRING TIDE IN JANUARY 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.613	BDL	41.07
		Low tide	0.746	BDL	49.98
2	KPT 2	High tide	0.732	BDL	49.04
		Low tide	0.834	BDL	55.88
3	KPT 3	High tide	0.850	BDL	56.95
		Low tide	0.509	BDL	34.10
CREEKS					
4	KPT-4 Khor-I	High tide	0.937	BDL	62.78
		Low tide	0.511	BDL	34.24
5	KPT-5 Nakti-I	High tide	1.038	BDL	69.54
		Low tide	0.936	BDL	62.71
6	KPT-5 Nakti-II	High tide	0.354	BDL	23.72
PATHFINDER CREEK VADINAR					
7	VADINA R-I jetty	High tide	0.917	BDL	61.44
8		Low tide	1.156	BDL	77.45
9	SPM	High tide	0.833	BDL	55.81
10	SPM	Low tide	0.628	BDL	42.08

BDL: Below Detectable Limit.

**TABLE #3 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA ,NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN JANUARY 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.629	BDL	42.14
		Low tide	0.747	BDL	50.04
2	KPT 2	High tide	0.512	BDL	34.30
		Low tide	0.526	BDL	35.24
3	KPT 3	High tide	0.850	BDL	56.95
		Low tide	0.627	BDL	42.01
CREEKS					
4	KPT-4 Khor-I	High tide	0.716	BDL	47.97
		Low tide	0.630	BDL	42.21
5	KPT-5 Nakti-I	High tide	0.732	BDL	49.04
		Low tide	0.834	BDL	55.88
6	KPT-5 Nakti-II	High tide	0.378	BDL	25.32
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.936	BDL	62.71
8		Low tide	0.953	BDL	63.85
9	SPM	High tide	0.833	BDL	55.81
10	SPM	Low tide	1.039	BDL	69.61

BDL: Below Detectable Limit.

### **PHYTOPLANKTON POPULATION:**

For the evaluation of the Phytoplankton population in DPT harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms blue green algae and dinoflagellates during spring tide period. Diatoms were represented by 24 genera. Blue green were represented by 2 genera and dinoflagellates were represented by 3 genera during the sampling conducted in spring tide in JANUARY 2022. Phytoplankton of

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the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 41-205 units/ L during high tide period and 110-178 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms. Blue green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 21 genera Blue green algae were represented 4 genera and dinoflagellates with 4 genera during the sampling conducted in Neap tide in January 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 118-271 units/ L during high tide period and 228-304 units/ L during low tide of Neap Tide.

For the evaluation of the Phytoplankton population in DPT OOT jetty area in Path Finder creek sampling was conducted from two sampling locations ; jetty area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green anlage and Dinoflagellates during spring tide period. Diatoms were represented by 13 genera , Blue Green algae and Dinoflagellates 3 genera each during the sampling conducted in spring tide in January 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area was varying from 193 units/ L during high tide period and 172 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the SPM area was varying from 107 units/ L during high tide period and 124 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 14 genera and Blue green algae and dinoflagellates by two genera each during the sampling conducted in Neap tide in January 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 117 units/ L during high tide period and 174 units/ L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 162 units/ L during high tide period and 202 units/ L during low tide of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness)S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of

individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 2.962-4.532 with an average of 3.837 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 3.482 - 3.86 with an average of 3.657 during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 3.149 - 5.12 with an average of 4.292 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 3.996 - 4.973 with an average of 4.456 during consecutive low tide. Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 3.407 at OOT jetty area and 3.282 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 3.381 and 3.493 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 3.772 at OOT jetty area and 3.823 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 2.779 and SPM area was 3.64 during the consecutive low tide period.

### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.844 - 1.02 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.941 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.799 - 1.002 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of

0.922 during consecutive low tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.9163- 1.209- ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.088 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 1.087 - 1.237 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.149 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.8483 at OOT jetty area and 0.992 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.9335 and 1.06 at SPM during the consecutive low tide period.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.9458 at OOT jetty area and 1.029 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.9644 and at SPM area was 0.9767 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.7702- 0.8524 between selected sampling stations with an average of 0.823 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.744- 0.853

between selected sampling stations with an average of 0.810 during consecutive low tide .

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during neap tide also, which was varying from 0.804- 0.905 with an average value of 0.866 between selected sampling stations during high tide period and 0.869 -0.908 varying from with an average value of 0.887 between selected sampling stations during consecutive low tide period Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.7143 at OOT jetty area and 0.8243 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek . While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.7944 and 0.8825 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.8103 at OOT jetty area and 0.8349 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.834 and at SPM area was 0.8239 during the consecutive low tide period.

Low species diversity suggests a relatively few successful species in this habitat. The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment. Any change in the environment would probably have quite serious effects.

**Table # 4 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN JANUARY 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	221	31/31	100	5.557	1.2	0.8849
	2	202	26/31	83.87	4.71	1.111	0.8589
	3	219	30/31	96.77	5.381	1.149	0.8646
	4	230	29/31	93.55	5.149	1.123	0.8458
	5	234	29/31	93.55	5.133	1.01	0.8031
	6	64	16/31	51.61	3.607	1.081	0.9038
LOW TIDE	1	201	24/31	77.42	4.337	1.092	0.86
	2	232	30/31	96.77	5.324	1.257	0.9132
	3	219	29/31	93.55	5.196	1.215	0.9083
	4	201	29/31	93.55	5.28	1.239	0.9122
	5	265	28/31	90.32	4.839	1.161	0.8949

**Table # 5 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING NEAP TIDE IN JANUARY 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	231	27/29	93.10	4.777	1.159	0.8801
	2	195	28/29	96.55	5.12	1.209	0.9051
	3	271	28/29	96.55	4.82	1.05	0.8426
	4	248	26/29	89.65	4.534	1.116	0.8704
	5	221	18/29	62.07	3.149	0.9163	0.8042
	6	118	17/29	58.52	3.354	1.078	0.8948
LOW TIDE	1	246	23/29	79.31	3.996	1.087	0.8709
	2	228	28/29	96.55	4.973	1.237	0.9085
	3	304	28/29	96.55	4.723	1.178	0.9005
	4	259	25/29	86.20	4.319	1.154	0.8859
	5	276	25/29	86.20	4.27	1.093	0.8697

**Table # 6 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND , NEAR BY CREEKS DURING SPRING TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phytoplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	57-209	22/31	70.97
			BLUE GREEN	7-20	5/31	16.13
			DINOFLAGELLATES	0-14	4/31	12.90
			TOTAL PHYTO PLANKTON	64-234	31	-
LOW TIDE	Sub surface	5	DIATOMS	181-201	22/31	70.97
			BLUE GREEN	19-18	5/31	16.13
			DINOFLAGELLATES	1-13	4/31	12.90
			TOTAL PHYTO PLANKTON	201-232	31	-

**Table # 7 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND , NEAR BY CREEKS DURING NEAP TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phytoplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	99-243	21/29	72.42
			BLUE GREEN	1-14	4/29	13.79
			DINOFLAGELLATES	7-23	4/29	13.79
			TOTAL PHYTO PLANKTON	118-271	29	
LOW TIDE	Sub surface	5	DIATOMS	185-269	21/29	72.42
			BLUE GREEN	10-19	4/29	13.79
			DINOFLAGELLATES	14-24	4/29	13.79
			TOTAL PHYTO PLANKTON	228-304	29	

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**Table # 8 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN JANUARY 2022**

<b>Tide</b>	<b>Sampli ng Station</b>	<b>Abundan ce In units/L</b>	<b>No of Species observ ed /total species</b>	<b>% of diversit y</b>	<b>Margale f's diversity index (Species Richnes s S)</b>	<b>Shanno n Weiner index H (log<sub>10</sub>)</b>	<b>Diversity Index (Simpson 's Index) 1-D</b>
HIGH TIDE	jetty	264	20/20	100	3.407	0.8483	0.7143
	SPM	276	20/20	100	3.381	0.9335	0.7944
LOW TIDE	jetty	241	19/20	95	3.282	0.992	0.8243
	SPM	173	19/20	95	3.493	1.06	0.8825

**Table # 9 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN JANUARY 2022**

<b>Tide</b>	<b>Sampli ng Station</b>	<b>Abundan ce In units/L</b>	<b>No of Species observ ed /total species</b>	<b>% of diversit y</b>	<b>Margale f's diversity index (Species Richnes s S)</b>	<b>Shanno n Weiner index H (log<sub>10</sub>)</b>	<b>Diversity Index (Simpson 's Index) 1-D</b>
HIGH TIDE	Jetty	154	20/20	100	3.772	0.9458	0.8103
	SPM	154	15/20	75	2.779	0.9644	0.834
LOW TIDE	Jetty	144	20/20	100	3.823	1.029	0.8349
	SPM	185	20/20	100	3.64	0.9767	0.8239



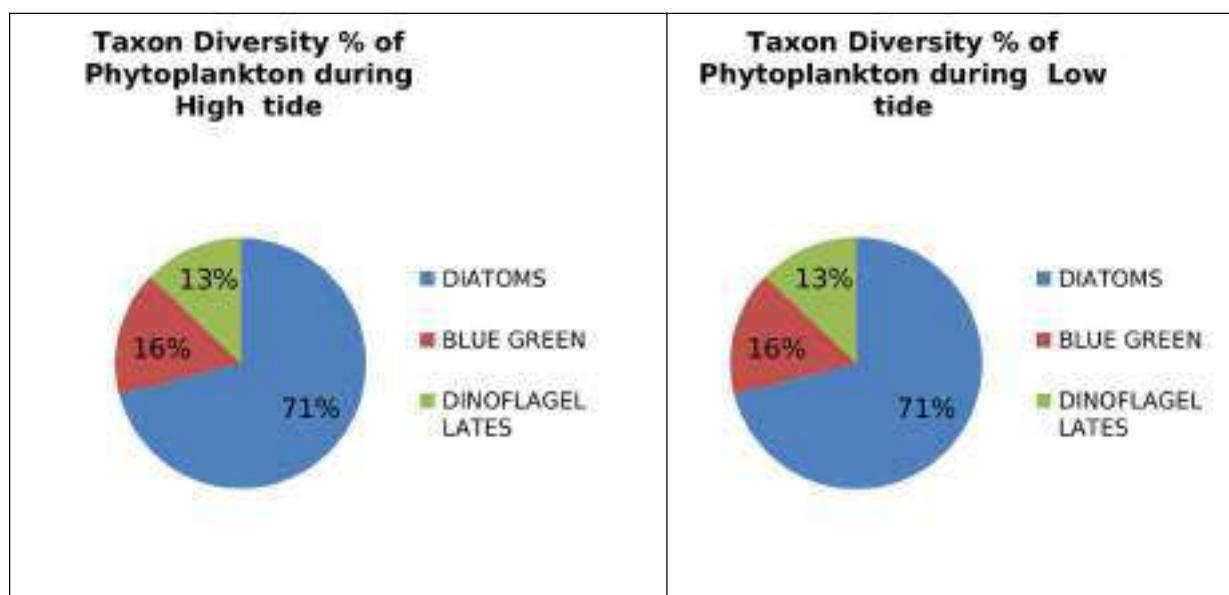
**Table # 10 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phytoplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	1	BLUE GREEN	4-9	3/19	15.78
			DIATOMS	102-177	13/19	68.44
			DINOFLAGELLATES	1-7	3/19	15.78
			TOTAL PHYTO PLANKTON	<b>107-193</b>	<b>19</b>	
LOW TIDE	Sub surface	1	BLUE GREEN	4-14	3/19	15.78
			DIATOMS	17-154	13/19	68.44
			DINOFLAGELLATES	4-3	3/19	15.78
			TOTAL PHYTO PLANKTON	<b>124-172</b>	<b>19</b>	

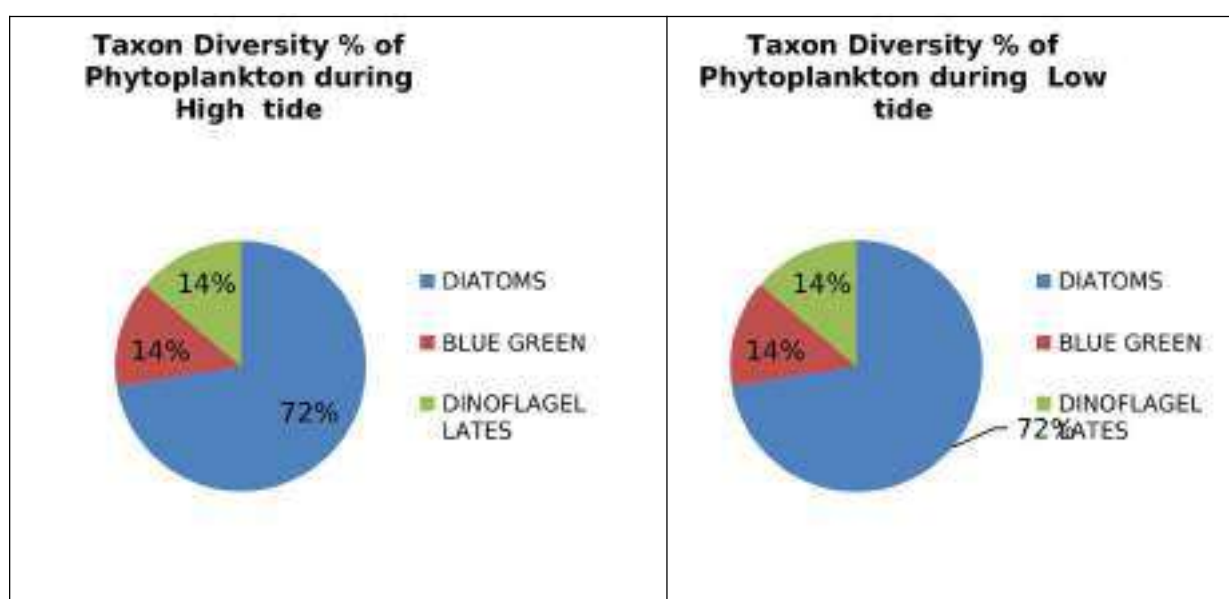
**Table # 11 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phytoplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN	4-5	2/18	11.11
			DIATOMS	109-154	14/18	77.78
			DINOFLAGELLATES	3-4	2/18	11.11
			TOTAL PHYTO PLANKTON	<b>117-162</b>	<b>18</b>	-
LOW TIDE	Sub surface	2	BLUE GREEN	5-8	2/18	11.11
			DIATOMS	158-194	14/18	77.78
			DINOFLAGELLATES	3-8	2/18	11.11
			TOTAL PHYTO PLANKTON	<b>174-202</b>	<b>18</b>	-

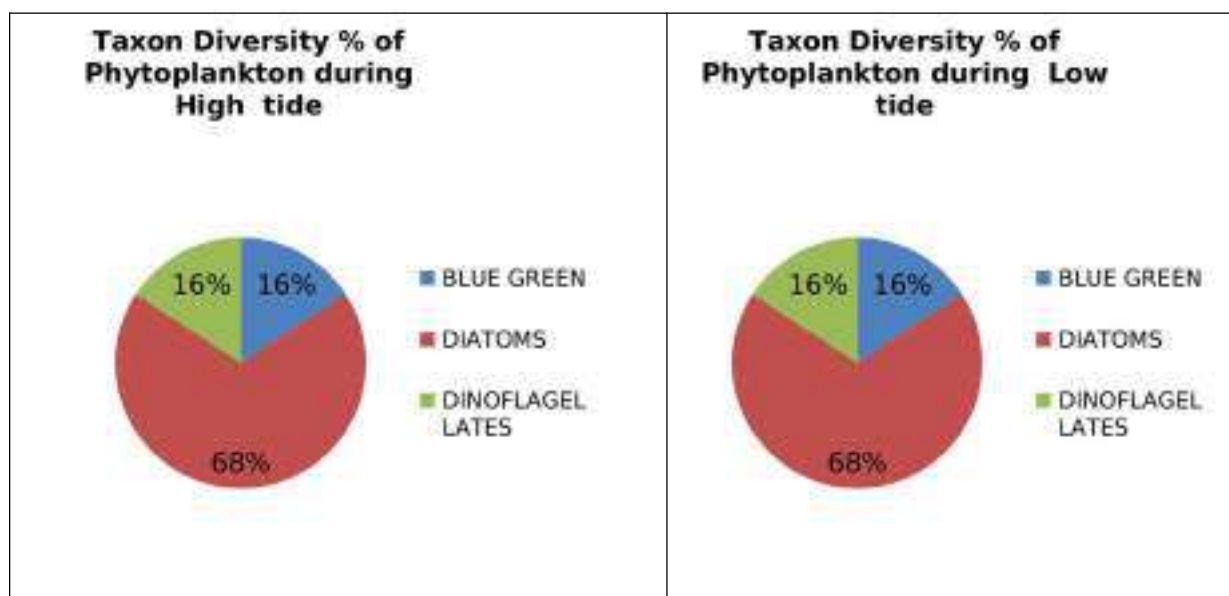
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Kandala creek and nearby creeks**



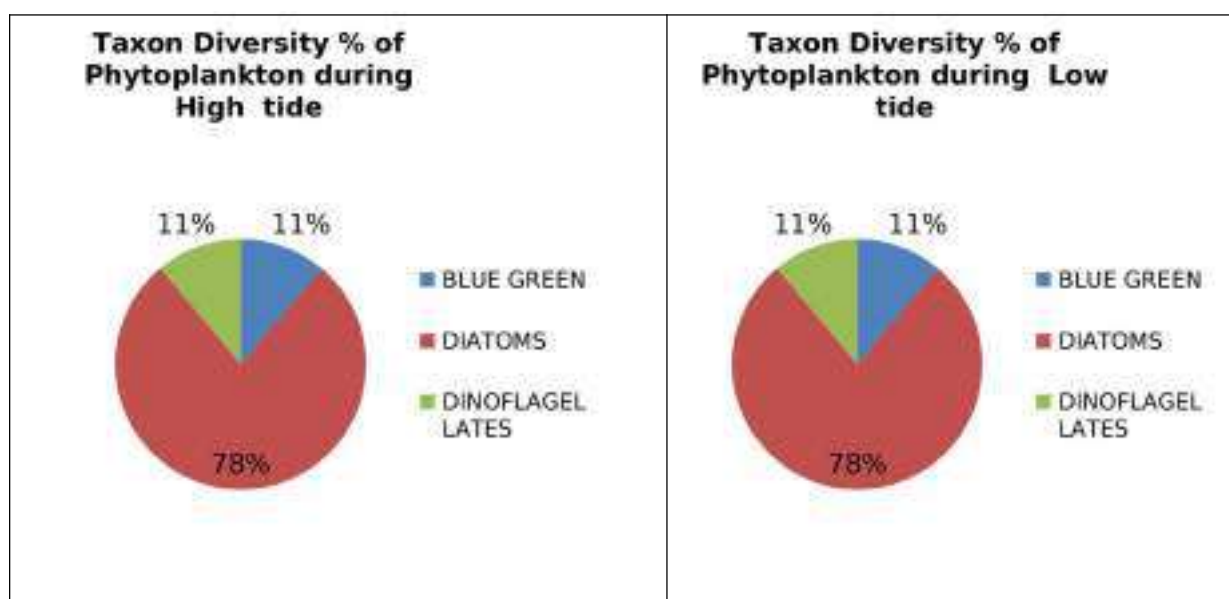
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Kandala creek and nearby creeks**



**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar**



**ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPT harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khori creek) during high tide period and low tide period of spring tide and Neap tide in January 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly 7

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groups, and 9 larval forms; Tintinids, Copepods, Arrow worms, Mysids, Urochordata, Medusa, Foraminiferans, and 9 larval forms; Nauplius larvae of Copepods, Actinula larvae, Brachyuran Zoea larvae, Cyphonautes larvae, Cirripede larvae, Ophioplutes larvae/ chinoplutes larvae, Opisthobranchia larvae, Trochophore larvae and Veliger larvae of Bivalves

. The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly 7 groups, Tintinids, Copepods, Arrow worms, Mysids, Urochordata, Ciliates and unidentified Cnidarian member, Foraminiferans and 9 larval forms; Nauplius larvae of Copepods, Actinula larvae, Brachyuran Zoea larvae, Cirripede larvae, Cyphonautes larvae, Opisthobranchia larvae, Ophioplutes larvae/ Echinoplutes larvae, Trochophore larvae, and Veliger larvae of Bivalves.

Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from 72-236 x10<sup>3</sup> N/ m<sup>3</sup> during high tide and 210-241 x10<sup>3</sup> N/ m<sup>3</sup> during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from 89-218 x10<sup>3</sup> N/ m<sup>3</sup> during high tide and 89-208 x10<sup>3</sup> N/ m<sup>3</sup> during low tide of Neap Tide period.

For the evaluation of the Zoo plankton population in DPT OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM) During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek creeks during spring tide was represented by mainly Tintinids, Copepods, Arrow worms and larval forms; Nauplius larvae of Copepods, Brachyuran Zoea larvae, Cirripede larvae, Opisthobranchia larvae, Trochophore larvae and Veliger larvae of Bivalves

.The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly two groups, Tintinids, Copepods, and, 7 Larval forms, . Nauplius larvae of Copepods, Cirripede larvae, Cyphonautes larvae, Ophioplutes larvae/ Echinoplutes larvae, Opisthobranchia larvae, Trochophore larvae and Veliger larvae of Bivalves

Zooplankton of the sampling stations at sub surface layer in the DPT OOT Jetty area of path finder creek was  $145 \times 10^3$  N/ m<sup>3</sup> during high tide and  $144 \times 10^3$  N/ m<sup>3</sup> during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area of path finder creek was  $155 \times 10^3$  N/ m<sup>3</sup> during high tide and  $124 \times 10^3$  N/ m<sup>3</sup> during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT OOT jetty area in path finder creek was recorded  $104 \times 10^3$  N/ m<sup>3</sup> during high tide and  $103 \times 10^3$  N/ m<sup>3</sup> during consecutive low tide period of Neap. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area in path finder creek was recorded  $131 \times 10^3$  N/ m<sup>3</sup> during high tide and  $134 \times 10^3$  N/ m<sup>3</sup> during consecutive low tide period of Neap Tide .

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the stations Kandla creek region and nearby creeks was varying from 3.274 - 5.353 with an average of 4.516 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities varying from 3.862 - 4.488 with an average of 4.323 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations was varying from 4.01-5.31 with an average of 4.479 during the sampling conducted in high tide and varying from 3.708-4.684 with an average of 4.218 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.416 and 3.421 respectively. Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High

tide period and low tide of spring tide was recorded as 3.172 and 3.319 respectively.

Margalef's diversity index (Species Richness) S of Zooplankton communities near Jetty at Path finder creek was varying from 3.66-2.805 during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) S of Zooplankton communities near SPM at Path finder creek was varying from 3.692-3.063 during the consecutive High tide and low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 1.051 - 1.316 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.203 ( $H'(\log_{10})$ ) during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 1.172- 1.274 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.231 ( $H'(\log_{10})$ ) during consecutive low tide period .

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 1.037- 1.254 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.163 ( $H'(\log_{10})$ ) during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 1.037-1.268 of ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.197 ( $H'(\log_{10})$ ) during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.101 and 1.114 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.070 and 1.059 respectively

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 1.081-0.897 during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek

was varying from 0.967 - 0.942 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of Zooplankton communities was above 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few, which was varying from 0.897-0.942 between selected sampling stations with an average of 0.921 during high tide period and was varying from 0.918- 0.940 with an average value of 0.928 between selected sampling stations during low tide

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of neap tide except few, which was varying from 0.844 - 0.929 between selected sampling stations with an average of 0.897 during high tide period and was varying from 0.844 -0.940 with an average value of 0.916 between selected sampling stations during consecutive low tide. This species diversity suggests a relatively more successful species in this habitat during January 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.902 and 0.906 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.892 and 0.894 respectively.



Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.896 - 0.810 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.805 and 0.814 respectively.

**Table # 12 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN JANUARY 2022**

Tide	Sampling Station	Abundance In N x10 <sup>3</sup> / m <sup>3</sup>	No of Species /groups observed /total species/ group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	197	29/33	87.88	5.3	1.301	0.9413
	2	187	29/33	87.88	5.353	1.316	0.9421
	3	224	25/33	75.75	4.435	1.208	0.9251
	4	236	28/33	84.85	4.942	1.218	0.9177
	5	195	21/33	63.64	3.793	1.124	0.8971
	6	72	15/33	45.45	3.274	1.051	0.9053
LOW TIDE	1	210	25/33	75.75	4.488	1.274	0.9402
	2	217	25/33	75.75	4.461	1.219	0.9268
	3	241	25/33	75.75	4.376	1.219	0.9186
	4	225	25/33	75.75	4.431	1.273	0.9394
	5	230	22/33	75.75	3.862	1.172	0.9185

**Table # 13 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN JANUARY 2022**

Tide	Sampling Station	Abundance In No $\times 10^3 / m^3$	No of Species /groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	195	29/31	93.55	5.31	1.254	0.9265
	2	159	22/31	70.97	4.143	1.173	0.9184
	3	205	25/31	80.64	4.509	1.227	0.9192
	4	218	27/31	87.09	4.829	1.109	0.8611
	5	135	21/31	67.74	4.077	1.181	0.9152
	6	89	19/31	61.29	4.01	1.037	0.844
LOW TIDE	1	199	25/31	80.64	4.534	1.268	0.9407
	2	192	24/31	77.42	4.375	1.216	0.9249
	3	208	26/31	83.87	4.684	1.257	0.9348
	4	191	22/31	70.96	3.998	1.221	0.9306
	5	168	20/31	64.52	3.708	1.183	0.9261

**Table # 14 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND , NEAR BY CREEKS DURING SPRING TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	4-46	7/33	21.22
			Copepods	62-47	11/33	33.33
			Arrow worms	0-4	1/33	3.03
			Mysids	0-4	1/33	3.03
			Urochordata	0-4	1/33	3.03
			Medusa	0-4	1/33	3.03
			Foraminiferans	8-14	2/33	6.06
			Larval forms	29-109	9/33	27.27
			TOTAL ZOOPLANKTON N/ M <sup>3</sup>	197-187	33	-
LOW TIDE	Sub surface	5	Tintinids	39-42	7/33	21.22
			Copepods	51-59	11/33	33.33
			Arrow worms	1-4	1/33	3.03
			Mysids	0-4	1/33	3.03
			Urochordata	0-4	1/33	3.03
			Medusa	0-4	1/33	3.03
			Foraminiferans	12-19	2/33	6.06
			Larval forms	92-117	9/33	27.27
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	210-217	33	-

**Table # 15 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK AND , NEAR BY CREEKS DURING NEAP TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	16-32	4/31	12.90
			Copepods	28-79	11/31	35.48
			Arrow worms	0-6	1/31	3.23
			Urochordata	0-6	2/31	6.45
			Ciliates	0-2	1/31	3.23
			Medusa	0-4	1/31	3.23
			Larval forms	38-115	9/31	29.03
			Foraminiferans	0-10	2/31	6.45
LOW TIDE	Sub surface	5	TOTAL ZOOPLANKTON $N/M^3$	89-218	31	-
			Tintinids	27-37	4/31	12.90
			Copepods	39-59	11/31	35.48
			Arrow worms	0-4	1/31	3.23
			Urochordata	0-4	2/31	6.45
			Ciliates	0-2	1/31	3.23
			Medusa	0-4	1/31	3.23
			Larval forms	93-102	9/31	29.03
			Foraminiferans	5-10	2/31	6.45
			TOTAL ZOOPLANKTON $N/M^3$	168-208	31	

**Table # 16 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH  
FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN JANUARY  
2022**

Tide	Sampling Station	Abundance In $\times 10^3 \text{N} / \text{m}^3$	No of Species /groups observed /total species/ group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	145	18/18	100	3.416	1.101	0.9023
	SPM	144	18/18	100	3.421	1.114	0.9068
LOW TIDE	Jetty	155	17/18	94.44	3.172	1.07	0.8925
	SPM	124	17/18	94.44	3.319	1.059	0.894

**Table # 17 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH  
FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN JANUARY  
2022**

Tide	Sampling Station	Abundance In $\text{N} \times 10^3 / \text{m}^3$	No of Species /groups observed /total species/ group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	104	18/19	94.74	3.66	1.081	0.8969
	SPM	103	14/19	73.68	2.805	0.8971	0.8104
LOW TIDE	Jetty	131	19/19	100	3.692	0.9673	0.8055
	SPM	134	16/19	100	3.063	0.9421	0.8147

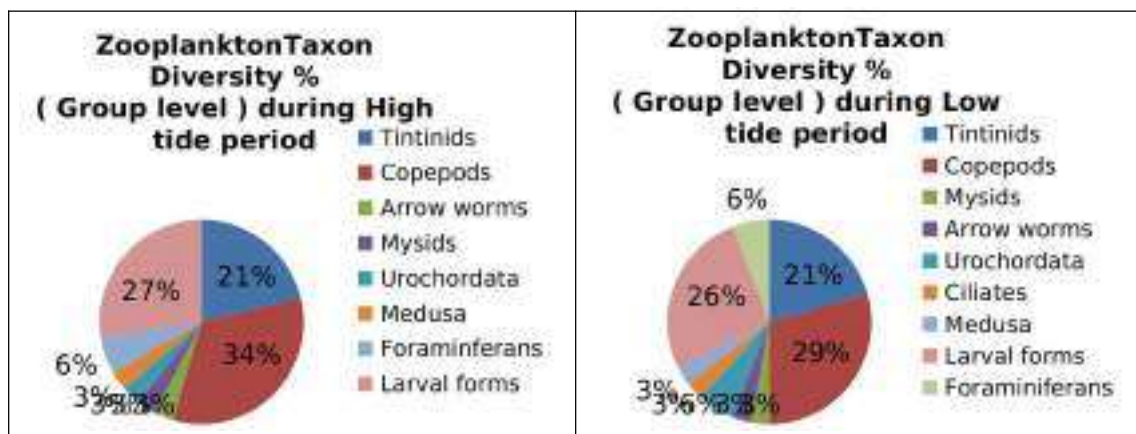
**Table # 18 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	25-27	4/18	22.22
			Copepods	49-57	6/18	33.33
			Arrow worms	4	1/18	5.56
			Foraminiferans	2-4	1/18	5.56
			Larval forms	55-62	6/18	33.33
			TOTAL ZOOPLANKTON NO/L	<b>144-145</b>	<b>18</b>	
LOW TIDE	Sub surface	2	Tintinids	22-25	4/18	22.22
			Copepods	44-62	6/18	33.33
			Arrow worms	1-2	1/18	5.56
			Foraminiferans	1-2	1/18	5.56
			Larval forms	55-63	6/18	33.33
			TOTAL ZOOPLANKTON NO/M3	<b>124-155</b>	<b>18</b>	

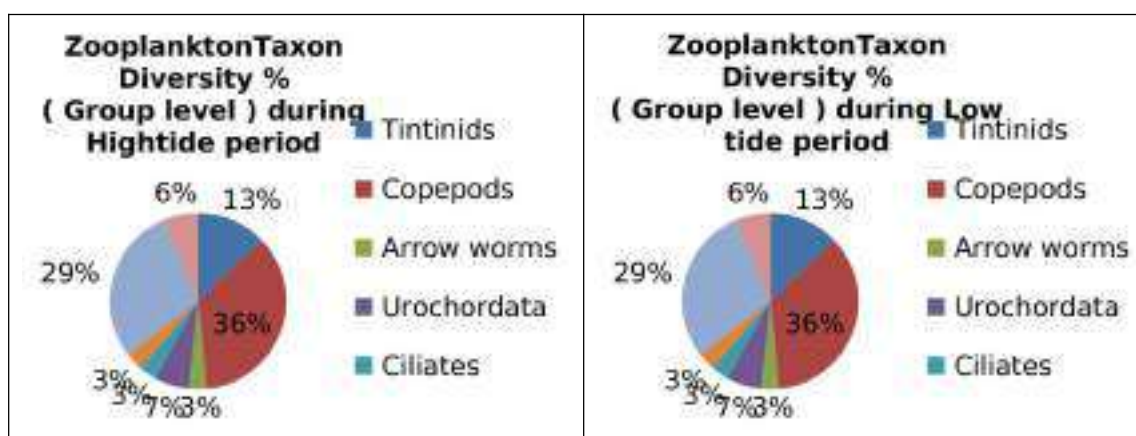
**Table # 19 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN JANUARY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	10-17	4/19	21.05
			Copepods	36-42	6/19	31.58
			Foraminiferans	0-2	2/19	10.53
			Larval forms	43-57	7/19	36.84
			TOTAL ZOOPLANKTON	<b>103-104</b>	<b>19</b>	-
LOW TIDE	Sub surface	2	Tintinids	14-21	4/19	21.05
			Copepods	31-39	6/19	31.58
			Foraminiferans	4-10	2/19	10.53
			Larval forms	71-75	7/19	36.84
			TOTAL ZOOPLANKTON NO/M3	<b>131-134</b>	<b>19</b>	-

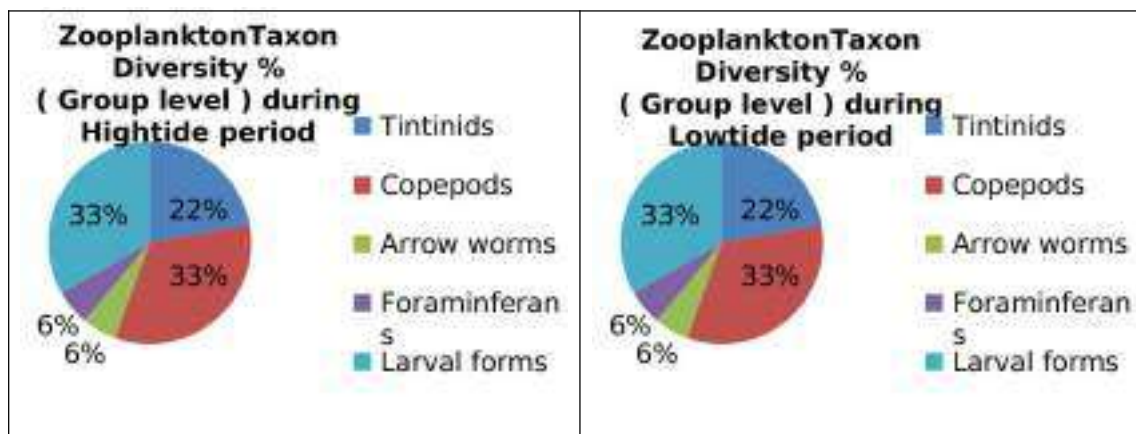
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Kandla Creek and nearby Creeks**



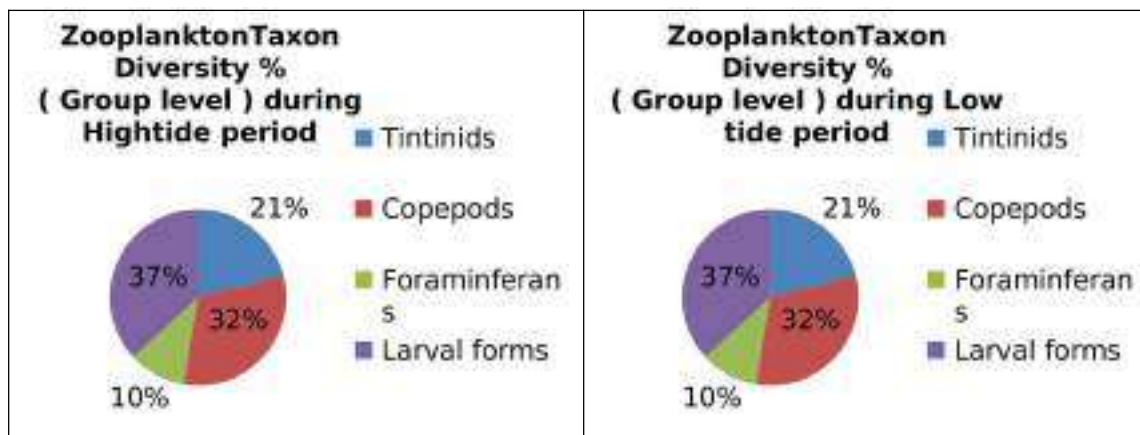
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Kandla Creek and nearby Creeks**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM**





**TABLE # 20 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPT HARBOUR AREA  
AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Very sparse
					<i>Oscillatoria sp.</i>	B2	Very sparse
					<i>Lyngbya sp.</i>	B3	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B4	Sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B5	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella sp.</i>	D1	Very sparse
			Coscinodisciales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D2	Dominant
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D3	Very sparse
					<i>Triceratium sp.</i>	D4	Very sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D5	Scattered
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp.</i>	D6	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D7	Scattered
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D8	Abundant
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D9	Sparse
			Melosirales	Melosiraceae	<i>Melosira sp.</i>	D10	Very sparse
		Bacillariophyceae	Naviculales	Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D11	Very sparse
			Naviculales Suborder: Sellaphorineae	Pinnulariaceae	<i>Pinnularia sp.</i>	D12	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D13	Sparse
					<i>Nitzschia sp.</i>	D14	Very sparse
			Surirellales	Surirellaceae	<i>Pseudo-nitzschia sp.</i>	D15	Very sparse
					<i>Surirella sp.</i>	D16	Very sparse
				Entomoneidaceae	<i>Entomoneis sp.</i>	D17	Very sparse
		Fragilariophyceae	Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D18	Sparse
			Fragilariales	Fragilariaceae	<i>Thalassionema sp.</i>	D19	Very sparse
					<i>Fragilaria sp.</i>	D20	Sparse
					<i>Synedra sp.</i>	D21	Sparse
			Tabellariales	Tabellariaceae	<i>Tabellaria sp.</i>	D22	Very sparse
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Noctiluca / Noctiluiphyceae (Dinokaryota)	Noctilucales	Noctilucaeae	<i>Noctiluca sp.</i>	DF1	Very sparse
		Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF2	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Sparse
					<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE # 21 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING AND NEAP TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very Sparse
					<i>Lyngbya sp.</i>	B2	Very Sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B3	Very Sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B4	Very Sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella sp</i>	D1	Very Sparse
					<i>Thalassiosira sp</i>	D2	Very Sparse
				Lauderiaceae	<i>Lauderia sp</i>	D3	Very Sparse
			Coscinodiscals	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D4	Dominant
			Triceratiales	Triceratiaceae	<i>Odontella sp</i>	D5	Very Sparse
					<i>Triceratium sp.</i>	D6	Very Sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp</i>	D7	Sparse
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp</i>	D8	Very Sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D9	Very Sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D10	Sparse
		Bacillariophyceae	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D11	Abundant
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D12	Scattered
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D13	Sparse
					<i>Nitzschia sp</i>	D14	Sparse
					<i>Pseudo-nitzschia sp.</i>	D15	Very Sparse
			Naviculales	Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D16	Sparse
		Fragilariophyceae	Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D17	Sparse
					<i>Thalassionema sp.</i>	D18	Very Sparse
			Fragilariales	Fragilariaceae	<i>Fragilaria sp</i>	D19	Sparse
					<i>Synedra sp</i>	D20	Sparse
			Tabellariales	Tabellariaceae	<i>Tabellaria sp</i>	D21	Very Sparse
DINO FLAGELLATES	Dinoflagellata / Dinzoa	Noctiluca / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca sp.</i>	DF1	Very Sparse
		Dinophyceae	Peridinales	Protopteridiniaceae	<i>Protopteridinium sp.</i>	DF2	Very Sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Sparse
					<i>Ceratium tripos</i>	DF4	Very Sparse

**TABLE # 22 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
					<i>Oscillatoria sp.</i>	B2	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Dominant
			Triceratiales	Triceratiaceae	<i>Odontella sp</i>	D2	Very sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp</i>	D3	Sparse
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp</i>	D4	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D5	Scattered
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp</i>	D6	Abundant
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D7	Sparse
		Bacillariophyceae	Naviculales	Pleurosigmaaceae	<i>Pleurosigma sp</i>	D8	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D9	Sparse
					<i>Nitzschia sp</i>	D10	Sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Fragilaria sp</i>	D11	Very sparse
					<i>Synedra sp.</i>	D12	Sparse
			Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D13	Very sparse
			Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D14	Very sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D15	Very sparse
DINOFLAGELLATES	Dinoflagellata / Dinzoa	Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF2	Sparse
					<i>Ceratium tripos</i>	DF3	Very sparse

**TABLE # 23 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND NEAP TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Very Sparse
					<i>Lyngbya sp.</i>	B2	Very Sparse
					<i>Oscillatoria sp.</i>	B3	Sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Dominant
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D2	Very Sparse
					<i>Triceratium sp.</i>	D3	Very Sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D4	Scattered
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp.</i>	D5	Very Sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D6	Very Sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D7	Sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D8	Scattered
		Bacillariophyceae	Naviculales	Naviculaceae	<i>Navicula sp.</i>	D9	Very Sparse
				Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D10	Very Sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D11	Scattered
					<i>Nitzschia sp.</i>	D12	Sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Synedra sp.</i>	D13	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D14	Sparse
			Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D15	Very Sparse
			Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D16	Very Sparse
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Dinophyceae	Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF1	Very Sparse

**TABLE # 24 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Scattered
				Codonellidae	<i>Tintinnopsis dadayi</i>	T2	Very sparse
					<i>Tintinnopsis failakkaensis</i>	T3	Sparse
					<i>Tintinnopsis gracilis</i>	T4	Sparse
					<i>Tintinnopsis mortensenii</i>	T5	Very sparse
					<i>Tintinnopsis radix</i>	T6	Sparse
				Xystonellidae	<i>Favella sp.</i>	T7	Very sparse
COPEPODS	ATHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Eucalanidae	<i>Pareucalanus sp.</i>	C3	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
				Euchaetidae	<i>Euchaeta sp.</i>	C5	Very sparse
			Cyclopoida	Centropagidae	<i>Centropages sp.</i>	C6	Very sparse
				Oithonidae	<i>Oithona sp.</i>	C7	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C8	Abundant
				Clytemnestridae	<i>Clytemnestra sp.</i>	C9	Very sparse
				Euterpinae	<i>Euterpina sp.</i>	C10	Very sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C11	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
MYSIDS	ATHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of Copepods	L1	Dominant
HYDROZOA LARVAE	CNIDARIA	Hydrozoa			Actinula larvae	L2	Very sparse
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran Zoea larvae	L3	Abundant
CYTHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse

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BARNACLE LARVAE	ATHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L5	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae/ Echinopluteus larvae	L6	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L7	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of Bivalves	L9	Sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Globigerinidae	<i>Globigerina</i> sp.	F1	Sparse
				Rotaliidae	<i>Rotalia</i> sp.	F2	Sparse

**TABLE # 25 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus</i> sp.	T1	Sparse
				Codonellidae	<i>Tintinnopsis gracilis</i>	T2	Very Sparse
					<i>Tintinnopsis radix</i>	T3	Sparse
					<i>Tintinnopsis failakkaensis</i>	T4	Sparse
COPEPODS	ATHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus</i> sp.	C1	Scattered
					<i>Parvocalanus</i> sp.	C2	Very Sparse
				Eucalanidae	<i>Pareucalanus</i> sp.	C3	Very Sparse
				Clausocalanidae	<i>Clausocalanus</i> sp.	C4	Very Sparse
				Centropagidae	<i>Centropages</i> sp.	C5	Very Sparse
				Temoridae	<i>Temora</i> sp.	C6	Very Sparse
			Cyclopoida	Oithonidae	<i>Oithona</i> sp.	C7	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella</i> sp.	C8	Abundant
				Euterpinidae	<i>Euterpina</i> sp.	C9	Very Sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea</i> sp.	C10	Very Sparse
				Corycaidae	<i>Corycaeus</i> sp.	C11	Very Sparse
ARROW WORMS	CHAETOGNATHA	Sagittioidea	Aphragmophora	Sagittidae	<i>Sagitta</i> sp.	A1	Very Sparse

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UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very Sparse
				Fritillariidae	<i>Fritillaria sp.</i>	U2	Very Sparse
CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very Sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME 1	Very Sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of Copepods	L1	Dominant
HYDROZOA LARVAE	CNIDARIA	Hydrozoa			Actinula larvae	L2	Very Sparse
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran Zoea larvae	L3	Scattered
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L4	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L5	Sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L6	Sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae/ Echinopluteus larvae	L7	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of Bivalves	L9	Very Sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Sparse
				Rotalliidae	<i>Rotalia sp.</i>	F2	Very Sparse



**TABLE # 26 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus sp.</i>	T1	Sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Sparse
				Xystonellidae	<i>Favella sp.</i>	T4	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
				Eucalanidae	<i>Pareucalanus sp.</i>	C2	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C3	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C4	Scattered
				Euterpinae	<i>Euterpina sp.</i>	C5	Sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C6	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of Copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran Zoea larvae	L2	Sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L4	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L5	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of Bivalves	L6	Very sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very sparse

**TABLE # 27 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF JANUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Sparse
					<i>Tintinnopsis gracilis</i>	T3	Very Sparse
				Xystonellidae	<i>Favella sp.</i>	T4	Very Sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Very Sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C3	Abundant
			Harpacticoida	Euterpinae	<i>Euterpina sp.</i>	C4	Sparse
				Ectinosomatidae	<i>Microsetella sp.</i>	C5	Very Sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C6	Very Sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of Copepods	L1	Dominant
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L2	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L3	Sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae/ Echinopluteus larvae	L4	Sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L5	Very Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L6	Very Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of Bivalves	L7	Very Sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very Sparse
				Rotaliidae	<i>Rotalia sp.</i>	F2	Very Sparse



### **BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPT harbour region and nearby creek. The meiobenthic organisms during spring tide were represented by Polychaetes *Dasybranchus* sp., *Notomastus* sp and *Syllis* sp., and Nematodes. , During Neap tide Polychaetes *Phyllodoce* sp. , *Dasybranchus* sp *Notomastus* sp and Nematode worms were detected.

**Table # 28 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING SPRING TIDE IN JANUARY 2022**

Benthic fauna	ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS REPRESENTATION BY GROUP						
	DPT HARBOUR			CREEKS			
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6	
Family : Capitellidae <i>Dasybranchus</i> sp.	0	60	0	20	10	0	
Family : Capitellidae <i>Notomastus</i> sp	0	40	20	40	20	0	
Family : Syllidae <i>Syllis</i> sp.	0	0	40	0	0	0	
Total Polychaetes N/M <sup>2</sup>	0	60	40	20	10	0	
Un identified Nematode worms	20	40	20	40	40		
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	200	120	120	80	0	

NS : No sample

**Table # 29 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING NEAP TIDE IN JANUARY 2022**

	ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS REPRESENTATION BY GROUP						
Benthic fauna	DPT HARBOUR			CREEKS			
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6	
Family Phyllodocidae <i>Phyllodoce</i> sp.	0	40	20	60	50	0	
Family : Capitellidae Dasybranchus sp	0	20	40	20	20	0	
Family : Capitellidae <i>Notomastus</i> sp	0	0	20	40	40	0	
Total Plychates	0	60	80	120	110	0	
Un identified Nematode worms	20	40	40	20	10	0	
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	100	120	140	120	0	

**Table # 30 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT OOT AT PATH FINDER CREEK DURING Spring TIDE IN JANUARY 2022**

Benthic fauna	ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS REPRESENTATION BY GROUP	
	OOT jetty	SPM
<b>POLYCHAETES</b>		
Family: Nereidae Perineris sp.	10	20
Family Glyceridae	10	40
Total Polychates N/M <sup>2</sup>		
Un identified Amphipods	20	40
Un identified Nematodes	30	40
Brittle star	0	10
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	70	150

## **6. Meteorological Data**

Automatic Weather station have been installed in Seva Sadan -3 at the Deendayal Port which records the data on Temperature (°C), Humidity (%), Wind (mph), Dew Point (°C), Wind Direction (°), Pressure, Solar radiation, heat Index and UVI.

### **Temperature**

The mean day time temperature for Deendayal Port was 19.8 °C. The day-time maximum temperature was 30.8°C. The mean night time temperature was 12.6 °C. The minimum mean night time temperature recorded was 25.2 °C.

### **Air Pressure**

The mean absolute air pressure for the month of January was 1015.9 hpa, whereas the mean relative pressure was 1016.04 hpa. The maximum absolute air pressure recorded for the month of January was 1021.9 hpa.

### **Heat Index**

The mean day-time heat index for the month of January was 27.18 °C. The maximum heat index recorded was 32°C.

### **Solar Radiation**

The mean Solar Radiation in January was 115.27 w/m<sup>2</sup>. The maximum solar radiation recorded in the month of October was 530.7 w/m<sup>2</sup>.

### **Humidity**

The mean day-time humidity was 61.69 % for the month of January and mean night time humidity was 47.22%. Maximum humidity recorded during day-time was 96.0 % and maximum humidity recorded during night-time was 69.0%.

### **Wind Velocity and Wind Direction**

The mean wind velocity for the entire month of January was 4.4 km/hour. Maximum wind velocity recorded was 20.9 Km/hr . The wind direction was mostly N to NW.

## **Conclusive Summary and Remedial measures Suggested**

The AAQ monitoring at six locations of Deendayal Port indicates that the mean PM<sub>10</sub> values at four locations viz. Coal storage area, Marine Bhavan, Gopalpuri, Tuna Port, Kandla Colony and Oil Jetty area were found above the permissible standards (100 µg/m<sup>3</sup>) and PM<sub>2.5</sub> was above permissible limits at Coal storage location (Limit 60 µg/m<sup>3</sup>).

Drinking water at all the twenty locations was found potable and was within permissible limits of BIS standards (IS 10500).

Noise quality was also within the set permissible standards of an Industrial Area. The noise level observed during day time was >75 dB (A) and at night time was >70 dB (A) during the entire monitoring period.

The sewage treated water of Deendayal Port Colony (Gopalpuri) was in line with the standards set by the Gujarat Pollution Control Board.

### **Reasons for higher Values of PM<sub>10</sub>**

Large amount of coal is handled at Berth No. 6, 7, 8 and 9. The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.

Also, the coal laden trucks are not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

### **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of January, 2022 were observed beyond the permissible limit at four locations mentioned above. Given below are the remedial measures suggest to minimize the Air pollution at Deendayal Port.

Guidelines for Coal Handling by GPCB should be strictly followed. (<http://gpcb.gov.in/pdf/coal-handling-guidelines.pdf>)

Except for the higher values of PM<sub>10</sub> & PM<sub>2.5</sub> at Coal storage site, Oil Jetty, Tuna Port and Marine Bhavan locations, the monitoring results for the present month suggest that the overall Environment Quality of Deendayal Port is satisfactory.



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## **Introduction**

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GPCB/CPCB/MoEF to identify non conformity in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.

## **1. Ambient Air Quality Monitoring**

As per the Environmental Monitoring Plan of Deendayal Port Trust, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

### **1.1 Air Quality Monitoring Methodology**

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub> & Benzene, and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours of the sampler, the reagents were replaced to obtain 3 samples per day for each parameter namely, SO<sub>2</sub>, NO<sub>x</sub>. The EPM 2000 filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected twice a week from all the eight locations as per the EMP.

### **1.2 Results**

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of February 2022 are given in Tables 1A to 6B. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 7A to 8B.

# Ambient Air Quality Monitoring

## Environmental Monitoring Report Of Deendayal Port Trust,

### Location 1: Marine Bhavan (AL1)

Table 1 : Results of Air Pollutant Concentration at Marine Bhavan										
Parameter	Date	TSPM [µg/m <sup>3</sup> ]	PM10 [µg/m <sup>3</sup> ]	PM2.5 [µg/m <sup>3</sup> ]	SO <sub>2</sub> [µg/m <sup>3</sup> ]		NOx [µg/m <sup>3</sup> ]		NH <sub>3</sub> [µg/m <sup>3</sup> ]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQ MS limit		NS	100 [µg/m <sup>3</sup> ]	60 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		400 [µg/m <sup>3</sup> ]
<b>AL1 - 1</b>	01.02.2022	330	188	76	3.08	4.69	18.42	15.46	10.47	11.57
					5.28					
					5.71					
<b>AL1 - 2</b>	04.02.2022	330	183	65	3.08	4.4	12.07	15.24	12.76	11.15
					4.84					
					5.28					
<b>AL1 - 3</b>	08.02.2022	341	195	84	3.52	4.1	15.24	19.48	10.21	9.87
					3.08					
					5.71					
<b>AL1 - 4</b>	11.02.2022	427	231	102	3.52	3.66	17.15	16.3	12.76	11.83
					2.64					
					4.84					
<b>AL1 - 5</b>	15.02.2022	477	304	108	3.08	4.4	15.24	16.09	7.4	9.36
					5.28					
					4.84					
<b>AL1 - 6</b>	18.02.2022	522	319	106	3.08	3.81	13.34	15.46	9.19	8.76
					4.4					
					3.96					
<b>AL1 - 7</b>	22.02.2022	423	231	93	3.52	3.37	13.34	16.94	9.7	8.68
					3.96					
					2.64					
<b>AL1 - 8</b>	25.02.2022	447	247	98	3.52	3.52	19.05	16.94	10.21	10.55
					2.64					
					4.4					
<b>DCP/DP/21-22/22</b>		412	237	92		3.99		16.49	5	10.22

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<b>Average</b>									
<b>Standard Deviation</b>	72	52	15		0.47		1.37		1.24

NS -Not Specified



<b>Table 1 : Results of Air Pollutant Concentration at Marine Bhavan</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC* [ppm]</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL1 - 1	01.02.2022	1.2	BDL	1.06	516
AL1 - 2	04.02.2022	1.16	BDL	1.92	430
AL1 - 3	08.02.2022	1.32	BDL	1.49	513
AL1 - 4	11.02.2022	1.2	BDL	2.09	923
AL1 - 5	15.02.2022	1.23	BDL	1.97	1038
AL1 - 6	18.02.2022	1.165	BDL	1.95	437
AL1 - 7	22.02.2022	1.181	BDL	1.94	1127
AL1 - 8	25.02.2022	1.033	BDL	2.24	435
<b>Monthly Average</b>		<b>1.19</b>	<b>-</b>	<b>1.83</b>	<b>677</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.38</b>	<b>298</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit -

NMHC: 0.5 ppm) NS -Not Specified

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 412µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 237.0 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean 92.0 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.99 µg/ m<sup>3</sup>, 16.49 µg/ m<sup>3</sup> & 10.22 µg/ m<sup>3</sup> respectively. These were within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.19 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit

and Carbon Monoxide concentration was 1.83 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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**Location 2: Oil Jetty (AL2)**

Table 1 : Results of Air Pollutant Concentration atOil Jetty										
Parame ter	Date	TSPM [µg/m³ ]	PM10 [µg/m³ ]	PM2.5 [µg/m³ ]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Samplin g Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQM S limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL2 - 1	01.02.20 22	260	10 8	72	3.08	3.52	15.24	18	12.51	11.66
					3.52		19.69		13.27	
					3.96		19.05		9.19	
AL2 - 2	04.02.20 22	337	17 9	80	2.2	2.93	20.33	17.15	7.91	7.4
					2.64		17.78		10.47	
					3.96		13.34		3.83	
AL2 - 3	08.02.20 22	377	18 0	88	5.71	4.98	11.43	16.73	10.98	11.23
					4.84		19.05		9.96	
					4.4		19.69		12.76	
AL2 - 4	11.02.20 22	467	27 2	96	3.52	3.08	19.05	18.21	7.66	9.02
					2.64		19.69		10.47	
					3.08		15.88		8.93	
AL2 - 5	15.02.20 22	431	25 2	92	3.52	3.96	19.05	17.36	8.93	8.42
					3.96		19.69		7.4	
					4.4		13.34		8.93	
AL2 - 6	18.02.20 22	500	29 8	10 0	5.28	4.84	17.15	13.97	7.4	8.68
					5.71		12.07		7.91	
					3.52		12.7		10.72	
AL2 - 7	22.02.20 22	354	19 0	98	4.4	4.98	19.69	19.9	8.93	10.38
					4.84		19.05		11.49	
					5.71		20.96		10.72	
AL2 - 8	25.02.20 22	418	22 8	94	5.71	4.69	15.24	16.51	7.15	7.74
					4.4		19.69		7.91	
					3.96		14.61		8.17	
Monthly Average		393	213	90		4.12		17.23		9.32
Standard Deviation		77	61	10		0.86		1.69		1.59

<b>Table 2B : Results of Air Pollutant Concentration at Oil Jetty</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL2 -1	01.02.2022	1.11	BQL	2.06	546
AL2 -2	04.02.2022	1.17	BQL	1.75	398
AL2 -3	08.02.2022	1.06	BQL	1.86	489
AL2 -4	11.02.2022	1.05	BQL	2.15	1042
AL2 - 5	15.02.2022	1.18	BQL	2.02	29.1
AL2 - 6	18.02.2022	1.13	BQL	1.84	511
AL2 -7	22.02.2022	1.02	BQL	2.03	1131
AL2 - 8	25.02.2022	1.12	BQL	1.95	509
<b>Monthly Average</b>		<b>1.09</b>	<b>-</b>	<b>1.96</b>	<b>644</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.13</b>	<b>461</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit –

NMHC: 0.5 ppm) NS- Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Oil Jetty area was mainly by motor vehicle emission produced from various types of vehicles Oil Jetty Area. The mean TSPM values at Oil Jetty were 393 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 213 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 90 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit, The mean concentration of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.12 µg/m<sup>3</sup>, 17.23 µg/m<sup>3</sup> and 9.32 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was **1.09** µg/m<sup>3</sup>. Well below the permissible limit of 5.0 µg/m<sup>3</sup>. , HC's were below the detectable limit and Carbon Monoxide concentration was 1.96 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 3: Kandla Colony - Estate Office (AL-3)

Table 1 : Results of Air Pollutant Concentration at Estate Office										
Parameter	Date	TSPM [µg/m <sup>3</sup> ]	PM10 [µg/m <sup>3</sup> ]	PM2.5 [µg/m <sup>3</sup> ]	SO2 [µg/m <sup>3</sup> ]		NOx [µg/m <sup>3</sup> ]		NH <sub>3</sub> [µg/m <sup>3</sup> ]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m <sup>3</sup> ]	60 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		400 [µg/m <sup>3</sup> ]
<b>AL3 - 1</b>	01.02.2022	219	115	80	3.52	3.66	10.8	13.55	10.47	11.83
					3.08		16.51		10.72	
					4.4		13.34		14.3	
<b>AL3 - 2</b>	04.02.2022	379	192	96	4.84	4.54	18.42	19.05	10.21	9.28
					5.28		19.05		10.47	
					3.52		19.69		7.15	
<b>AL3 - 3</b>	08.02.2022	392	248	89	3.08	3.22	14.61	13.13	8.93	9.87
					3.96		12.07		10.21	
					2.64		12.7		10.47	
<b>AL3 - 4</b>	11.02.2022	445	280	100	5.71	4.25	19.05	16.73	8.17	8.17
					3.96		17.78		8.93	
					3.08		13.34		7.4	
<b>AL3 - 5</b>	15.02.2022	425	247	177	5.28	3.37	20.96	18.21	9.96	9.36
					2.2		16.51		10.21	
					2.64		17.15		7.91	
<b>AL3 - 6</b>	18.02.2022	476	282	88	5.71	4.25	17.78	17.15	10.47	10.47
					3.08		13.97		10.21	
					3.96		19.69		10.72	
<b>AL3 - 7</b>	22.02.2022	303	162	96	3.08	3.22	12.07	13.13	10.21	8.51
					3.96		12.7		7.4	
					2.64		14.61		7.91	
<b>AL3 - 8</b>	25.02.2022	328	196	90	3.08	3.96	12.7	17.15	10.21	8.42
					3.52		19.05		7.66	
					5.28		19.69		7.4	
<b>Monthly Average</b>		371	215	102		3.81		16.01		9.49
<b>Standard Deviation</b>		84	59	31		0.51		2.39		1.22

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NS: Not Specified

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<b>Table 3B : Results of Air Pollutant Concentration at Estate Office</b>					
<b>Parameter</b>	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL3 -1	01.02.2022	1.12	BQL	2.14	535
AL3 -2	04.02.2022	1.18	BQL	1.92	444
AL3 -3	08.02.2022	1.04	BQL	7.03	378
AL3 -4	11.02.2022	1.19	BQL	1.97	1087
AL3 - 5	15.02.2022	1.18	BQL	2.05	1122
AL3 - 6	18.02.2022	1.19	BQL	1.73	421
AL3 - 7	22.02.2022	1.16	BQL	1.95	966
AL3 - 8	25.02.2022	1.111	BDL	2.23	419
<b>Month ly Average</b>		<b>1.15</b>	<b>-</b>	<b>2.63</b>	<b>672</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>1.79</b>	<b>326</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm) NS- Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Kandla Port Colony was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Oil Jetty were 371µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 215 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean =102 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.81 µg/m<sup>3</sup>, 16.01 µg/m<sup>3</sup> and 9.49 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was **1.15** µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the



detectable limit and Carbon Monoxide concentration was

**2.63** mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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**Location 4: Gopalpuri Hospital (AL-4)**

Table 1 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO2 [µg/m³]		NOx [µg/m³]		NH3 [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m³]	60 [µg/m³]		80 [µg/m³]		80 [µg/m³]		400 [µg/m³]
AL4 -1	01.02.2022	160	102	54	3.52	3.96	9.53	11.43	7.4	8.08
					3.96					
					4.4					
AL4 -2	04.02.2022	218	124	91	3.96	2.93	13.34	13.34	5.87	7.57
					2.64					
					2.2					
AL4 -3	08.02.2022	277	147	80	3.08	3.22	13.34	14.61	7.15	7.06
					2.64					
					3.96					
AL4 -4	11.02.2022	204	113	88	2.2	2.93	11.43	13.13	7.91	8.17
					3.08					
					3.52					
AL4 -5	15.02.2022	355	211	92	3.08	3.52	13.97	13.97	7.66	7.66
					3.52					
					3.96					
AL4 -6	18.02.2022	257	155	90	3.08	3.08	15.88	13.97	7.4	8.34
					2.64					
					3.52					
AL4 -7	22.02.2022	216	113	72	3.08	3.52	15.24	13.76	7.15	7.57
					3.96					
					3.52					
AL4 -8	25.02.2022	261	144	90	3.52	3.66	12.07	13.55	8.42	9.19
					3.08					
					4.4					
Monthly Average		243	139	82		3.35		13.47		7.96
Standard DPT/21-22/22		58	35	13		0.37		0.94	11	0.64

## Environmental Monitoring Report Of Deendayal Port Trust,

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NS: Not Specified

<b>Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
<b>Parameter</b>	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL4 -1	01.02.2022	1.1	BDL	2.17	532
AL4 -2	04.02.2022	1.26	BDL	1.55	394
AL4 -3	08.02.2022	1.09	BDL	1.68	579
AL4 -4	11.02.2022	1.06	BDL	1.87	994
AL4 - 5	15.02.2022	1.14	BDL	2.1	1123
AL4 - 6	18.02.2022	1.13	BDL	1.78	784
AL4 - 7	22.02.2022	1.14	BDL	2.05	473
AL4 - 8	25.02.2022	1.1	BDL	2.18	780
<b>Monthly Average</b>		<b>1.13</b>	<b>-</b>	<b>1.92</b>	<b>707</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.24</b>	<b>258</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit –

NMHC: 0.5 ppm) NS-Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Oil Jetty were 243 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 139 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean= 82 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.35 µg/m<sup>3</sup>, 13.47 µg/m<sup>3</sup> and 7.96 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was **1.13** µg/m<sup>3</sup>, well below the permissible limit of

5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was **1.92**

mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 5: Coal Storage Area (AL-5)**

**Table 1 : Results of Air Pollutant Concentration at Coal Storage Area**

Parameter	Date	TSPM [µg/m <sup>3</sup> ]	PM10 [µg/m <sup>3</sup> ]	PM2.5 [µg/m <sup>3</sup> ]	SO2 [µg/m <sup>3</sup> ]		NOx [µg/m <sup>3</sup> ]		NH3 [µg/m <sup>3</sup> ]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m <sup>3</sup> ]	60 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		400 [µg/m <sup>3</sup> ]
<b>AL5 - 1</b>	01.02.2022	390	208	108	3.52	4.1	20.33	17.57	11.74	9.19
					3.96					
					4.84					
<b>AL5 - 2</b>	04.02.2022	413	248	104	2.64	3.81	15.88	16.51	8.93	9.45
					4.84		16.51		9.19	
					3.96		17.15		10.21	
<b>AL5 - 3</b>	08.02.2022	566	314	112	4.4	4.54	17.78	15.24	9.96	8.17
					3.96		15.24		7.4	
					5.28		12.7		7.15	
<b>AL5 - 4</b>	11.02.2022	539	301	116	4.4	3.66	13.34	13.97	10.98	9.45
					3.52		14.61		9.19	
					3.08		13.97		8.17	
<b>AL5 - 5</b>	15.02.2022	623	389	130	3.52	3.96	19.69	19.05	10.72	11.66
					3.96		17.78		11.49	
					4.4		19.69		12.76	
<b>AL5 - 6</b>	18.02.2022	640	391	118	3.08	3.81	13.34	17.36	10.21	10.47
					3.52		19.05		10.47	
					4.84		19.69		10.72	
<b>AL5 - 7</b>	22.02.2022	474	253	100	3.08	3.81	12.07	14.4	7.66	7.91
					4.84		12.7		7.91	
					3.52		18.42		8.17	
<b>AL5 - 8</b>	25.02.2022	537	300	109	3.52	4.54	17.78	15.24	9.96	9.02
					4.84		13.34		8.93	
					5.28		14.61		8.17	
<b>Monthly Average</b>		523	300	112		4.03		16.17		9.41
<b>Standard Deviation</b>		91	65	9		0.34		1.75		1.2

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NS: Not Specified

<b>Table 6 : Results of Air Pollutant Concentration at Coal Storage Area</b>					
<b>Parameter</b>	<b>Date</b>	<b>C6H6 [µg/m3]</b>	<b>HC* ppm</b>	<b>CO [mg/m3]</b>	<b>CO2 [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m3</b>	<b>NS</b>	<b>4.0 mg/m3</b>	<b>NS</b>
AL5 - 1	01.02.2022	1.114	BDL	2.12	524
AL5 - 2	04.02.2022	1.127	BDL	1.4	432
AL5 - 3	08.02.2022	1.201	BDL	1.93	539
AL5 - 4	11.02.2022	1.097	BDL	1.97	1164
AL5 - 5	15.02.2022	1.231	BDL	2	1447
AL5 - 6	18.02.2022	1.103	BDL	1.87	562
AL5 - 7	22.02.2022	1.165	BDL	2.09	1408
AL5 - 8	25.02.2022	1.2	BDL	2.17	561
<b>Monthly Average</b>		<b>1.15</b>	<b>-</b>	<b>1.94</b>	<b>830</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.24</b>	<b>432</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit -

NMHC: 0.5 ppm) NS-Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 523 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 300 µg/m<sup>3</sup>, which is well above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 112 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.03 µg/m<sup>3</sup>, 16.17 µg/m<sup>3</sup> and 9.41 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.15 µg/m<sup>3</sup>,



well below the permissible limit of 5.0  $\mu\text{g}/\text{m}^3$ . HC's were below the detectable limit and Carbon Monoxide concentration was **1.94**  $\text{mg}/\text{m}^3$ , well below the permissible limit of 4.0  $\text{mg}/\text{m}^3$ .

**Location 6: Tuna Port (AL-6)**

**Table 1 : Results of Air Pollutant Concentration atTuna Port**

Parame ter	Date	TSPM [µg/m <sup>3</sup> ]	PM10 [µg/m <sup>3</sup> ]	PM2.5 [µg/m <sup>3</sup> ]	SO <sub>2</sub> [µg/m <sup>3</sup> ]		NOx [µg/m <sup>3</sup> ]		NH <sub>3</sub> [µg/m <sup>3</sup> ]	
Sampli ng Perio d		24hr	24hr	24hr	8 hr	24h r (Av g.)	8 hr	24h r (Av g.)	8 hr	24h r (Av g.)
NAAQ MS limit		NS	100 [µg/m <sup>3</sup> ]	60 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		80 [µg/m <sup>3</sup> ]		400 [µg/m <sup>3</sup> ]
<b>AL6 -1</b>	01.02.2 02 2	21 1	96	88	4.84	4.69	15.88	13.97	9.96	9.1
					5.28		14.61		10.21	
					3.96		11.43		7.15	
<b>AL6 - 2</b>	04.02.2 02 2	24 1	159	77	3.08	3.66	17.78	15.03	7.15	8
					4.4		15.24		7.91	
					3.52		12.07		8.93	
<b>AL6 - 3</b>	08.02.2 02 2	37 0	203	167	4.4	4.84	19.05	20.75	7.91	7.7 4
					5.28		20.96		7.4	
					4.84		22.23		7.91	
<b>AL6 - 4</b>	11.02.2 02 2	30 4	183	114	3.96	4.4	12.07	13.55	10.21	9.3 6
					4.4		12.7		10.47	
					4.84		15.88		7.4	
<b>AL6 - 5</b>	15.02.2 02 2	28 7	172	113	4.4	4.98	19.05	18.84	10.72	11.66
					4.84		17.78		11.49	
					5.71		19.69		12.76	
<b>AL6 - 6</b>	18.02.2 02 2	30 6	171	128	3.96	4.4	19.05	19.9	7.66	12
					4.4		19.69		15.57	
					4.84		20.96		12.76	
<b>AL6 - 7</b>	22.02.2 02 2	24 2	137	97	4.4	4.25	17.78	18.84	8.93	9.8 7
					4.84		19.05		10.21	
					3.52		19.69		10.47	
<b>AL6 - 8</b>	25.02.2 02 2	31 3	169	127	4.84	4.69	19.69	17.78	10.47	9.7 9
					5.28		16.51		9.7	
					3.96		17.15		9.19	
<b>Month ly Avera ge</b>		284	161	114		4.49		17.33		9.69
<b>Stand ard Deviat</b>		51	32	28		0.41		2.78		1.53

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NS: Not Specified

<b>Table 6B : Results of Air Pollutant Concentration at Tuna Port</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
<b>AL6 -1</b>	01.02.2022	1.115	BDL	1.64	552
<b>AL6 -2</b>	04.02.2022	1.088	BDL	1.5	425
<b>AL6 -3</b>	08.02.2022	1.271	BDL	1.9	466
<b>AL6 -4</b>	11.02.2022	1.197	BDL	2.12	1122
<b>AL6 -5</b>	15.02.2022	1.088	BDL	2.18	1006
<b>AL6 -6</b>	18.02.2022	1.044	BDL	1.96	430
<b>AL6 -7</b>	22.02.2022	1.096	BDL	2.07	436
<b>AL6 -8</b>	25.02.2022	1.145	BDL	2.22	430
<b>Monthly Average</b>		<b>1.13</b>	<b>-</b>	<b>1.95</b>	<b>608</b>
<b>Standard Deviation</b>		<b>0.07</b>	<b>-</b>	<b>0.26</b>	<b>286</b>

\* NMHC- Non- Methane Hydrocarbons  
 BQL- Below Quantification Limit (Quantification Limit –  
 NMHC: 0.5 ppm) NS- Not Specified

The mean TSPM values at Tuna Port were 284 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 161 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 114 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.49µg/m<sup>3</sup>, 17.33 µg/m<sup>3</sup> and 9.69 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was **1.13** µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.95 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 7: Signal Building (Vadinar) (AL-7)**

**Table 1 : Results of Air Pollutant Concentration at Signal Building**

Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL7 -1	01.02.22	170	101	68	3.96	3.81	13.34	13.34	8.42	8.34
					3.08		12.07		8.93	
					4.4		14.61		7.66	
AL7 -2	04.02.22	190	114	73	4.84	4.1	22.23	18.42	7.66	7.32
					3.96		19.69		7.91	
					3.52		13.34		6.38	
AL7 -3	08.02.22	152	86	64	4.84	5.28	12.7	14.61	8.68	9.79
					5.28		14.61		10.21	
					5.71		16.51		10.47	
AL7 -4	11.02.22	211	119	90	4.4	4.84	19.69	16.94	7.66	8.34
					4.84		17.78		8.42	
					5.28		13.34		8.93	
AL7 -5	15.02.22	154	86	65	5.71	4.69	20.33	19.9	9.7	8
					4.84		22.87		7.4	
					3.52		16.51		6.89	
AL7 -6	18.02.22	173	94	70	3.08	3.66	12.07	13.97	7.66	9.45
					3.52		13.34		10.21	
					4.4		16.51		10.47	
AL7 -7	22.02.22	154	93	58	3.52	3.52	14.61	16.51	10.72	9.36
					3.96		19.69		8.93	
					3.08		15.24		8.42	
AL7 -8	25.02.22	165	89	68	5.28	4.25	12.07	15.46	10.21	9.87
					3.96		15.24		10.98	
					3.52		19.05		8.42	
Monthly Average		171	98	69		4		16		9
Standard Deviation		21	13	9		1		2		1

Station: DPT/21-22/22 - 21

DPT/21-22/22 -

NS: Not Specified

<b>Table 7B : Results of Air Pollutant Concentration at Signal Building</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL7 -1	01.02.2022	1.17	BQL	1.73	485
AL7 - 2	04.02.2022	1.2	BQL	1.95	323
AL7 - 3	08.02.2022	1.02	BQL	2.04	227
AL7 - 4	11.02.2022	1.13	BQL	1.99	232
AL7 - 5	15.02.2022	1.04	BQL	2.11	400
AL7 - 6	18.02.2022	1.15	BQL	1.93	165
AL7 - 7	22.02.2022	1.2	BQL	1.75	312
AL7 - 8	25.02.2022	1.23	BQL	1.87	275
<b>Monthly Average</b>		<b>1.14</b>	<b>-</b>	<b>1.92</b>	<b>302</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.13</b>	<b>103</b>

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit -

NMHC: 0.5 ppm) NS Not Specified

The mean TSPM values at Vadinar Port were 171 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 98 µg/m<sup>3</sup>, which is below the permissible limit. PM<sub>2.5</sub> values were also within the permissible limit (mean = 69 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.0 µg/m<sup>3</sup>, 16.0 µg/m<sup>3</sup> and 9.0 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.14 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.92mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



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### Location 8: Admin Building (Vadinar) (AL-8)

Table 1 : Results of Air Pollutant Concentration at Admin Building										
Parame ter	Date	TSPM [µg/m³ ]	PM10 [µg/m³ ]	PM2.5 [µg/m³ ]	SO <sub>2</sub> [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Samplin g Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQM S limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL8 -1	01.02.22	120	74	43	5.28	4.54	17.78	17.78	7.15	8.08
					2.64		19.69		6.89	
					5.71		15.88		10.21	
AL8 -2	04.02.22	188	111	75	3.08	3.37	16.51	18.21	8.42	7.83
					2.64		20.33		7.4	
					4.4		17.78		7.66	
AL8 -3	08.02.22	189	108	79	3.96	3.22	17.15	18.21	7.66	7.15
					3.08		22.23		7.4	
					2.64		15.24		6.38	
AL8 -4	11.02.22	168	96	69	3.52	3.96	12.07	16.94	7.4	9.36
					3.96		19.69		10.21	
					4.4		19.05		10.47	
AL8 -5	15.02.22	213	113	90	3.08	3.37	13.34	14.61	7.91	8.08
					2.64		14.61		8.93	
					4.4		15.88		7.4	
AL8 -6	18.02.22	210	107	88	4.84	5.28	19.05	18.63	9.7	8.51
					5.71		20.96		8.42	
					5.28		15.88		7.4	
AL8 -5	22.02.22	195	109	85	2.64	3.96	17.78	19.69	8.68	7.91
					4.4		19.69		7.4	
					4.84		21.6		7.66	
AL8-6	25.02.22	206	114	80	4.84	5.42	19.69	19.69	9.45	8
					5.28		20.96		7.4	
					6.15		18.42		7.15	
Monthly Average		186	104	76		4		18		8
Standard Deviation		31	13	15		1		2		1

NS: Not Specified



<b>Table 8B : Results of Air Pollutant Concentration at Admin Building</b>					
<b>Parameter</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC* ppm</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>NS</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>NS</b>
AL8 -1	01.02.2022	1.14	BQL	1.63	545
AL8-2	04.02.2022	1.15	BQL	2	346
AL8 -3	08.02.2022	1.16	BQL	2.09	160
AL8-4	11.02.2022	1.13	BQL	2.17	216
AL8 -5	15.02.2022	1.01	BQL	2.16	352
AL8-6	18.02.2022	1.26	BQL	1.95	292
AL8-7	22.02.2022	1.04	BQL	2.14	148
AL8-8	25.02.2022	1.13	BQL	1.87	275
<b>Monthly Average</b>		<b>1.13</b>	<b>-</b>	<b>2</b>	<b>292</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.18</b>	<b>128</b>

\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit -

NMHC: 0.5 ppm) NS-Not Specified

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Admin Building Vadinar was comparatively low among all the locations of Air Quality monitoring in Kandla Port and Vadinar Port. The mean TSPM values at Vadinar Port were 186 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 104 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were above the permissible limit (mean = 76.0 µg/m<sup>3</sup>). The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.0µg/m<sup>3</sup>, 18.0µg/m<sup>3</sup> and 8.0µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Admin Building, Vadinar Port. The mean Benzene concentration was 1.13 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was

2.00 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

#### **1.4 Observations and Conclusion**

During the monitoring period, the overall Ambient Air Quality of the port area was found to be well within the desired levels for various gaseous pollutants. However, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan, Estate Office, Tuna Port and Oil Jetty area.

# Drinking Water Monitoring

## 2. Drinking Water Quality Monitoring

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

### 2.1 Drinking Water Monitoring Methodology

Drinking water samples were collected from 20 locations as prescribed in the tender document. Samples for physico-chemical analysis were collected in 1 liter carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling and Analysis was done as per standard methods - IS 10500:2012. The water samples were analyzed for various parameters, viz. Color, Odor, Turbidity, Conductivity, pH, Chlorides, TDS, Total Hardness, Iron, Sulphate, Salinity, DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (cfu).

### 2.2 Results

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 9 to Table No. 15



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**Table 9: Drinking Water Quality Monitoring Parameters for Nirman Building 1, P & C building & Main Gate (North) at Kandla**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C building	Main Gate North	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.2	7.1	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	950	1120	1020	500	2000
3	Turbidity	NTU	0	0	1	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1720	2130	1820	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	561.2	606.35	546.21	250	1000
9	Ca as Ca	mg/l	60.12	64.13	68.14	75	200
10	Mg as Mg	mg/l	68.04	68.04	70.47	30	100
11	Total Hardness	mg/l	430	440	460	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.74	0.69	0.81	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	254.4	222	206.4	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	ND	ND	ND	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	7.18	6.9	7.88	45	No Relaxation
17	Salinity	%	1.01	1.09	0.98	NS*	NS*
18	Sodium as Na	mg/l	322.8	278.8	319.4	NS*	NS*
19	Potassium as K	mg/l	3.89	3.18	4.11	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05

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2 5	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
2 6	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
2 7	Zinc	mg/l	BQL	BQL	BQL	5	15
2 8	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

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**Table 10: Drinking Water Quality Monitoring Parameters for Canteen, West Gate - I & Wharf Area at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate - I	Wharf Area	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.4	7.5	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1160	970	1060	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	2160	1790	1950	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	626.39	586.3	616.37	250	1000
9	Ca as Ca	mg/l	56.11	52.1	60.12	75	200
10	Mg as Mg	mg/l	75.33	70.47	63.18	30	100
11	Total Hardness	mg/l	450	420	410	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.82	0.4	0.52	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	246	217.2	214.8	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	ND	ND	ND	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	8.65	9.5	9.92	45	No Relaxation
17	Salinity	%	1.13	1.06	1.11	NS*	NS*
18	Sodium as Na	mg/l	301.8	284.8	310.8	NS*	NS*
19	Potassium as K	mg/l	3.74	3.94	4.74	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15

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28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent
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\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 11: Drinking Water Quality Monitoring Parameters for Sewa sadan - 3, Workshop I & Custom Building at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan - 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.2	7.6	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	980	1120	1210	500	2000
3	Turbidity	NTU	0	0	1	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1730	2090	2230	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	546.21	581.29	611.35	250	1000
9	Ca as Ca	mg/l	72.14	56.11	48.1	75	200
10	Mg as Mg	mg/l	63.18	75.33	72.9	30	100
11	Total Hardness	mg/l	440	450	420	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.55	0.85	0.92	1	1.5
14	Sulphate	mg/l	231.6	252	265.2	200	400
15	Nitrite	mg/l	ND	ND	ND	NS*	NS*
16	Nitrate	mg/l	12.32	10.77	11.33	45	No Relaxation
17	Salinity	%	0.98	1.05	1.1	NS*	NS*
18	Sodium as Na	mg/l	286.3	334.8	326.4	NS*	NS*
19	Potassium as K	mg/l	3.69	5.08	4.57	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05

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2 5	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
2 6	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
2 7	Zinc	mg/l	BQL	BQL	BQL	5	15
2 8	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 12: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla & A.O. Building at Gandhidham**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.3	7.5	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1130	1210	960	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	2040	2360	1750	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	656.45	646.43	576.28	250	1000
9	Ca as Ca	mg/l	52.1	60.12	64.13	75	200
10	Mg as Mg	mg/l	1.18	1.16	1.04	30	100
11	Total Hardness	mg/l	410	440	450	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.81	0.73	0.86	1	1.5
14	Sulphate	mg/l	184.8	195.6	202.8	200	400
15	Nitrite	mg/l	ND	ND	ND	NS*	NS*
16	Nitrate	mg/l	8.87	12.32	12.74	45	No Relaxation
17	Salinity	%	1.18	1.16	1.04	NS*	NS*
18	Sodium as Na	mg/l	301.8	332.4	296.3	NS*	NS*
19	Potassium as K	mg/l	4.86	5.11	3.73	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15



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28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent
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\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 13: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House & E - Type Quarter at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	School Gopalpuri	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.3	7.6	7.5	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1060	1220	1130	500	2000
3	Turbidity	NTU	0	1	1	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1850	2360	2100	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	616.37	531.181	516.147	250	1000
9	Ca as Ca	mg/l	68.14	60.12	64.13	75	200
10	Mg as Mg	mg/l	72.9	75.33	70.47	30	100
11	Total Hardness	mg/l	470	460	450	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.636	0.69	0.74	1	1.5
14	Sulphate	mg/l	206.4	198	174	200	400
15	Nitrite	mg/l	ND	ND	ND	NS*	NS*
16	Nitrate	mg/l	10	10.98	9.5	45	No Relaxation
17	Salinity	%	1.11	0.95	0.93	NS*	NS*
18	Sodium as Na	mg/l	312.7	304.8	88.26	NS*	NS*
19	Potassium as K	mg/l	4.39	4.27	7.43	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003

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24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 14: Drinking Water Quality Monitoring Parameters for F - Type Quarter, Hospital Gopalpuri & Tuna Port**

Sr. No .	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.4	7.3	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1080	1100	980	500	2000
3	Turbidity	NTU	1	0	0	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Unit	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1830	2140	1920	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride	mg/l	566.25	616.37	542.14	250	1000
9	Ca as Ca	mg/l	68.14	72.14	76.15	75	200
10	Mg as Mg	mg/l	58.32	60.75	55.89	30	100
11	Total Hardness	mg/l	410	430	420	200	600
12	Iron as Fe+3	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.95	0.86	0.66	1	1.5
14	Sulphate	mg/l	181.2	213.6	218.4	200	400
15	Nitrite	mg/l	ND	ND	ND	NS*	NS*
16	Nitrate	mg/l	10.77	8.51	7.6	45	No Relaxation
17	Salinity	%	1.02	1.11	0.93	NS*	NS*
18	Sodium as Na	mg/l	325.9	286.8	330.9	NS*	NS*
19	Potassium as K	mg/l	4.12	3.36	5.28	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15

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28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent
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\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 15: Drinking Water Quality Monitoring Parameters for Vadinar Jetty & Port Colony at Vadinar**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.5	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1070	1030	500	2000
3	Turbidity	NTU	0	1	1	5
4	Odor	-	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	5	15
6	Conductivity	µs/cm	2010	1030	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride	mg/l	496.1	511.13	250	1000
9	Ca as Ca	mg/l	64.13	56.11	75	200
10	Mg as Mg	mg/l	72.9	75.33	30	100
11	Total Hardness	mg/l	460	450	200	600
12	Iron as Fe+3	mg/l	BQL	BQL	0.3	No Relaxation
13	Fluorides	mg/l	0.86	0.8	1	1.5
14	Sulphate	mg/l	19.44	19.08	200	400
15	Nitrite	mg/l	ND	ND	NS*	NS*
16	Nitrate	mg/l	7.95	8.51	45	No Relaxation
17	Salinity	%	0.89	0.92	NS*	NS*
18	Sodium as Na	mg/l	467.8	478	NS*	NS*
19	Potassium as K	mg/l	4.36	4.72	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100	Absent	Absent	Absent	Absent

DCPL/DPT/21-22/22

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		ml				
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\*NS: Not Specified,

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



### **2.3 Results & Discussion**

The colour of all drinking water samples was <5 Hazen unit and odour of the samples was also agreeable. All parameters are found to be within the specified limit of the Drinking water Standard.

#### **pH**

The limit of pH value for drinking water is specified as 6.5 to 8.5. pH value in the studied area varied from 7.1 to 7.6 pH unit. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Total Dissolved Solids (TDS)**

TDS values in the studied area varied between 950 - 1220 mg/l. None of the sampling points showed higher TDS values than the prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of February ranged from 1030-2360  $\mu\text{S}/\text{cm}$ . Electrical conductivity standards do not appear in BIS standards for drinking water.

#### **BOD**

BOD value in the studied area was found Below Quantification Limit (2.0 mg/l). Indian standards does not show any standard values for BOD in drinking water.

#### **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. Chloride value in the studied area varied between 496.1- 656.4 mg/l and is found to be within the Permissible limit of the Drinking Water Standard.

#### **Calcium**

Calcium value in the studied area varied between 48.09 - 76.15 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. If calcium is present beyond the maximum acceptable limit, it causes incrustation of pipes.

## **Magnesium**

Magnesium value in the studied area varied between 55.89 - 75.33 mg/l. All the locations had Magnesium within the prescribed limits of 30-100 mg/L.

## **Total Hardness**

Hardness value in the studied area varied between 410 - 470 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. The prescribed limit by Indian Standards is 200-600 mg/L.

## **Iron**

Iron value in the studied area was found Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards is 0.3 mg/L. The excess amount of iron causes slight toxicity; gives stringent taste to water.

## **Fluoride**

Fluoride value in the studied area varied between 0.4 - 0.9 mg/l and hence well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

## **Sulphates**

Sulphate value in the studied area varied between 19.08 - 265.2mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

## **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

Nitrite values in all the water samples were found Below Quantification Limit (0.1 mg/l). There are no specified standard values for Nitrites in Drinking water. The minimum Nitrate value in drinking water of KPT was 0.0055 mg/l which is well within the permissible limit of the Drinking water Standard.

## **Salinity**

Salinity in drinking water in the present samples collected ranged from 0.8 to 1.1%. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected ranged from 88 - 478 mg/l and Potassium salts ranged from 3.18 to 7.43 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter at all location shows that Bacteria is not present and hence Bacterial count is in line with the permissible limit of drinking water. This shows that all the drinking water samples were safe from any bacteriological contamination.

### **2.4 Conclusions**

These results are compared with acceptable limits as prescribed in IS 10500:2012 - Drinking Water Specification. It is seen from the analysis data that during the study period the water was safe for human consumption at all drinking water monitoring stations.

# Noise Quality Monitoring

### 3. Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

#### 3.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

#### 3.2 Results

**Table 16: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	<b>Sampling Time</b>	<b>6:00 am to 10:00 PM</b>	<b>10:00PM to 6:00 AM</b>
1	Marine Bhavan	55.2	55.5
2	Nirman Building 1	47	53.9
3	Tuna Port	45.2	44.6
4	Main Gate North	60.8	53.1
5	West Gate I	61.8	60.3
6	Canteen Area	54.5	53.4
7	Main Road	58.4	57.1
8	ATM Building	60.7	51.5
9	Wharf Area /Jetty Area	64	58.8
10	Port & Custom Office	48.4	47.2
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	59.8	58
12	Nr. Port Colony, Vadinar	57	53.4
13	Nr. Vadinar Jetty	58.3	54.7

### **3.3 Conclusions**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 13 locations at Deendayal Port ranged from 45.24 dB(A) to 63.98 dB(A) and it was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from 44.58 dB to 60.26 dB(A) and it was within the permissible limits of 70 dB(A) for the industrial area for the night time.

# Soil Quality Monitoring



#### 4. Soil Monitoring

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

##### 4.1 Methodology

The soil samples were collected in the month of February 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

##### 4.2 Results

**Table-17: Chemical Characteristics of Soil in the Study Area**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	KPT Admin Site	KPT Colony
			Near main gate of Port	10 m away from main gate	Sand from creek at low tide			Vadinar
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	8.59	8.6	8.68	8.47	7.64	7.11
3	Electrical Conductivity	µs/cm	2,839.00	1,442.00	1,950.00	2,848.00	1,417.00	299.6
4	Moisture	%	22	28.37	21	24.88	8.49	3.96
5	Total Organic Carbon	%	0.96	0.71	0.98	0.84	0.32	0.67
6	Alkalinity	mg/kg	40.04	40.04	40.04	40.04	60.06	40.04
7	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
8	Chloride	mg/kg	3,545.00	2,481.50	2,836.00	3,190.50	141.8	70.9
9	Sulphate	mg/kg	3,891.18	1,650.89	1,292.27	4,950.89	250.38	BQL
10	Phosphorus	mg/kg	50.87	5.33	8.87	8.5	1..88	BQL
11	Potassium	mg/kg	192.3	155.01	160.36	178.48	30.01	28.87
12	Sodium	mg/kg	2,466.12	1,500.32	1,839.79	2,450.29	153.5	20.32
13	Calcium	mg/kg	284.57	432.86	232.46	492.9	837.67	472.94

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1 4	Copper as Cu	mg/kg	26.2	35.6	31.8	25	18.3	62.3
1 5	Lead as Pb	mg/kg	7.5	10.8	5.4	7.6	BQL	BQL
1 6	Nickel as Ni	mg/kg	39.1	42.9	42	31.9	60.2	33.3
1 7	Zinc as Zn	mg/kg	58.2	102.7	76.7	48.1	84.6	44
1 8	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg).

### 4.3 Discussion

The data shows that value of pH ranges from 7.11 at KPT Colony (Vadinar) to 8.68 at Khori Creek indicating that all soil samples are neutral to slight basic. Nakti creek samples showed maximum conductivity of 2848.0  $\mu\text{mhos/cm}$ , while KPT Colony (Vadinar) location showed minimum conductivity of 299.6  $\mu\text{mhos/cm}$ . Conductivity at Vadinar Port was 299.6 and 1417.0  $\mu\text{mhos/cm}$  at Admin site and Vadinar Port colony respectively.

Total organic Carbon ranged from 0.32 % to 0.98 at Deendayal Port. At Vadinar Port, organic

The concentration of Phosphorus and Potassium in the soil samples varies from 5.33 to 50.87 mg/kg and 28.87 to 192.3 mg/kg respectively at Deendayal Port. The mean concentration of Phosphorous at Vadinar site was 1.88 mg/kg and mean concentration of Potassium at Vadinar site was 29.44 mg/kg.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) are of saline nature as they are coastal soil; where as other locations are inland locations and have different chemical properties.

### Heavy Metals in the Soil

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### 4.4 Conclusion

The soils of Deendayal Port and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

# Sewage Treatment Quality Monitoring

## **5. Sewage Treatment Plant Monitoring**

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guide lines of State Pollution Control Board and other statutory bodies.

### **5.1 Methodology for STP Monitoring**

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

### **5.2 Results**

#### **Kandla STP**

**Table 18: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>		03.02. 22		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>KPT STP I/L</b>	<b>KPT STP O/L</b>
1	pH	pH unit	7.75	7.54
2	Total Suspended Solids	mg/l	144	93.1
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	434.3	102
5	BOD @ 27 °C	mg/l	140	28
6	Fecal Coliform	MPN Index / 100 ml	-	110
<b>Aeration Tank</b>				
7	MLSS	mg/l	88	
8	MLVSS	%	56	

**Table 19: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

Date of Sampling		07.02.		
Sr. No.	Parameters	Unit	Results	
			KPT STP I/L	KPT STP O/L
1	pH	pH unit	7.72	7.41
2	Total Suspended Solids	mg/l	193.4	101.5
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	373	104
5	BOD @ 27 °C	mg/l	108	24
6	Fecal Coliform	MPN Index / 100 ml	-	920
<b>Aeration Tank</b>				
7	MLSS	mg/l	80	
8	MLVSS	%	52	

**Table 20: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

Date of Sampling		14.02.22		
Sr. No.	Parameters	Unit	Results	
			KPT STP I/L	KPT STP O/L
1	pH	pH unit	7.73	7.5
2	Total Suspended Solids	mg/l	211.2	101.3
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	242.4	105
5	BOD @ 27 °C	mg/l	108	24
6	Fecal Coliform	MPN Index / 100 ml	-	>1600.0
<b>Aeration Tank</b>				
7	MLSS	mg/l	85	

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8	MLVSS	%	63
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**Table 21: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>		21.02. 22		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>KPT STP I/L</b>	<b>KPT STP O/L</b>
1	pH	pH unit	7.51	7.35
2	Total Suspended Solids	mg/l	191.4	105.2
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	232.3	101.1
5	BOD @ 27 °C	mg/l	64	21
6	Fecal Coliform	MPN Index / 100 ml	-	320
<b>Aeration Tank</b>				
7	MLSS	mg/l	87	
8	MLVSS	%	51	

### Gopalpuri Colony STP

**Table 22: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>		03.02. 22		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>Gopalpuri STP I/L</b>	<b>Gopalpuri STP O/L</b>
1	pH	pH unit	7.8	7.61
2	Total Suspended Solids	mg/l	198.2	97
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	393.9	102.1
5	BOD @ 27 °C	mg/l	130	26
6	Fecal Coliform	MPN Index / 100 ml	-	350
<b>Aeration Tank</b>				
7	MLSS	mg/l	28	
8	MLVSS	%	92	

**Table 23: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	07.02. 22
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Sr. No.	Parameters	Unit	Results	
			Gopalpuri STP I/L	Gopalpuri STP O/L
1	pH	pH unit	7.51	7.25
2	Total Suspended Solids	mg/l	405.6	107.2
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	384	112
5	BOD @ 27 °C	mg/l	122	28
6	Fecal Coliform	MPN Index / 100 ml	-	170
<b>Aeration Tank</b>				
7	MLSS	mg/l	32	
8	MLVSS	%	90	

**Table 24: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	14.02. 22
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Sr. No.	Parameters	Unit	Results	
			Gopalpuri STP I/L	Gopalpuri STP O/L
1	pH	pH unit	7.6	7.4
2	Total Suspended Solids	mg/l	308.4	119.7
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	474	101
5	BOD @ 27 °C	mg/l	160	28
6	Fecal Coliform	MPN Index / 100 ml	-	>1600.0
<b>Aeration Tank</b>				
7	MLSS	mg/l	27	
8	MLVSS	%	98	

**Table 25: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

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<b>Date of Sampling</b>	21.02. 22
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Sr. No.	Parameters	Unit	Results	
			Gopalpuri STP I/L	Gopalpuri STP O/L
1	pH	pH unit	7.75	7.45
2	Total Suspended Solids	mg/l	244.2	102.5
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	212.1	101
5	BOD @ 27 °C	mg/l	72	20
6	Fecal Coliform	MPN Index / 100 ml	-	
<b>Aeration Tank</b>				
7	MLSS	mg/l	37	
8	MLVSS	%	90	

### Vadinar STP

**Table 26: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	03.02. 22
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Sr. No.	Parameters	Unit	Results	
			Vadinar STP I/L	Vadinar STP O/L
1	pH	pH unit	7.65	7.36
2	Total Suspended Solids	mg/l	103.8	63.5
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	243	98
5	BOD @ 27 °C	mg/l	86	24
6	Fecal Coliform	MPN Index /100 ml	-	540

**Table 27: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>		07.02. 22		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>Vadinar STP I/L</b>	<b>Vadinar O/L</b>
1	pH	pH unit	7.5	7.3
2	Total Suspended Solids	mg/l	108.8	31
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	373.0	102.0
5	BOD @ 27 °C	mg/l	102.0	28.0
6.	Fecal Coliform	MPN Index /100 ml	-	540.0

**Table 28: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>		14.02. 22		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>Vadinar STP I/L</b>	<b>Vadinar O/L</b>
1	pH	pH unit	7.39	7.2
2	Total Suspend edSolids	mg/l	107	56.5
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	171.0	61.0
5	BOD @ 27 °C	mg/l	56.0	21.0

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6 .	Fecal Coliform	MPN Index /100 ml	-	350. 0
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**Table 29: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>		21.02. 22		
<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>	
			<b>Vadinar STP I/L</b>	<b>Vadinar O/L</b>
1	pH	pH unit	7.4 2	7.26
2	Total Suspended Solids	mg/l	105	58.8
3	Residual Chlorine	mg/l	-	<0.5
4	COD	mg/l	202	80.8
5	BOD @ 27 °C	mg/l	88. 0	23.0
6.	Fecal Coliform	MPN Index /100 ml	-	220.0

### **5.3 Conclusions:**

The GPCB standards of BOD, TSS and Residual Chlorine for STP outlet are 20 mg/lit, 30 mg/lit &

0.5 mg/lit respectively. It is suggested to do treatment on regular basis to avoid flow of contaminated/polluted water into the sea.

# Marine Water Quality Monitoring



## **Marine Water Monitoring**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of 'green thinking'. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A(g) states that the "fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures".

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision- making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at "integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources." The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

## **Marine Environment**

On national and state levels, we have several policies and regulation like Water (Prevention and Control of Pollution) Act, 1974, to regulate pollution discharges and restore water quality of our aquatic resources including the prescription of monitoring activities. One of the important provisions of the Water Act, 1974, is to maintain and restore the 'wholesomeness' of our aquatic resources. Water quality monitoring is one of the first steps required in the rational development and management of water resources. In the field of water quality management, there has been a steady evolution in procedures for designing system to

all activities to obtain 'information' with respect to the water system.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 03<sup>rd</sup> & 04<sup>th</sup> February-2022 in harbor regions of KPT and on 03<sup>rd</sup> February-2022 at Vadinar during spring tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 10<sup>th</sup> & 11<sup>th</sup> February 2022 in harbor regions of KPT. 10<sup>th</sup> February -2022 in Vadinar during Neap tide period first quarter of Lunar Cycle..

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and two stations in Nakti creek and one station in Khori creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

### **Sampling Locations**

<b>Offshore monitoring requirement</b>	<b>Number of locations</b>
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khori creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### **5.4 Marine Water Quality**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality and Marine sediments are as below;

**Table 30: Marine Water Quality Monitoring Parameters for location near KPT colony**

Sr. No.	Parameters	Unit	Kandla Creek Near KPT colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.3	7.32	7.4	7.35
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.2	31	32.3	32
5	Turbidity	NTU	34	31	36	32
6	Total Dissolved Solids	mg/l	41406	42523	40796	42487
7	Total Suspended Solids	mg/l	532	643	663.9	659.2
8	Total Solids	mg/l	41976	43186	41520	43162
9	DO	mg/l	4.1	4.2	4.3	4.2
10	COD	mg/l	78	80	82	86
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.75	0.69	0.82	0.71
13	Phosphate	mg/l	0.25	0.23	0.23	0.22
14	Sulphate	mg/l	2676	2304	2256	2340
15	Nitrate	mg/l	2.68	2.53	3.03	2.75
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	681.36	721.44	641.28	601.2
18	Magnesium	mg/l	1652.4	1603.8	1628.1	1628.1
19	Sodium	mg/l	9167	9088	9038	9181
20	Potassium	mg/l	346	335	338	342
21	Iron	mg/l	1.71	1.98	0.62	0.25
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL

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28	Zinc	mg/l	BQL	BQL	BQL	BQL
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BQL- Below Quantification Limit, (BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 31: Marine Water Quality Monitoring Parameters for location near passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.4	7.26	7.45	7..38
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.8	32.1	31.8	31.9
5	Turbidity	NTU	30	28	29	35
6	Total Dissolved Solids	mg/l	41960	40901	42303	41608
7	Total Suspended Solids	mg/l	656	706	657.3	558.1
8	Total Solids	mg/l	42620	41610	42961	42170
9	DO	mg/l	4.3	4.4	4.6	4.7
10	COD	mg/l	80	78	86	88
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.65	0.6	0.75	0.65
13	Phosphate	mg/l	0.24	0.21	0.22	0.21
14	Sulphate	mg/l	2544	2520	2412	2544
15	Nitrate	mg/l	2.89	3.17	3.17	3.59
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	641.28	601.2	521.04	681.36
18	Magnesium	mg/l	1628.1	1628.1	1725.3	1676.7
19	Sodium	mg/l	9748	9232	9530	9408
20	Potassium	mg/l	385	353	379	371
21	Iron	mg/l	0.55	0.1	BQL	0.2
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL

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28	Zinc	mg/l	BQL	BQL	BQL	BQL
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BQL- Below Quantification Limit, (BOD-2.0 mg/l, Nitrite: 0.05mg/l Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 32: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.36	7.4	7.28	7.31
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.7	31.8	32	31.9
5	Turbidity	NTU	29	32	34	31
6	Total Dissolved Solids	mg/l	40799	38680	41634	42504
7	Total Suspended Solids	mg/l	599	709	599.5	614
8	Total Solids	mg/l	41401	39390	42233	43120
9	DO	mg/l	4.5	4.7	4.8	4.4
10	COD	mg/l	82	86	88	90
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.78	0.82	0.84	0.93
13	Phosphate	mg/l	0.19	0.2	0.21	0.2
14	Sulphate	mg/l	2220	2268	2100	2184
15	Nitrate	mg/l	3.94	3.59	3.87	4.01
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	561.12	641.28	721.44	641.28
18	Magnesium	mg/l	1749.6	1676.7	1676.7	1676.7
19	Sodium	mg/l	9446	9008	9030	9278
20	Potassium	mg/l	372	319	337	349
21	Iron	mg/l	0.62	1.55	0.21	1.36
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL

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28	Zinc	mg/l	BQL	BQL	BQL	4.28
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BQL- Below Quantification Limit, (BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 33: Marine Water Quality Monitoring Parameters for location Khorī creek at Kandla**

Sr. No.	Parameters	Unit	KPT 4			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.41	7.36	7.41	7.46
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32	31.5	31.8	32.1
5	Turbidity	NTU	38	36	30	28
6	Total Dissolved Solids	mg/l	40160	42448	39993	39941
7	Total Suspended Solids	mg/l	661	720	715.9	723.9
8	Total Solids	mg/l	40830	43187	40710	40670
9	DO	mg/l	4.6	4.3	4.5	4.6
10	COD	mg/l	88	80	78	72
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.93	0.89	0.89	0.71
13	Phosphate	mg/l	0.21	0.2	0.23	0.23
14	Sulphate	mg/l	1872	1944	2652	2700
15	Nitrate	mg/l	4.36	4.58	4.44	4.29
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	681.36	601.2	601.2	561.12
18	Magnesium	mg/l	1676.7	1749.6	1676.7	1652.4
19	Sodium	mg/l	9423	9064	9390	9725
20	Potassium	mg/l	332	299	357	387
21	Iron	mg/l	0.74	0.32	1.13	0.52
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL

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27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 34: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.4	7.48	7.33	7.39
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.8	31.8	32	31.8
5	Turbidity	NTU	35	37	37	38
6	Total Dissolved Solids	mg/l	38698	41456	38575	33050
7	Total Suspended Solids	mg/l	674	789	704.4	733.2
8	Total Solids	mg/l	39380	42245	39280	33790
9	DO	mg/l	4.4	4.5	4.3	4.4
10	COD	mg/l	96	90	92	90
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.65	0.67	0.67	0.73
13	Phosphate	mg/l	0.22	0.21	0.19	0.2
14	Sulphate	mg/l	2100	2172	2628	2580
15	Nitrate	mg/l	5	4.86	5.07	4.93
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	721.44	761.52	521.04	480.96
18	Magnesium	mg/l	1579.5	1530.9	1701	1773.9
19	Sodium	mg/l	10518	10127	9831	9748
20	Potassium	mg/l	415	403	388	376
21	Iron	mg/l	BQL	0.65	1.12	0.46
22	Chromium	mg/l	BQL	BQL	BQL	BQL

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2 3	Copper	mg/l	BQL	BQL	BQL	BQL
2 4	Arsenic	mg/l	BQL	BQL	BQL	BQL
2 5	Cadmium	mg/l	BQL	BQL	BQL	BQL
2 6	Mercury	mg/l	BQL	BQL	BQL	BQL
2 7	Lead	mg/l	BQL	BQL	BQL	BQL
2 8	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 35: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.5	Sampling not possible during Low Tide	7.5	Sampling not possible during Low Tide
2	Color	-	Colorless		Colorless	
3	Odor	-	Odorless		Odorless	
4	Salinity	ppt	20.8		18.1	
5	Turbidity	NTU	41		40	
6	Total Dissolved Solids	mg/l	35179		41035	
7	Total Suspended Solids	mg/l	614		678.5	
8	Total Solids	mg/l	35793		41714	
9	DO	mg/l	4.3		4.5	
10	COD	mg/l	96		90	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	0.82		0.85	
13	Phosphate	mg/l	0.21		0.21	
14	Sulphate	mg/l	2340		2376	
15	Nitrate	mg/l	5.07		4.65	
16	Nitrite	mg/l	BQL		BQL	
17	Calcium	mg/l	641.28		641.28	
18	Magnesium	mg/l	1676.7		1725.3	
19	Sodium	mg/l	10489		9631	
20	Potassium	mg/l	429		376	
21	Iron	mg/l	2.08		1.07	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		BQL	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	



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BQL- Below Quantification Limit, (BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 36: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.42	7.38	7.45	7.39
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	20.4	19.9	20.4	19.9
5	Turbidity	NTU	42	43	42	43
6	Total Dissolved Solids	mg/l	42652	41202	42652	41202
7	Total Suspended Solids	mg/l	690.6	741.7	690.6	741.7
8	Total Solids	mg/l	43343	41944	43343	41943
9	DO	mg/l	4.6	4.7	4.6	4.7
10	COD	mg/l	70	68	72	76
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.93	0.89	0.93	0.89
13	Phosphate	mg/l	0.22	0.2	0.22	0.2
14	Sulphate	mg/l	2508	2388	2508	2388
15	Nitrate	mg/l	3.17	2.89	3.17	2.89
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	561.12	601.2	561.12	601.2
18	Magnesium	mg/l	1798.2	1725.3	1798.2	1725.3
19	Sodium	mg/l	9768	9808	9106	9020
20	Potassium	mg/l	240	272	250	262
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL

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27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 36 (a): Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr.Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.4	7.6	7.45	7.26
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odor	Odor	Odor	Odor
4	Salinity	ppt	22.2	22.1	22	21.8
5	Turbidity	NTU	33	34	36	33
6	Total Dissolved Solids	mg/l	21700	21987	20620	20825
7	Total Suspended Solids	mg/l	635	480	513	548
8	Total Solids	mg/l	23340	23324	21384	22000
9	DO	mg/l	4.3	4.1	4.5	4.3
10	COD	mg/l	89	92	78	70
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.92	0.96	0.6	0.78
13	Phosphate	mg/l	0.24	0.25	0.2	0.16
14	Sulphate	mg/l	2628	2364	2316	2556
15	Nitrate	mg/l	3.1	3.38	3.34	3.68
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	481	561.12	521	561.12
18	Magnesium	mg/l	1652.4	2065.5	1676.7	1701
19	Sodium	mg/l	9318	9829	9428	9686
20	Potassium	mg/l	254	255	277	254
21	Iron	mg/l	1.11	1.62	1.27	1.9
22	Chromium	mg/l	BQL	BQL	BQL	BQL

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2 3	Copper	mg/l	BQL	BQL	BQL	BQL
2 4	Arsenic	mg/l	BQL	BQL	BQL	BQL
2 5	Cadmium	mg/l	BQL	BQL	BQL	BQL
2 6	Mercury	mg/l	BQL	BQL	BQL	BQL
2 7	Lead	mg/l	BQL	BQL	BQL	BQL
2 8	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

# Marine Sediment Quality Monitoring

### 5.4.1 Marine Sediments

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

### 5.5 Results

The Sediment Quality results are given in below from table no. 34 A & 34 B.

**Table 34 A: Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	KPT - 1	KPT - 2	KPT - 3	KPT - 4	KPT - 5	Jetty	SPM
1	Texture	-	Sand y Loam	Sand y Loam	Sand y Loam	Sand y Loam	Sand y Loam	Sand y Loam	Sandy Loam
2	Organic Matter	mg/kg	3.29	2.98	1.62	1.31	3.72	3.84	3.38
3	Organic Carbon	mg/kg	1.91	1.73	0.94	0.76	2.16	2.22	1.96
4	Inorganic Phosphate	mg/kg	110	121	122	135	125	118	119
5	Moisture	%	6.86	29.03	0.33	5.05	14.71	31.25	34.64
6	Aluminium	mg/kg	N D	N D	ND	ND	N D	ND	ND
7	Silica	mg/kg	12.5	11.6	10	11.3	12.5	12.7	11.1
8	Phosphate	mg/kg	17.75	14.14	6.72	3.15	2.11	14.34	ND
9	Sulphate	mg/kg	395.09	747.14	258.86	280.97	639.06	1178.56	977.43
10	Nitrite	mg/kg	0.12	0.11	0.12	0.11	0.13	232.46	228.46
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	160.32	168.34	156.31	168.34	200.4	232.46	228.46
13	Magnesium	mg/kg	38.88	80.19	46.17	55.89	121.5	119.07	94.77
14	Sodium	mg/kg	347.42	986.9	290.88	488.44	840.13	1381.03	1134.96
15	Potassium	mg/kg	22.5	97.95	36.87	52.4	89.96	180.87	158.17
16	Chromium	mg/kg	24.4	21.8	17.3	11	20.3	82.5	106
17	Nickel	mg/kg	2.5	14.8	13.9	3.2	9	41.5	34.6

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18	Copper	mg/kg	3.3	8.3	4.1	3.1	4	29	25.6
19	Zinc	mg/kg	11.1	20	16.8	9.8	14.9	40.3	107.5
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	3.6	4.2	3.4	3.8	3.5	6.6	8.2
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

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**Table 34 B: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameter s	Unit	KPT - 1	KPT - 2	KPT - 3	KPT - 4	KPT - 5	Jetty	SPM
1	Texture	-	Sand y Loam	Sandy Loam	Sand y Loam	Sand y Loam	Sand y Loam	Sand y Loam	Sand y Loam
2	Organic Matter	mg/kg	1.53	1.5	1.62	1.31	3.72	3.05	3.14
3	Organic Carbon	mg/kg	0.89	0.87	0.94	0.76	2.16	1.83	1.82
4	Inorgani c Phospha te	mg/kg	116	120	123	111	128	112	129
5	Moisture	%	0.81	0.27	0.33	5.05	14.71	24.04	26.83
6	Aluminium	mg/kg	ND	ND	ND	ND	ND	N D	ND
7	Silica	mg/kg	12.3	11.8	12.2	11.3	13.2	11.7	10
8	Phosphate	mg/kg	18.07	15.08	6.72	3.15	2.11	0.63	ND
9	Sulphate	mg/kg	456.82	295.8	258.86	280.97	639.06	577.88	756.91
10	Nitrite	mg/kg	0.12	0.11	0.11	0.12	0.11	0.11	0.12
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	152.3	160.32	156.31	168.34	200.4	196.39	208.42
13	Magnesium	mg/kg	41.31	51.03	46.17	55.89	121.5	143.37	179.82
14	Sodium	mg/kg	435.4	357.09	290.88	488.44	840.13	1019.68	1354.17
15	Potassium	mg/kg	22.6	39.84	36.87	52.4	89.96	191.04	187.09
16	Chromium	mg/kg	10.8	38.6	16.2	6.9	30.9	40	40.3
17	Nickel	mg/kg	3.6	5.4	15.5	5.5	21.5	26.2	25.9
18	Copper	mg/kg	2.8	4.3	127.1	0.9	7.6	14.5	13.2
19	Zinc	mg/kg	7	11.5	66.5	3.4	26	37.8	32
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	3.1	2.7	3.6	3.4	2.2	4.6	3.7
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

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\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg,Cd: 1.0mg/kg,Hg: 1.0mg/kg, As: 1.0mg/kg)

**REPORT  
ON  
ECOLOGICAL  
MONITORING OF  
MARINE ENVIRONMENT  
IN**

**DPT HARBOUR AREA, NEAR BY  
CREEKS AND  
VADINAR JETTY AND  
SPM FOR**

**DEENDAYAL PORT TRUST**

February, 2022

## **INTRODUCTION:**

### **Sampling Stations:**

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 02<sup>nd</sup> February 2022 in harbour region of DPT at Kandla Creek, and on 03<sup>rd</sup> February 2022 in creeks near by the port during spring tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 8<sup>th</sup> February, 2022 in harbour region of DPT at Kandla Creek and on 9<sup>th</sup> February, 2022 in creeks near by the port during neap tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and one stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period. The same sampling schedule was repeated during consecutive Neap tide and spring tide in same month.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during neap tide on 02/02/2022 and spring tide period on 08/02/2022 .Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

**TABLE #1 SAMPLING LOCATIONS**

<b>monitoring requirement</b>	<b>Number of locations</b>
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near 1 <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

### **Sampling methodology adopted:**

**A** marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency

distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample were taken in an opaque plastic bottle for

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chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with nilyobolt cloth of 20µm mesh size.

#### **Samples Processing for chlorophyll estimation:**

Samples for the chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 1998).

#### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is general term for organisms have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplankton is free floating organisms that are capable of photosynthesis and zooplankton is the various free floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, **plankton** and **nekton** (Lalli and Parsons, 1997). **Plankton** consists of all organisms drifting in the water and is unable to swim against water currents, whereas **Nekton** includes organisms having strong locomotive power. Ecological

studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating

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organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

### **Phytoplankton in the marine environment:**

Phytoplankton is free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio purifier and bio indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; diatoms and dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers



of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival

rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital

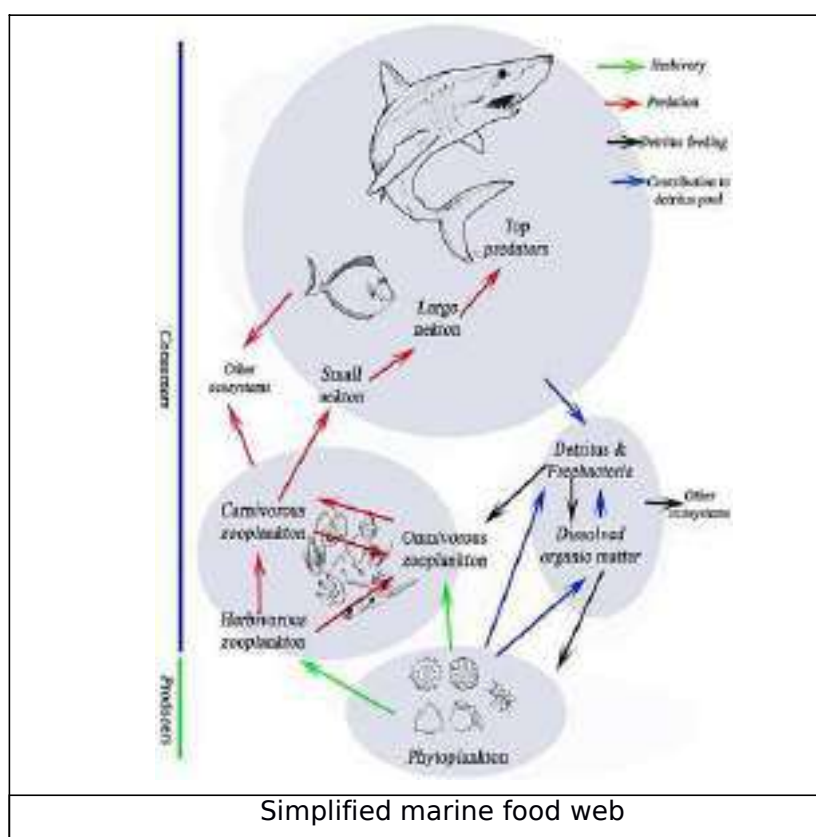
link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014) Of all the marine zooplankton groups, copepods mainly

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Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991;) It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplankton is efficient grazers of the phytoplankton and is referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### **Spatial distribution of Plankton:**

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilometres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate

that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

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At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton may also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

#### **Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight after the tow of about 15-30 minutes, plankton net was pulled up and washed down to the tail and collected the plankton adhered to plankton net in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward. For quantitative evaluation 50 L water samples were collected from subsurface layer and filtered through 20µm mesh size net by using bucket and filtration assembly.

#### **Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

#### **Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50ml with 5% formalin -Glycerine mixture.

#### **Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of zooplankton

that were encountered

***Cell counts by drop count method:***

The common glass slide mounted with a 1ml of concentrated phytoplankton / zooplankton sample in glycerol and covered with cover slip 22 x 60 mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the

microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total number of plankton in the original volume of sample filtered was calculated as units/L.

### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment-water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42 $\mu$  in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes.

### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The dis-aggregated sediments were then passed through the sieves.

### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the



preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in

a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

### **DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurran, A. E. (1988).

A diversity index is a measure of species diversity within a community that consists of co- occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H.R. *etal.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. The diversity measures that incorporate the two concepts may be termed heterogeneity measures (Magurran, 2004).

Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate species richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness ( $S$ ) and evenness ( $J$ ).

### **Simpson's diversity index** **DCPL/DPT/21-22/22 -**

Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present.. The Simson index is one of the meaningful and robust biodiversity measures available.( Magurran ,2004).

The formula for calculating D is presented as:

$$D \ll \frac{n_i n_i - 1}{N(N - 1)}$$

Where  $n_i$  = the total number of organisms of each individual species  
 $N$  = the total number of organisms of all species

The value of  $D$  ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When  $D$  increases diversity decreases. Simpson's index is therefore usually expressed as  $1-D$  or  $1/D$ . (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment
- food webs which are relatively simple
- change in the environment would probably have quite

serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile
- complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

### Species richness indices

The species richness ( **$S$** ) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness may be concomitant with severe or chronic human-induced perturbation (Fair weather 1990). Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001).

Species richness is the iconic measure of biological diversity (Magurran, 2004).

The species richness ( **$S$** ) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index ( $d$ ), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when the number of individuals increases. For a given number of types, the value of diversity

index is maximised when all types are equally abundant (Rosenzweig, M. L. (1995).

### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon- Wiener's index (**H**), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index (**H**) reproduces community parameters to a single number by using an equation.

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to

4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

$$H' = - \sum_{j=1}^s \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

### **RESULTS:**

#### **CHLOROPHYLL-a:**

Water Samples for the chlorophyll estimation were collected from sub surface layer during high tide and low tide period of the tidal cycle for each sampling locations and analysed for Chlorophyll-a and after acidification for Pheophytin-a. Chlorophyll- a value was used as algal biomass indicator (APHA,1998). Algal biomass was estimated by converting Chlorophyll value.

In the sub surface water chlorophyll-a was varying from 0.597 - 0.951 mg/m<sup>3</sup> with an average value 0.828 mg/m<sup>3</sup> of in harbour region of DPT in Kandla Creek during sampling done in spring tide period of February 2022. In the nearby creeks chlorophyll-a was varying from 0.395 - 1.528 mg/m<sup>3</sup> with an average value 1.007 mg/m<sup>3</sup> Pheophytin-a level was below detectable limit. All the sampling stations during spring tide.

In the sub surface water chlorophyll-a was varying from 0.709 - 1.0546 mg/m<sup>3</sup> with an average value 0.867 mg/m<sup>3</sup> in harbour region of DPT in Kandla Creek during sampling done in neap tide period of February 2022. In the nearby creeks chlorophyll-a was varying from

0.536 - 1.055 mg/m<sup>3</sup> with an average value 0.828mg/m<sup>3</sup>. Pheophytin-a level was below detectable limit- the all the sampling stations.

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In the sub surface water chlorophyll-a was varying from 0.628 - 1.156 mg/m<sup>3</sup> with an average value 0.883 mg/m<sup>3</sup>. in harbour region of DPT OOT in path finder Creek during sampling done in spring tide period of February 2022. In the sub surface water chlorophyll- a was varying from 0.833 - 1.039 mg/m<sup>3</sup> with an average value 0.940 mg/m<sup>3</sup>.in harbour region of DPT OOT in path finder Creek during sampling done in Neap tide period of February 2022.

**TABLE #2 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK, NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING SPRING TIDE IN FEBRUARY 2022**

Sr. No.	Station	Tide		Pheophytn- a (mg/m3)	Algal Biomass (Chlorophyll method) mg/m3
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.951	BD L	63.72
		Low tide	0.85	BD L	56.95
2	KPT 2	High tide	0.92	BD L	61.64
		Low tide	0.834	BD L	55.88
3	KPT 3	High tide	0.597	BD L	39.99
		Low tide	0.818	BD L	54.81
CREEKS					
4	KPT-4 Khor-I	High tide	1.156	BD L	77.45
		Low tide	0.903	BD L	60.5
5	KPT-5 Nakti-I	High tide	1.528	BD L	102.38
		Low tide	1.053	BD L	70.55
6	KPT-5 Nakti-II	High tide	0.395	BD L	26.46
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.833	BD L	55.81

BDL: Below Detectable Limit.





**TABLE #3 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA ,NEAR BY CREEKSAND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN FEBRUARY 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m3)	Pheophytin-a (mg/m3)	Algal Biomass (Chlorophyll method) mg/m3
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.834	BDL	55.88
		Low tide	1.054	BDL	70.62
2	KPT 2	High tide	0.709	BDL	47.5
		Low tide	0.952	BDL	63.78
3	KPT 3	High tide	0.833	BDL	55.81
		Low tide	0.819	BDL	54.87
CREEKS					
4	KPT-4 Khor-I	High tide	1.055	BDL	70.68
		Low tide	0.732	BDL	49.04
5	KPT-5 Nakti-I	High tide	0.865	BDL	57.96
		Low tide	0.953	BDL	63.85
6	KPT-5 Nakti-II	High tide	0.536	BDL	35.91
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.63	BDL	42.21
8		Low tide	0.936	BDL	62.71
9	SPM	High tide	0.833	BDL	55.81
10	SPM	Low tide	0.747	BDL	50.05

BDL: Below Detectable Limit.

**PHYTOPLANKTON POPULATION:**

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For the evaluation of the Phytoplankton population in DPT harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3

in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms blue green algae and dinoflagellates during spring tide period. Diatoms were represented by 20 genera. Blue green were represented by 2 genera and dinoflagellates were represented by 4 genera during the sampling conducted in spring tide in February, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 87-239 units/ L during high tide period and 163-- 236 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms. Blue green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 22 genera Blue green algae were represented 3 genera and dinoflagellates with 4 genera during the sampling conducted in Neap tide in February, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 112-286 units/ L during high tide period and 198-279 units/ L during low tide of Neap Tide.

For the evaluation of the Phytoplankton population in DPT OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; jetty area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green alage and Dinoflagellates during spring tide period. Diatoms were represented by 15 genera, Blue Green algae by 2 genera and Dinoflagellates

3 genera each during the sampling conducted in spring tide in February, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area was varying from 285 units/ L during high tide period and 166 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the SPM area was varying from 240 units/ L during high tide period and 285 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 19 genera and Blue green algae 2 genera and dinoflagellates by 3 genera each during the sampling conducted in Neap tide in February, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from

125 units/ L during high tide period and 187 units/ L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 146 units/ L during high tide period and 144 units/ L during low tide of Neap Tide.

### Species Richness Indices and Diversity Indices:

#### Margalef's diversity index (Species Richness)S

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 3.359 - 4.208 with an average of 3.945 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 3.482 - 3.86 with an average of 3.657 during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 3.049 - 4.319 with an average of 3.489 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.56 - 3.382 with an average of 3.091 during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 3.008 at OOT jetty area and 2.919 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 2.934 and 3.008 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 3.935 at OOT jetty area and 3.411 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 4.014 and SPM area was 3.823 during the consecutive low tide period.

#### Shannon-Wiener's index:

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.962 - 1.057 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.012 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton

communities in the sampling stations was in the range of 0.963 - 1.137- ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.018 during consecutive low tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.836 - 1.137 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of

0.934 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon- Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.794 - 0.888 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.847 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.866 at OOTjetty area and 0.934 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.048 and 0.914 at SPM during the consecutive low tide period.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.868 at OOTjetty area and 0.800 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.861 and at SPM area was 0.990 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.833 - 0.885 between selected sampling stations with an average of 0.854 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.846 - 0.905 between selected sampling stations with an average of 0.870 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks,



during high tide period and low tide period during neap tide also, which was varying from 0.800 - 0.912 with an average value of 0.831 between selected sampling stations during high tide period and 0.744 - 0.824 varying from with an average value of 0.787 between selected sampling stations during consecutive low tide period Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.738 at OOT jetty area and 0.815 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.889 and 0.760 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.749 at OOT jetty area and 0.716 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.727 and at SPM area was 0.832 during the consecutive low tide period.

Low species diversity suggests a relatively few successful species in this habitat. The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment. Any change in the environment would probably have quite serious effects.

**Table # 4 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN FEBRUARY 2022**

<b>Tide</b>	<b>Sampli ng Statio n</b>	<b>Abunda nce In units/L</b>	<b>No of Specie s observ ed /tota l speci es</b>	<b>% of divers ity</b>	<b>Margal ef's diversit y index (Specie s Richnes s S)</b>	<b>Shann on Wein er index H (log1 0)</b>	<b>Diversit y Index (Simp son's Index) 1-D</b>
<b>HIG H TID E</b>	1	218	23/26	88.46	4.086	1.011	0.8464
	3	147	22/26	84.61	4.208	1.057	0.8737
	4	223	22/26	84.61	3.884	1.014	0.8443
	5	239	23/26	88.46	4.017	0.962 9	0.8333
	6	87	16/26	61.54	3.359	1.012	0.8851
	1	174	18/26	69.23	3.295	0.963 2	0.846
	2	163	23/26	88.46	4.319	1.137	0.9052

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LOW TIDE	3	174	19/26	73.07	3.489	1.051	0.8827
	4	190	17/26	65.38	3.049	0.972	0.8635
	5	236	19/26	73.07	3.294	0.971 7	0.853

**Table # 5 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN FEBRUARY 2022**

Tide	Sampli ng Statio n	Abunda nce In units/L	No of Specie s observ ed /total speci es	% of divers ity	Margale f's diversit y index (Specie s Richnes s S)	Shann on Wein er index H (log1 0)	Diversit y Index (Simpso n's Index) <sup>1</sup> -D
HIG H TID E	1	21 1	17/2 9	58.6 2	2.99	0.8661	0.8005
	2	16 8	17/2 9	58.6 2	3.123	0.9041	0.8364
	3	21 2	21/2 9	72.4 1	3.734	0.9227	0.8042
	4	28 6	21/2 9	72.4 1	3.536	0.9378	0.8261
	5	22 9	18/2 9	62.0 7	3.129	0.8368	0.8123
	6	11 2	20/2 9	68.9 6	4.027	1.137	0.9122
LO W TID E	1	27 9	19/2 9	65.5 2	3.196	0.8887	0.8249
	2	23 7	15/2 9	51.7 2	2.56	0.8066	0.7813
	3	20 5	19/2 9	65.5 1	3.382	0.8768	0.7906
	4	19 8	18/2 9	62.0 7	3.215	0.8716	0.7976
	5	24 0	18/2 9	62.0 7	3.102	0.7941	0.7449

**Table # 6 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN FEBRUARY 2022**

Tide	Surfac e	No of Sampli ng locatio n	Group of phytoplankton	Phytoplan kton Group range Units/L	Genera or specie s /total Phyto plankt on	Taxon Diversit y % (Group level)
			DIATOMS	84-225	20/26	76.9 3
			BLUE GREEN	8-Feb	26-Feb	7.69

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HIGH TIDE	Sub surface	6	DINOFLAGELLATES	9-Jan	26-Apr	15.38
			TOTAL PHYTO PLANKTON	87-239	26	
LOW TIDE	Sub surface	5	DIATOMS	152-229	20/26	76.93
			BLUE GREEN	8-Apr	26-Feb	7.69
			DINOFLAGELLATES	4-Jan	26-Apr	15.38
			TOTAL PHYTO PLANKTON	163-236	26	

**Table # 7 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAPTIDE IN FEBRUARY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phytoplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	108-272	22/29	75.87
			BLUE GREEN	8-Feb	29-Mar	10.34
			DINOFLAGELLATES	8-Feb	29-Apr	13.79
			TOTAL PHYTOPLANKTON	<b>211-168</b>	<b>29</b>	-
LOW TIDE	Sub surface	5	DIATOMS	192-274	22/29	75.87
			BLUE GREEN	5-Jan	29-Mar	10.34
			DINOFLAGELLATES	8-Feb	29-Apr	13.79
			TOTAL PHYTOPLANKTON	<b>279-237</b>	<b>29</b>	-

**Table # 8 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR& NEAR BY SPM, DURING SPRING TIDE IN FEBRUARY 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log10)	Diversity Index (Simpson's Index) 1-D
HIGH	jett y	285	18/20	90	3.008	0.8666	0.7389

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H TID E	SP M	240	17/20	85	2.919	0.934 6	0.8154
LO W TID E	jett y	166	16/20	80	2.934	1.048	0.8895
	SP M	285	18/20	90	3.008	0.914 7	0.7601

**Table # 9 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN FEBRUARY 2022**

Tide	Sampli ng Statio n	Abunda nce In units/L	No of Specie s observ ed /total speci es	% of divers ity	Margal ef's diversit y index (Specie s Richnes s S)	Shann on Weiner index H (log1 0)	Diversit y Index (Simpson's Index) 1-D
HIG H TID E	Jetty	125	20/24	83.33	3.935	0.8681	0.7497
	SPM	146	18/24	75	3.411	0.8008	0.7165
LO W TID E	Jetty	187	22/24	91.67	4.014	0.8616	0.7277
	SPM	144	20/24	83.33	3.823	0.9907	0.8325

**Table # 10 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN FEBRUARY 2022**

Tide	Surfac e	No of Sampli ng locati on	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or specie s /total Phyto plankton	Taxon Diversit y % (Group level)
HIG H TID E	Sub surfa ce	1	BLUE GREEN	19-27	20-Feb	10
			DIATOMS	212-263	15/20	75
			DINOFLAGELLATES	3-Jan	20-Mar	15
			TOTAL PHYTO PLANKTON	240-285	20	-
			BLUE GREEN	23	20-Feb	10



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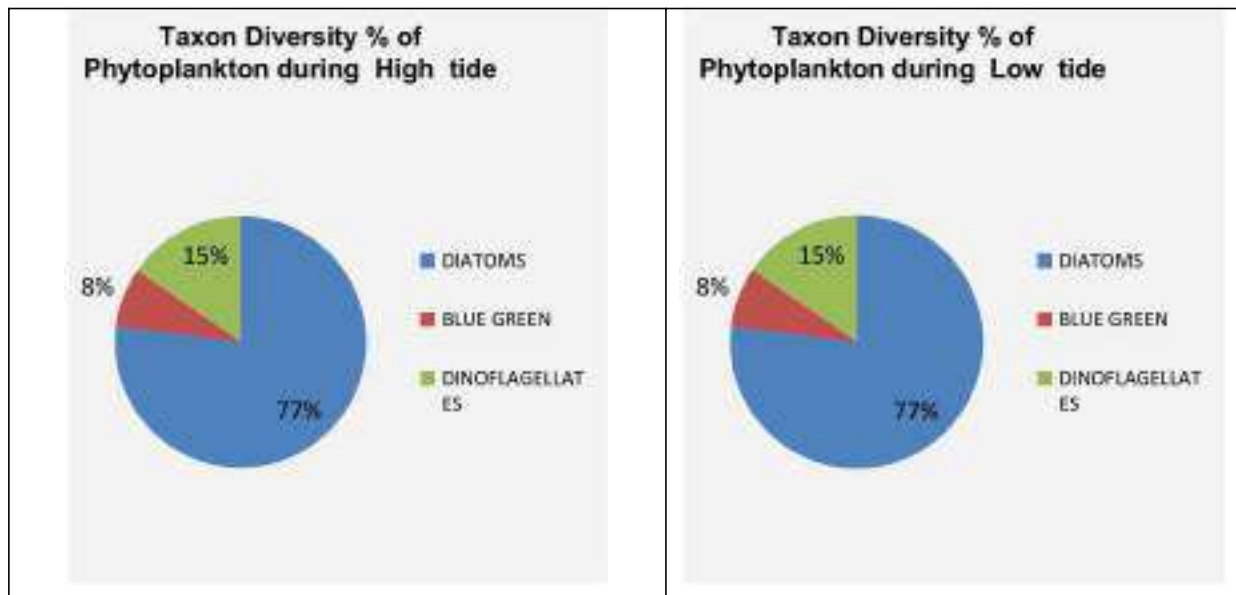
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LOW TIDE	Sub surface	1	DIATOMS	143-261	15/20	75
			DINOFLAGELLATES	0-1	20-Mar	15
			TOTAL PHYTO PLANKTON	166-285	20	

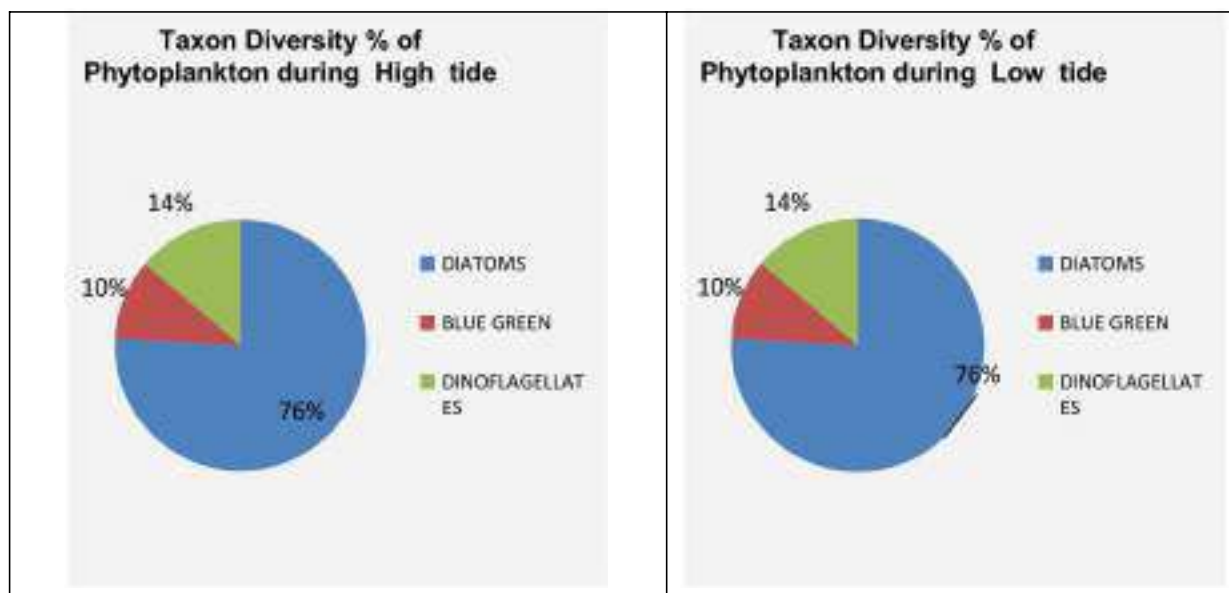
**Table # 11 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONSIN DPT DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN FEBRUARY 2022**

<b>Tide</b>	<b>Surface</b>	<b>No of Sampling location</b>	<b>Group of phytoplankton</b>	<b>Phytoplankton Group range Units/L</b>	<b>Genera or species /total Phytoplankton</b>	<b>Taxon Diversity % (Group level)</b>
HIGH TIDE	Sub surface	2	BLUE GREEN	5-Jan	24-Feb	8.33
			DIATOMS	116-140	19/24	79.17
			DINOFLAGELLATES	5-Apr	24-Mar	12.5
			TOTAL PHYTOPLANKTON	125-146	24	-
LOW TIDE	Sub surface	2	BLUE GREEN	6	24-Feb	8.33
			DIATOMS	129-176	19/24	79.17
			DINOFLAGELLATES	9-May	24-Mar	12.5
			TOTAL PHYTOPLANKTON	144-187	24	-

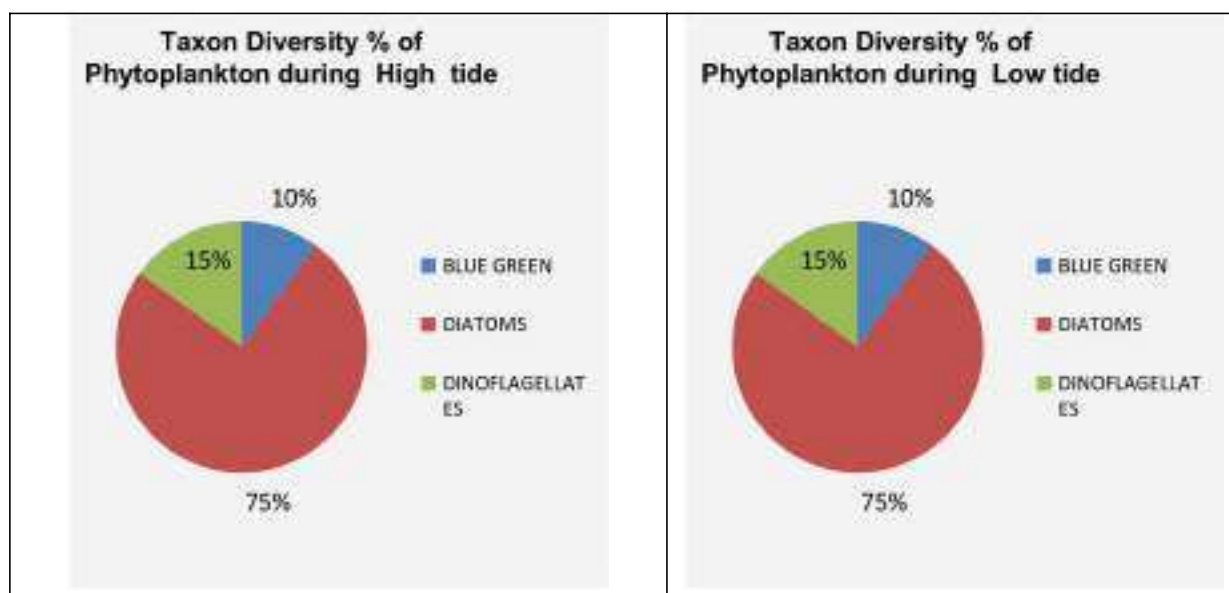
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Kandala creek and nearby creeks**



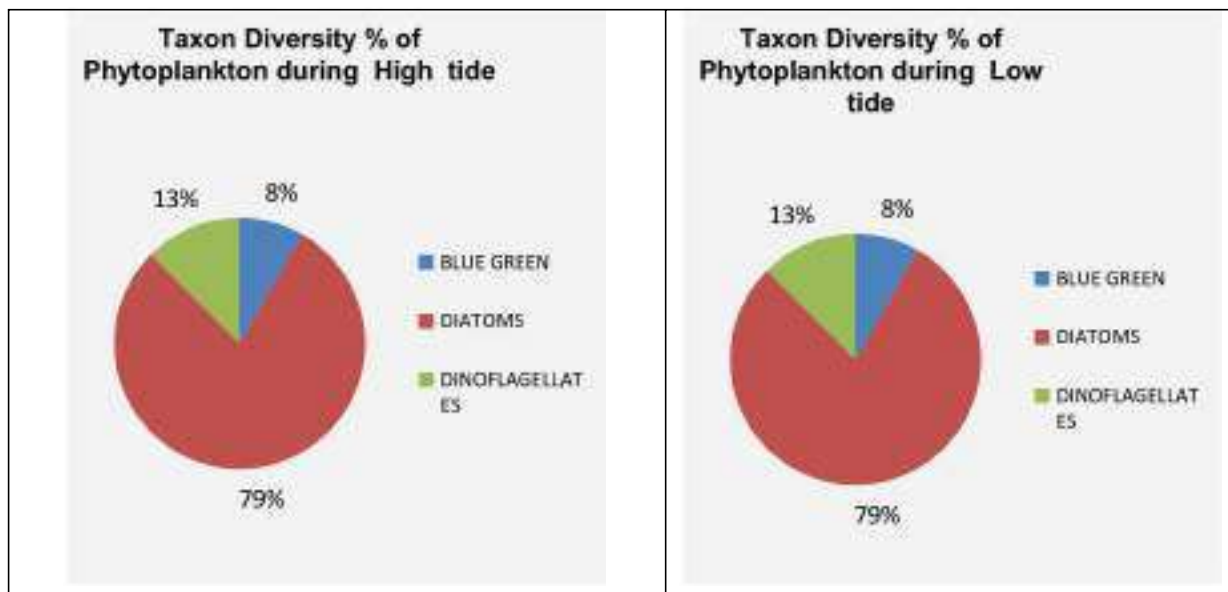
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Kandala creek and nearby creeks**



**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



### Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar



### ZOOPLANKTON POPULATION:

For the evaluation of the Zooplankton population in DPT harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khori creek) during high tide period and low tide period of spring tide and Neap tide in February, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly 4 groups, and 9 larval forms; Tintinids, Copepods, Arrow worms, Urochordata, Medusa, and 9 larval forms; Nauplius larvae of Copepods, Brachyuran zoea larvae, Cirripede larvae, Cyphonautes larvae, Ophioplutes larvae/ Echinoplutes larvae, Fish larvae, Opisthobranchia larvae, Trochophore larvae and Veliger larvae of bivalves.

The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly 4 groups, Tintinids, Copepods, Urochordata, and , Foraminiferans and 7 larval forms; Nauplius larvae of Copepods, Brachyuran zoea larvae, Cirripede larvae, Cyphonautes larvae, Opisthobranchia larvae, Trochophore larvae and Veliger larvae of bivalves.

Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from  $46-122 \times 10^3$  N/  $m^3$  during high tide and  $86-102 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek

DEPL/DPT/21-120/228-160  $\times 10^3$  N/  $m^3$  during high tide and  $123-152 \times 10^3$  N/  $m^3$

during low tide of Neap Tide period.

For the evaluation of the Zoo plankton population in DPT OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM) During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek creeks during spring tide was represented by mainly Tintinids, Copepods, Arrow worms and larval forms; Nauplius larvae of Copepods, Brachyuran Zoea larvae, Cirripede larvae, Cyphonautes larvae, Opisthobranchia larvae, and Trochophore larvae .

The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly four groups, Tintinids, Copepods, Arrow worms , Foraminiferans and , 6 Larval forms. Nauplius larvae of Copepods, Cirripede larvae, Cyphonautes larvae, Ophioplutes larvae/ Echinoplutes larvae, Opisthobranchia larvae, and Trochophore larvae.

Zooplankton of the sampling stations at sub surface layer in the DPT OOT Jetty area of path finder creek was  $91 \times 10^3$  N/  $m^3$  during high tide and  $56 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area of path finder creek was  $99 \times 10^3$  N/  $m^3$  during high tide and  $84 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT OOT jetty area in path finder creek was recorded  $111 \times 10^3$  N/  $m^3$  during high tide and  $125 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area in path finder creek was recorded  $102 \times 10^3$  N/  $m^3$  during high tide and  $99 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of Zooplankton communities in

the stations Kandla creek region and nearby creeks was varying from 2.873-4.371 with an average of 3.887 during the sampling conducted in High tide period. Margalef's diversity index (Species



Richness) S of Zooplankton communities varying from 3.49 - 4.939 with an average of 4.206 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the Kandlacreek region and nearby creeks sampling stations was varying from 4.02 - 4.729 with an average of 4.342 during the sampling conducted in high tide and varying from 3.782 - 4.954 with an average of 4.283 during the sampling conducted in low tide during Neap tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.99 and 3.478 respectively. Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.264 and 3.611 respectively.

Margalef's diversity index (Species Richness) S of Zooplankton communities near Jetty at Path finder creek was varying from 3.61 - 3.728 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) S of Zooplankton communities near SPM at Path finder creek was varying from 2.811 - 3.047 respectively during the consecutive High tide and low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.7775 - 1.009 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.920 ( $H'(\log_{10})$ ) during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.958 - 1.134 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.050 ( $H'(\log_{10})$ ) during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 1.035 - 1.177 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.096 ( $H'(\log_{10})$ ) during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 1.052 - 1.214 of ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.1036 ( $H'(\log_{10})$ ) during consecutive

low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.916.101 and 0.976 respectively. Shannon-

Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.916 and 1.062 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 1.075-1.004 during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 0.867 - 0.925 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period, which was varying from 0.761 - 0.866 between selected sampling stations with an average of 0.797 during high tide period and was varying from 0.858 - 0.895 with an average value of 0.879 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of neap tide except few, which was varying from 0.847 - 0.929 between selected sampling stations with an average of 0.884 during high tide period and was varying from 0.861 - 0.922 with an average value of 0.885 0.916 between selected sampling stations during consecutive low tide. This species diversity suggests a relatively more successful species in this habitat during February 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in

consecutive High tide period and low tide of spring tide was recorded as 0.820 and 0.874 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.825 and 0.898 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.894 - 0.853 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.816 and 0.842 respectively.

**Table # 12 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT  
KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN  
FEBRUARY 2022**

<b>Tide</b>	<b>Sampling Station</b>	<b>Abundance In N x103/ m3</b>	<b>No of Species/ groups observed /total species/ group</b>	<b>% of diversity</b>	<b>Margalef's diversity index (Species Richness S)</b>	<b>Shannon Weiner index H (log10)</b>	<b>Diversity Index (Simpson's Index) 1-D</b>
<b>HIGH TIDE</b>	1	97	20/36	55.55	4.153	0.925	0.7734
	2	84	18/36	50	3.837	1.009	0.8663
	3	114	19/36	52.77	3.801	0.8884	0.7614
	4	122	22/36	61.11	4.371	0.9676	0.8147
	5	106	21/36	58.33	4.289	0.9532	0.8102
	6	46	Dec-36	33.33	2.873	0.7775	0.7614
<b>LOW TIDE</b>	1	102	22/36	61.11	4.541	1.106	0.8956
	2	95	20/36	55.55	4.172	1.044	0.8701
	3	86	23/36	63.88	4.939	1.134	0.8949
	4	102	19/36	52.77	3.892	1.008	0.8773
	5	98	17/36	47.22	3.49	0.9581	0.858

**Table # 13 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT  
KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN FEBRUARY  
2022**

Tide	Sampli ng Statio n	Abundanc e In No x103/ m3	No of Species/gr oups observed /total species/gro up	% of divers ity	Margale f's diversit y index (Specie s Richnes s S)	Shan non Wein er index H (log1 0)	Divers ity Index (Simp son's Index) 1-D
HIG H TID E	1	132	23/31	74.19	4.506	1.061	0.8632
	2	99	21/31	67.74	4.352	1.071	0.8813
	3	160	25/31	80.65	4.729	1.148	0.9039
	4	158	23/31	74.19	4.346	1.035	0.8471
	5	131	21/31	67.74	4.102	1.087	0.8843
	6	88	19/31	61.29	4.02	1.177	0.9297
LO W TID E	1	128	21/31	67.74	4.122	1.066	0.877
	2	127	25/31	80.64	4.954	1.214	0.9228
	3	123	21/31	67.74	4.156	1.125	0.8996
	4	148	23/31	74.19	4.402	1.061	0.8676
	5	152	20/31	64.52	3.782	1.052	0.8615

**Table # 14 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING  
STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY  
CREEKS DURING SPRING TIDE IN FEBRUARY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x103 Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIG H TID E	Sub surface	6	Tintinids	12-Feb	Jun-36	16.67
			Copepods	19-46	16/36	44.45
			Arrow worms	0-4	Jan-36	2.78
			Urochordata	0-4	Feb-36	5.55
			Foraminiferans	6-Jan	Feb-36	5.55
			Larval forms	51-28	Sep-	91.25
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					36	
			TOTAL ZOOPLANKTON N/ M <sup>3</sup>	<b>97-84</b>	<b>36</b>	-
LOW TIDE	Sub surface	5	Tintinids	13-Mar	Jun- 36	16.67
			Copepods	34-45	16/36	44.45
			Arrow worms	0-4	Jan- 36	2.78
			Urochordata	0-4	Feb- 36	5.55
			Foraminiferans	0-3	Feb- 36	5.55
			Larval forms	35-48	Sep- 36	25
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>86-102</b>	<b>36</b>	-

**Table # 15 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAPTIDE IN FEBRUARY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x103 Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	18-Oct	Jun-31	19.35
			Copepods	21-50	31-Oct	32.26
			Arrow worms	0-4	31-Jan	3.23
			Mysids	0-2	31-Jan	3.23
			Urochordata	0-5	Feb-31	6.45
			Foraminiferans	10-Jan	Feb-31	6.45
			Larval forms	37-83	Sep-31	29.03
			TOTAL ZOOPLANKTON N/M3	<b>88-160</b>	<b>31</b>	
LOW TIDE	Sub surface	5	Tintinids	15-24	Jun-31	19.35
			Copepods	38-50	31-Oct	32.26
			Arrow worms	0-4	31-Jan	3.23
			Mysids	0-2	31-Jan	3.23
			Urochordata	0-4	Feb-31	6.45
			Foraminiferans	9-Jan	Feb-31	6.45
			Larval forms	43-82	Sep-31	29.03
			TOTAL ZOOPLANKTON N/M3	<b>123-152</b>	<b>31</b>	

**Table # 16 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN FEBRUARY 2022**



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Tide	Sampli ng Statio n	Abundanc e In x103N / m3	No of Species/gr oups observed /total species/gro up	% of divers ity	Margal ef's diversit y index (Specie s Richnes s S)	Shann on Wein er index H (log1 0)	Diversit y Index (Simpson's Index) 1-D
HIG H TID E	Jetty	9 1	19/22	86.3 6	3.99	0.916	0.82
	SPM	9 9	16/22	72.7 3	3.264	0.9164	0.825
LO W TID E	Jetty	5 6	15/22	68.1 8	3.478	0.9767	0.8747
	SPM	8 4	17/22	77.2 7	3.611	1.062	0.8985

**Table # 17 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH  
FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN FEBRUARY  
2022**

Tide	Sampli ng Statio n	Abunda nce In N x103/ m3	No of Specie s/g roups observ ed /total species /group	% of dive rsity	Margal ef's diversi ty index (Specie s Richne ss S)	Sha nn on Wein er inde xH (log1 0)	Diversi ty Index (Simp son's Index) 1-D
HIG H TID E	Jetty	111	18/19	94.7 4	3.61	1.075	0.8945
	SPM	102	14/19	73.6 8	2.811	0.867	0.8169
LO W TID E	Jetty	125	19/19	100	3.728	1.004	0.8534
	SPM	99	15/19	78.9 5	3.047	0.925 2	0.8423

**Table # 18 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING  
STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM  
DURING SPRING TIDE IN FEBRUARY 2022**

Tid e	Surface	No of Sampli ng locatio ns	Group of Zooplank ton	Abundan ce of Zooplank ton x103 Group Range	Genera or species /total Zooplank ton	Taxon Divers ity % (Gro up level )
HIGH TIDE	Sub surface	2	Tintinids	11- Sep	22- Apr	18.18
			Copepods	43-50	22- Sep	40.91
			Arrow worms	0-1	22- Jan	4.55
			Foraminfera ns	0-1	22- Feb	9.09
			Larval forms	37	22- Jun	27.27
			TOTAL ZOOPLANKT ONNO/L	<b>91- 99</b>	<b>22</b>	
<b>DCPL/DPT/21-22/22 -</b>			Tintinids	9-Jun	22- Apr	18.18
			Copepods	31-46	22- Sep	40.91 95

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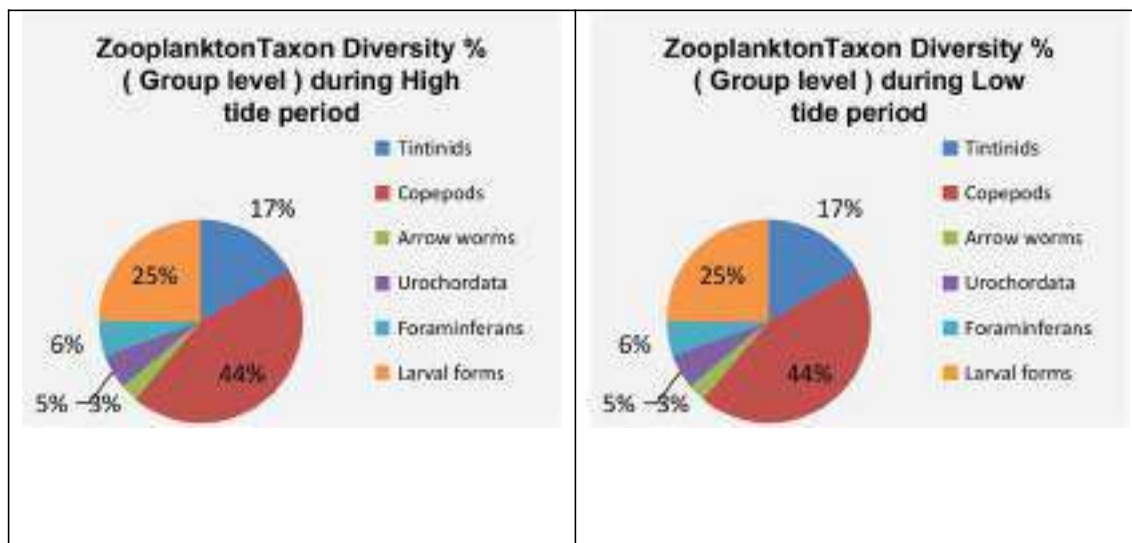
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LOW TIDE	Sub surface	2	Arrow worms	0-1	22-Jan	4.55
			Foraminferans	6-Jan	22-Feb	9.09
			Larval forms	18-23	22-Jun	27.27
			TOTAL ZOOPLANKTON NO/M3	<b>56-84</b>	<b>22</b>	

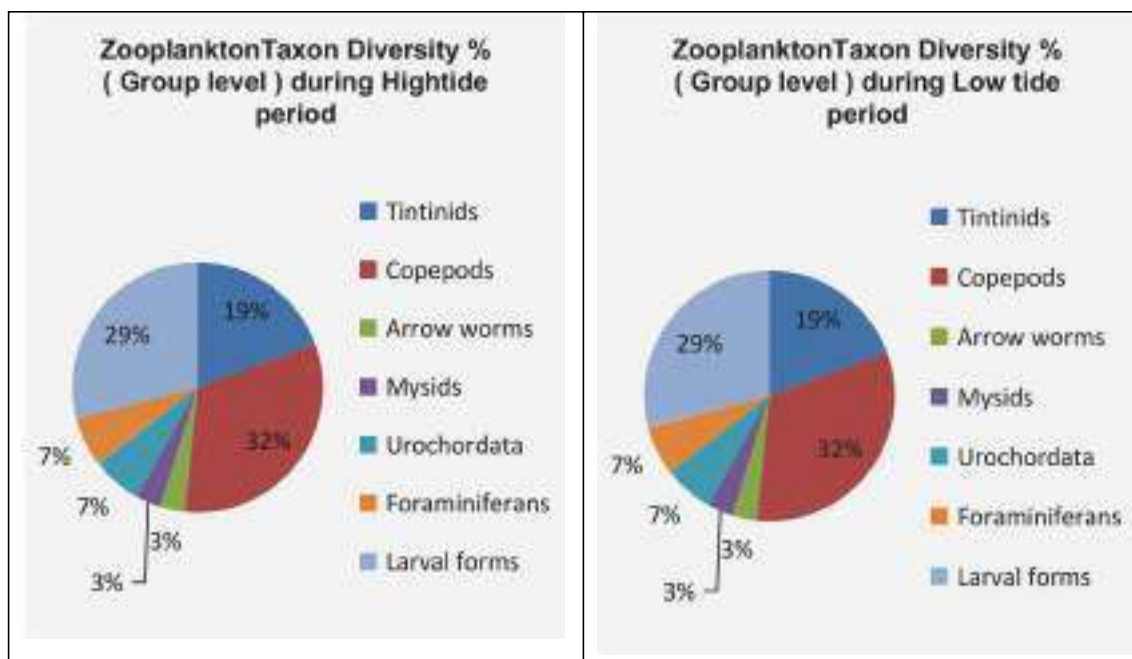
**Table # 19 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN FEBRUARY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x103 Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	9-May	19-Mar	15.79
			Copepods	35-37	19-Jun	31.58
			Urochordata	0-2	19-Jan	5.26
			Foraminferans	5-Apr	19-Feb	10.53
			Larval forms	58	19-Jul	36.84
			TOTAL ZOOPLANKTON	<b>102-111</b>	<b>19</b>	
LOW TIDE	Sub surface	2	Tintinids	9-May	19-Mar	15.79
			Copepods	36-49	19-Jun	31.58
			Urochordata	2-Jan	19-Jan	5.26
			Foraminferans	5-Mar	19-Feb	10.53
			Larval forms	49-65	19-Jul	36.84
			TOTAL ZOOPLANKTON	<b>99-125</b>	<b>19</b>	

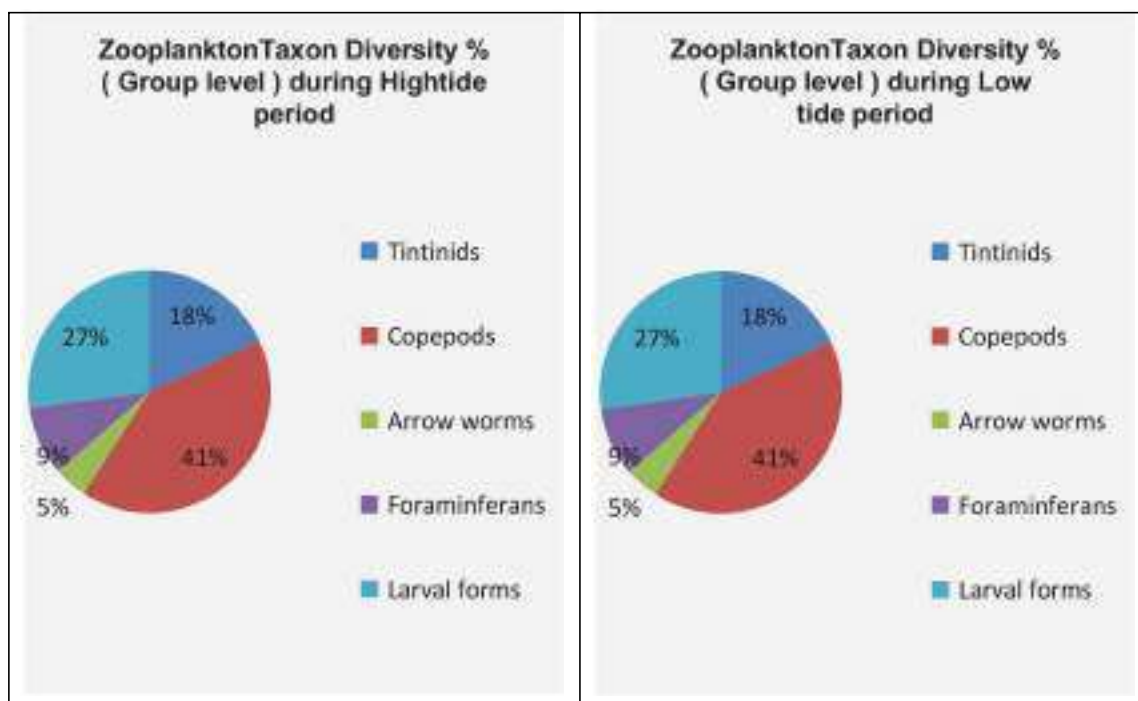
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Kandla Creek and nearby Creeks**



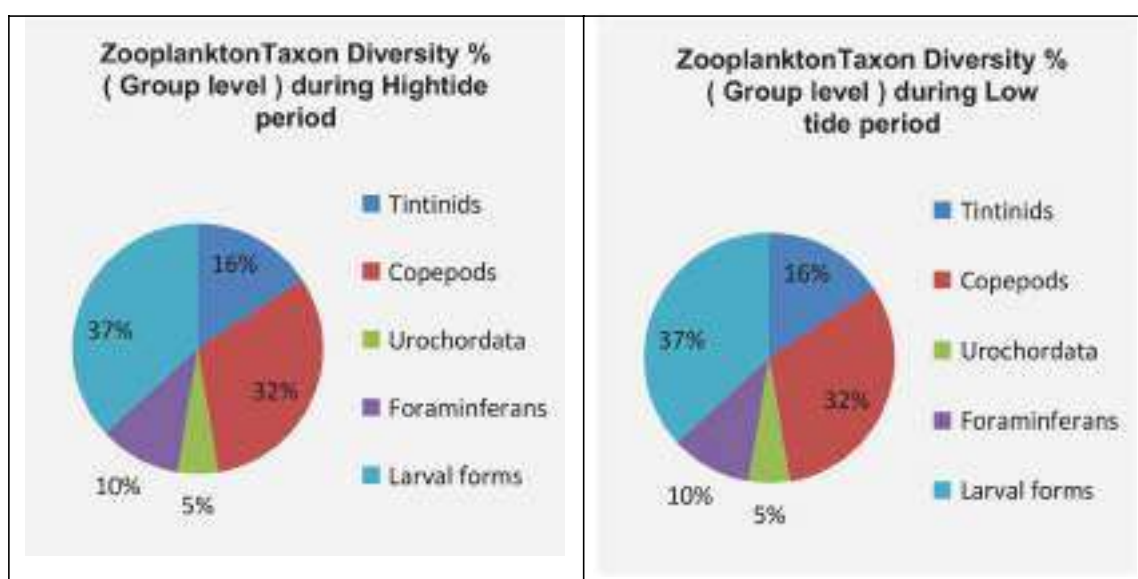
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Kandla Creek and nearby Creeks**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM**



**TABLE # 20 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF FEBRUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B2	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella sp.</i>	D1	Very sparse
			Coscinodisciales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D2	Dominant
			Triceratiales	Triceratiaceae	<i>Triceratium sp.</i>	D3	Very sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D4	Sparse
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp.</i>	D5	Sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D7	Scattered
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D8	Abundant
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D9	Scattered
		Bacillariophyceae	Naviculales	Pleurosigmaaceae	<i>Navicula sp.</i>	D10	Very sparse
			Bacillariales	Bacillariaceae	<i>Pleurosigma sp.</i>	D11	Sparse
					<i>Bacillaria sp.</i>	D12	Sparse
					<i>Nitzschia sp.</i>	D13	Sparse
					<i>Pseudo-nitzschia sp.</i>	D14	Very sparse
			Surirellales	Surirellaceae	<i>Surirella sp.</i>	D15	Very sparse
		Fragilariophyceae	Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D16	Very sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D17	Scattered
					<i>Thalassionema sp.</i>	D18	Very sparse
			Fragilariales	Fragilariaceae	<i>Fragilaria sp.</i>	D19	Very sparse
					<i>Synedra sp.</i>	D20	Sparse
DINO FLAGELLATES	Dinoflagellata / Dinzoa	Noctiluca / Noctiluiphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca sp.</i>	DF1	Very sparse
		Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF2	Very sparse
			Ceratiales	Cerataceae	<i>Ceratium furca</i>	DF3	Sparse

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					<i>Ceratium tripos</i>	DF4	Very sparse
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**TABLE # 21 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING AND NEAP TIDE OF FEBRUARY 2022**

GROU P	PHYLUM	CLA SS	ORD ER	FAMILY	GENUS/SPECIE S	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
					<i>Planktothrix sp.</i>	B2	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktoniella sp</i>	D1	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	Thalassiosiraceae	<i>Coscinodiscus sp.</i>	D2	Dominant
					<i>Triceratium sp.</i>	D3	Very sparse
			Coscinodiscales	Coscinodiscaceae	<i>Biddulphia sp</i>	D4	Sparse
			Triceratiales	Triceratiaceae	<i>Bellerocha sp</i>	D5	Sparse
			Biddulphiales	Biddulphiaceae	<i>Cerataulina sp.</i>	D6	Very sparse
			Hemiaulales	Bellerochaeeae	<i>Rhizosolenia sp.</i>	D7	Scattered
				Hemiaulaceae	<i>Chaetoceros sp</i>	D8	Abundant
			Rhizosoleniales	Rhizosoleniaceae	<i>Ditylum sp</i>	D9	Scattered
			Chaetocerotales	Chaetocerotaceae	<i>Navicula sp</i>	D10	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Pleurosigma sp</i>	D11	Sparse
		Bacillariophyceae	Naviculales	<i>Pleurosigmataceae</i>	<i>Bacillaria sp.</i>	D12	Sparse
			Bacillariales	Bacillariaceae	<i>Nitzschia sp</i>	D13	Sparse
					<i>Pseudo-nitzschia sp</i>	D14	Very sparse
					<i>Surirella sp</i>	D15	Very sparse

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				<i>Climacosphenia sp.</i>	D16	Very sparse
				<i>Thalassiothrix sp.</i>	D17	Scattered
				<i>Thalassionema sp.</i>	D18	Very sparse

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			Surirellales	Surirellaceae	<i>Fragilaria sp</i>	D19	Very sparse
		Fragilariophyceae	Climacospheniales	Climacospheeniaceae	<i>Synedra sp</i>	D20	Sparse
					<i>Noctiluca sp.</i>	DF1	Very sparse
			Thalassionematales	Thalassionemataceae	<i>Protoperidinium sp.</i>	DF2	Very sparse
					<i>Ceratium furca</i>	DF3	Sparse
			Fragilariales	Fragilariaceae	<i>Ceratium tripos</i>	DF4	Very sparse
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Noctiluca / Noctilucaeae (Dinokaryota)	Noctilucal es	Noctilucaeae	<i>Oscillatoria sp.</i>	B1	Very sparse
		Dinophyceae	Peridinales	Protoperidiniaceae	<i>Planktothrix sp.</i>	B2	Very sparse
					<i>Planktoniella sp</i>	D1	Very sparse

**TABLE # 22 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF FEBRUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Sparse
					<i>Oscillatoria sp.</i>	B2	Sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Dominant
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp</i>	D2	Sparse
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp</i>	D3	Sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D4	Abundant
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp</i>	D5	Sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D6	Sparse
		Bacillariophyceae	Naviculales	Pleurosigmaataceae	<i>Pleurosigma sp</i>	D7	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D8	Scattered
					<i>Nitzschia sp</i>	D9	Sparse
					<i>Pseudo-nitzschia sp</i>	D10	Sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Fragilaria sp</i>	D11	Very sparse
					<i>Synedra sp.</i>	D12	Sparse
			Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D13	Sparse
			Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D14	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D15	Scattered
DCPL/DPT/21-22/22	Dinoflagella	Noctiluca / Noctilucae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca sp.</i>	DF1	Very sparse <sup>98</sup>

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	ta / Dinzoa	Dinophyceae	Peridinales	Protoperidiniacea e	<i>Protoperidinium sp.</i>	DF 1	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF 2	Very sparse

**TABLE # 23 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND NEAP TIDE OF FEBRUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
					<i>Oscillatoria sp.</i>	B2	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella sp</i>	D1	Very sparse
					<i>Thalassiosira sp</i>	D2	Sparse
			Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D3	Dominant
			Triceratiales	Triceratiaceae	<i>Odontella sp</i>	D4	Sparse
					<i>Triceratium sp</i>	D5	Sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp</i>	D6	Sparse
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp</i>	D7	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D8	Sparse
			Chaetocerotales	Chaetoceroteaceae	<i>Chaetoceros sp</i>	D9	Scattered
		Bacillariophyceae	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D10	Sparse
			Melosirales	Melosiraceae	<i>Melosira sp</i>	D11	Very sparse
			Naviculales	<i>Pleurosigmataceae</i>	<i>Pleurosigma sp</i>	D12	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D13	Abundant
					<i>Nitzschia sp</i>	D14	Sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Fragilaria sp</i>	D15	Sparse
					<i>Synedra sp.</i>	D16	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D17	Sparse

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DINO FLAGELLATES	Dinoflagella ta / Dinozoa		Climacosphenia les	Climacospheniac eae	<i>Climacosphenia sp.</i>	D1 8	Sparse
			Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D1 9	Sparse
		Noctilucea / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca sp.</i>	DF 1	Very sparse
		Dinophyceae	Peridinales	Proto-peridiniaceae	<i>Proto-peridinium sp.</i>	DF 2	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF 3	Very sparse

**TABLE # 24 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF FEBRUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
				Codonellidae	<i>Tintinnopsis acuminate</i>	T2	Very sparse
					<i>Tintinnopsis failakkaensis</i>	T3	Sparse
					<i>Tintinnopsis gracilis</i>	T4	Very sparse
					<i>Tintinnopsis radix</i>	T5	Sparse
				Xystonellidae	<i>Favella sp.</i>	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Sparse
				Eucalanidae	<i>Pareucalanus sp.</i>	C3	Very sparse
					<i>Subeucalanus sp.</i>	C4	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C5	Very sparse
				Euchaetidae	<i>Euchaeta sp.</i>	C6	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C7	Sparse
				Acartiidae	<i>Acartia sp.</i>	C8	Sparse
				Temoridae	<i>Temora sp.</i>	C9	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C10	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C11	Scattered
				Clytemnestridae	<i>Clytemnestra sp.</i>	C12	Very sparse
				Euterpinidae	<i>Euterpina sp.</i>	C13	Very sparse



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				Canthocamptida e	<i>Canthocamptus sp</i>	C14	Very sparse
			Poicilostomatatoid a	Corycaeidae	<i>Corycaeus sp.</i>	C15	Very sparse
				Oncaeidae	<i>Oncaea sp.</i>	C16	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmoph ora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
UROCHORDATA	CHORDATA SUB	Appendiculari a		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse

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	PHYLUM UROCHORDATA			Fritillariidae	<i>Fritillaria sp.</i>	U2	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L2	Abundant
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopo da Thecostra ca			Cirripede larvae	L3	Very sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophioplutes larvae/ Echinoplutes larvae	L5	Very sparse
FISH LARVAE	CHORDATA SUBPHYLUM: VERTEBRATA	Superclass: Pisces			Fish larvae	L6	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L7	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Very sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L9	Very sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very sparse
				Rotalliidae	<i>Rotalia sp.</i>	F2	Very sparse

**TABLE # 25 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF FEBRUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
				Codonellidae	<i>Tintinnopsis accuminata</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Sparse
					<i>Tintinnopsis radix</i>	T4	Scattered
					<i>Tintinnopsis failakkaensis</i>	T5	Sparse
				Dictyocystidae	<i>Luminella sp.</i>	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Sparse
				Eucalanidae	<i>Subeucalanus sp.</i>	C3	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C6	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C7	Abundant
				Euterpinae	<i>Euterpina sp.</i>	C8	Very sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C9	Very sparse
				Corycaeidae	<i>Corycaeus sp.</i>	C10	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse

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MYSIDS	ATHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Solenocerida e	<i>Solenocera sp.</i>	M1	Very sparse
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UROCHORDATA	CHORDATA SUBPHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Sparse
				Fritillariidae	<i>Fritillaria sp.</i>	U2	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L2	Sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Scattered
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L5	Sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophioplutes larvae/	L6	Very sparse
					Echinoplutes larvae		
FISH LARVAE	CHORDATA SUBPHYLUM: VERTEBRATA	Superclass: Pisces			Fish larvae	L7	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L9	Sparse

**TABLE # 26 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF FEBRUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus sp.</i>	T1	Very sparse
				Codonellidae	<i>Tintinnopsis accuminata</i>	T2	Very sparse
					<i>Tintinnopsis failakkaensis</i>	T3	Very sparse
					<i>Tintinnopsis gracilis</i>	T4	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C3	Very sparse
			Cyclopoida	Centropagidae	<i>Centropages sp.</i>	C4	Very sparse
				Oithonidae	<i>Oithona sp.</i>	C5	Abundant
			Harpacticoida	Canthocamptidae	<i>Canthocamptus sp.</i>	C6	Very sparse
				Ectinosomatidae	<i>Microsetella sp.</i>	C7	Sparse
				Euterpinae	<i>Euterpina sp.</i>	C8	Sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C9	Sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca	Decapoda		Brachyuran zoea larvae	L2	Very sparse

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BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
CYPHONAUTE S LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
MOLLUSCAN	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L5	Sparse

LARVAE							
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L6	Very sparse
FORAMINIFER A	FORAMINIFERA	Globothalamea	Rotaliida	Globigerinidae	<i>Globigerina</i> sp.	F1	Very sparse
				Rotalliidae	<i>Rotalia</i> sp.	F2	Very sparse



**TABLE # 27 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF FEBRUARY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
					<i>Planktothrix sp.</i>	B2	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktoniella sp</i>	D1	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Thalassiosirales	Thalassiosiraceae	<i>Coscinodiscus sp.</i>	D2	Dominant
					<i>Triceratium sp.</i>	D3	Very sparse
			Coscinodiscales	Coscinodiscaceae	<i>Biddulphia sp</i>	D4	Sparse
			Triceratiales	Triceratiaceae	<i>Bellerochea sp</i>	D5	Sparse
			Biddulphiales	Biddulphiaceae	<i>Cerataulina sp.</i>	D6	Very sparse
			Hemiaulales	Bellerocheaceae	<i>Rhizosolenia sp.</i>	D7	Scattered
				Hemiaulaceae	<i>Chaetoceros sp</i>	D8	Abundant
			Rhizosoleniales	Rhizosoleniaceae	<i>Ditylum sp</i>	D9	Scattered
			Chaetocerotales	Chaetocerotaceae	<i>Navicula sp</i>	D10	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Pleurosigma sp</i>	D11	Sparse
		Bacillariophyceae	Naviculales	<i>Pleurosigmataceae</i>	<i>Bacillaria sp.</i>	D12	Sparse

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			Bacillariales	Bacillariaceae	Nitzschia sp	D13	Sparse	
					Pseudo-nitzschia sp	D14	Very sparse	
					Surirella <b>sp</b>	D15	Very sparse	
							Climacophenia sp.	D16
							Thalassiothrix sp.	D17

**BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPT harbour region and nearby creek. The meiobenthic organisms during spring tide were represented by Polychaetes *Dasybranchus* sp., and *Notomastus* sp., During Neap tide Polychaetes observed were *Dasybranchus* sp and *Prinispo*.sp

**Table # 28 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING SPRING TIDE IN FEBRUARY 2022**

Benthic fauna	ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS					
	REPRESENTATION BY GROUP					
	DPT HARBOUR			CREEKS		
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family : Capitellidae <i>Dasybranchus</i> sp.	10	100	10	20	40	NS
	20	0	0	0	20	NS
Family : Capitellidae <i>Notomastus</i> sp	30	100	10	20	60	

NS : No sample

**Table # 29 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING NEAP TIDE IN FEBRUARY 2022**

Benthic fauna	ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS					
	REPRESENTATION BY GROUP					
	DPT HARBOUR			CREEKS		
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family Spionidae <i>Prinispo</i> sp.	0	10	20	0	0	NS
Family : <i>Capitellidae</i> <i>Dasybranchus</i> <i>sp</i>	0	30	40	20	40	NS

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Total Polychaetes	0	40	60	20	40	NS
Un identified Amphipods	10					
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	10	40	60	20	40	

## 6. Meteorological Data

Automatic Weather station have been installed in Seva Sadan - 3 at the Deendayal Port which records the data on Temperature (°C), Humidity (%), Wind (mph), Dew Point (°C), Wind Direction (°), Pressure, Solar radiation, heat Index and UVI.

### Temperature

The mean day time temperature for Deendayal Port was 19.8 °C. The day-time maximum temperature was 29.2°C. The minimum mean night time temperature recorded was 12.6 °C.

### Air Pressure

The mean absolute air pressure for the month of February was 1006.3 hpa, whereas the mean relative pressure was 10064 hpa. The maximum absolute air pressure recorded for the month of February was 1022 hpa.

### Heat Index

The mean day-time heat index for the month of February was 27.77 °C. The maximum heat index recorded was 33°C.

### Solar Radiation

The mean Solar Radiation in February was 119.20 w/m<sup>2</sup>. The maximum solar radiation recorded in the month of February was 530.7 w/m<sup>2</sup>.

### Humidity

The mean day-time humidity was 60.22 % for the month of February and mean night time humidity was 45.60 %. Maximum humidity recorded during day-time was 98.0 % and maximum humidity recorded during night-time was 69.0%.

### Wind Velocity and Wind Direction

The mean wind velocity for the entire month of February was 4.8 km/hour. Maximum wind velocity recorded was 34.6 Km/hr . The wind direction was mostly N to NW.

### Conclusive Summary and Remedial measures Suggested

The AAQ monitoring at six locations of Deendayal Port indicates that the mean PM<sub>10</sub> values at four locations viz. Coal storage area, Marine Bhavan, Gopalpuri, Tuna Port, Kandla Colony and Oil Jetty area were found above the permissible standards (100 µg/m<sup>3</sup>) and PM<sub>2.5</sub> was above permissible limits at Coal storage location (Limit 60 µg/m<sup>3</sup>). The AAQ monitoring Vadinar at Admin building found above the permissible standards for both PM<sub>10</sub> (Limit 100 µg/m<sup>3</sup>) & PM<sub>2.5</sub> (Limit 60 µg/m<sup>3</sup>).

Drinking water at all the twenty locations was found potable and was within permissible limits of BIS standards (IS 10500).

Noise quality was also within the set permissible standards of an Industrial Area. The noise level observed during day time was >75 dB (A) and at night time was >70 dB (A) during the entire monitoring period.

The sewage treated water of Deendayal Port Colony (Gopalpuri) was in line with the standards set by the Gujarat Pollution Control Board.

### Reasons for higher Values of PM<sub>10</sub>

Large amount of coal is handled at Berth No. 6, 7, 8 and 9. The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.

Also, the coal laden trucks are not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

### Remedial Measures

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of February, 2022 were observed beyond the permissible limit at all locations mentioned above Except Vadinar Signal building for PM<sub>10</sub>. Given below are the remedial measures suggest to minimize the Air pollution at Deendayal Port.

Guidelines for Coal Handling by GPCB should be strictly followed. (<http://gpcb.gov.in/pdf/coal-handling-guidelines.pdf>)

Except for the higher values of PM<sub>10</sub> & PM<sub>2.5</sub> at Coal storage site, Oil Jetty, Tuna Port and Marine Bhavan locations, the monitoring results for the present month suggest that the overall Environment Quality of Deendayal Port is satisfactory.

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## **ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY**



**REPORT : DCPL/DPT/21-22/23**  
**Mont : March**  
**Issue : 01**  
**Revision : 00**  
**Prepare : DETOX CORPORATION PVT. LTD., SURAT**

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## **ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTAL MONITORING REPORT- MARCH 2022**

### **1. EXECUTIVE SUMMARY**

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to identify non conformity in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### **A) Ambient Air**

Average concentration of PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> for 24-hr & other parameters were measured at Six locations with continuous viz. Gopalpuri Tuna Port, marine Bhavan building, Coal storage area, Estate building, and Oil jetty, and at Vadinar port, Vadinar Jetty and vadinar colony area using high volume air samplers, respirable dust sampler (RDS 10 PM and FPS 2.5 PM) and gaseous sampler and at using continuous air quality monitoring station.

The overall values for March of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The TSPM values were found from 416 µg/m<sup>3</sup> To 173 µg/m<sup>3</sup>. The PM<sub>10</sub> values were found from 304 µg/m<sup>3</sup> To 98 µg/m<sup>3</sup>, The PM<sub>2.5</sub> values were found from 111 µg/m<sup>3</sup> To 69 µg/m<sup>3</sup>. All values are found for all locations to above the permissible limit.

The overall values of March for SO<sub>2</sub> were found 4.98 µg/m<sup>3</sup> to 3.48 µg/m<sup>3</sup>. NO<sub>x</sub> were found 20.96 µg/m<sup>3</sup> to 13.02 µg/m<sup>3</sup>, NH<sub>3</sub> were found 10.74 µg/m<sup>3</sup> to 8.13 µg/m<sup>3</sup>, C<sub>6</sub>H<sub>6</sub> were found 1.25 µg/m<sup>3</sup> to 1.12 µg/m<sup>3</sup>, CO were found 2.04 mg/m<sup>3</sup> to 1.70 mg/m<sup>3</sup>, CO<sub>2</sub> were found 658 ppm to 446 ppm and there is reported result for NMHC were BQL (Below Quantification Limit).

#### **B) Marine Ecology (Flora and Fauna):**

The results obtained from the study for the month of March, 2022. Physic-chemical parameters were observed as per prescribed standards limits of ecological parameters

for Arabian Sea at Kachchh Creek. Net Primary Productivity and Chlorophyll-a were well for ecological parameters for Arabian Sea. However, considering the activities in DPT Harbour, it is seen that the marine ecosystem is not adversely affected by Port activities.

### **C) Drinking Water Quality**

Drinking water is water intended for human consumption for drinking and cooking purposes from any source. It includes water (treated or untreated) supplied by any means for human consumption. The drinking water being supplied to Deendayal Port is safe for drinking purpose. At all drinking water monitoring stations around port area are found to be as per the drinking water specifications given in IS 10500:2012 and also on the basis of analysis parameter.

The average results for 20 locations as per below. PH were found Min 7.1 to 7.6, TDS were found min 950mg/l to Max found 1220 mg/l, Chloride were found Min 496.1 mg/l to Max 656.46 mg/l, Total Hardness were found Min 410mg/l to Max 470 mg/l and Calcium were found Min 48.1 mg/l to Max 76.15 mg/l. colour found colourless and odour were odourless. All water sample found for BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count is absent in all drinking water samples.

### **D) Monitoring Performance of Sewage Treatment Plant**

It is seen that the performance of STP at Deendayal Township, KPT STP Plant and Vadinar STP plant is satisfactory by overall. The treatment plant was well maintained during [March 2022] with considerable removal efficiency achieving the standards prescribed for final disposal.

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Table : a - March Result of Sewage Treatment Plant

Location			Kandla STP				Gopalpuri STP				Vadinar STP				
Date			04.03.22	07.03.22	14.03.22	21.03.22	04.03.22	07.03.22	14.03.22	21.03.22	04.03.22	07.03.22	14.03.22	21.03.22	GPCB Prescribed Limit
Sr. No.	Parameters	Unit	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	STP O/L	
1	pH	pH unit	7.2	7.18	7.32	7.38	7.38	7.29	7.12	7.26	7.28	7.41	7.4	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	37.7	93.4	77	85	85	70	88	59.4	47.70	54	39.1	44	100
3	Residual Chlorine	mg/l	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-
4	COD	mg/l	99	98	97	100	96	91	98	100	96	98	98	100	100
5	BOD @ 27 °C	mg/l	28	28	28	30	27	26	28	30	27	28	26	28	30
6	Fecal Coliform	MPN Index / 100 ml	865	780	920	840	340	280	540	630	7.8	21	32	220	< 1000

## **E) Weather**

The historical data collected from Automatic weather station have been installed and other secondary sources to represent the metrological conditions of the project area has been reviewed and presented below for various attributes such as Temperature, Wind, Cloud cover, Humidity, Rainfall, and Visibility.

The predominant wind direction (blowing from) was the Southeast in the port area. Average values of wind speed, temperature, relative humidity and solar radiation recorded were wind velocity for the predominant entire month.

The Day maximum Temperature of March was 32.8°C and min 19.8°C.

Pressure recorded at min of 1013.21 hpa and Max 1021.9 hpa. Heat Index was recorded Min 30.03°C and Max 42.0°C. Humidity was recorded Mean at day 44.54 % and at night 58.77%. Solar Radiation was recorded 118.58 w/m<sup>2</sup> and maximum of 530.7 w/m<sup>2</sup>. The mean wind velocity for the entire month was 5.20 km/hour. Maximum wind velocity recorded was 34.6 Km/hr . The wind direction was mostly SouthEast.

## **F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 13 locations at Deendayal Port ranged from 47.1 dB(A) to 74.4 dB(A) and it was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from 45.30 dB to 68.40 dB(A) and it was within the permissible limits of 70 dB(A) for the industrial area for the night time.

## **2.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 kms. From the mouth of Gulf of Kachchh. **Latitude: 23° 01" N Longitude: 70° 13"E**. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rose to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 14<sup>th</sup> consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles southeast of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. The west coast port handled 72,225 million tonnes of cargo in 2008-09, over 11% more than 64,920 million tonnes handled in 2007-08. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. Although Deendayal Port Authority officials declined to elaborate given the ongoing election code of conduct, it is reliably learnt that the port will soon initiate the process of selecting developers for four clean cargo berths that together aim to handle 8 million tonnes of cargo. The four berths will be supported by a 14 m draft capable of handling 75,000 dwt vessels. The port has already received encouraging response from prospective bidders, for the project that is estimated to cost nearly 5,000 million INR.

The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural upgradation has been affected & excellent maritime infrastructure has been created at Vadinar for the 32MMTPA Essar Oil Refinery in Jamnagar District.



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Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to identify non conformity in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd

# **Ambient Air Quality Monitoring**

### **3. Introduction**

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

#### **3.1 Ambient Air Quality Monitoring**

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

##### **Air Quality Monitoring Methodology**

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub>, HC & Benzene, and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours of the sampler, the reagents were replaced to obtain 3 samples per day for each parameter namely, SO<sub>2</sub>, NO<sub>x</sub>. The EPM 2000 filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected twice a week from all the eight locations as per the EMP.

#### **3.2 Results**

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of March 2022 are given in Tables 1 to 6. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 7 to 8.

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**Note:AL1 To AL8 are Air Monitoring Location 1 to 8. Where AL1 Marine Bhavan, AL2 Oil Jetty, AL3 Estate Office, AL4 Gopalpuri Hospital, AL5 Coal Storage, AL6 Tuna Port, AL7 Signal Building (Vadinar) and AL8 Admin Building (Vadinar).**

**Location 1: Marine Bhavan (AL1)**

Table 1 : Results of Air Pollutant Concentration at Marine Bhavan										
Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO <sub>2</sub> [µg/m³]		NO <sub>x</sub> [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL1 - 1	01.03.2022	260	183	69	2.64	2.40	20.33	21.17	9.45	9.87
					0.62		19.05		9.70	
					3.96		24.14		10.47	
AL1 - 2	04.03.2022	272	189	72	7.03	6.15	14.61	20.11	13.79	13.70
					5.71		15.88		13.53	
					5.71		29.85		13.79	
AL1 - 3	07.03.2022	292	197	87	8.35	7.03	29.85	27.10	12.00	11.49
					7.91		31.76		13.02	
					4.84		19.69		9.45	
AL1 - 4	10.03.2022	412	301	101	2.20	2.05	18.42	17.15	14.55	15.68
					1.76		15.88		17.69	
					2.20		17.15		14.81	
AL1 - 5	14.03.2022	408	315	106	3.96	3.66	19.69	21.38	5.36	9.62
					4.40		20.33		12.00	
					2.64		24.14		11.49	
AL1 - 6	21.03.2022	339	251	92	3.08	3.22	17.78	16.51	10.47	6.13
					4.40		21.60		5.36	
					2.20		10.16		2.55	
AL1 - 7	24.03.2022	352	259	95	2.64	2.64	13.34	18.00	14.81	11.57
					3.52		22.23		10.47	
					1.76		18.42		9.45	
AL1 - 8	28.03.2022	234	178	65	3.08	2.93	27.31	26.25	10.98	7.83
					1.76		30.49		5.62	
					3.96		20.96		6.89	
Monthly Average		321	234	86		3.76		20.96		10.74
Standard Deviation		67	55	15		1.83		3.96		3.08

**Table 1 : Results of Air Pollutant Concentration at Marine Bhavan**

Sampling Period	Date	C6H6 [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>	ppm	4.0 mg/m <sup>3</sup>	-
AL1 - 1	01.03.2022	1.145	BQL	2.01	678
AL1 - 2	04.03.2022	1.201	BQL	1.94	588
AL1 - 3	07.03.2022	1.245	BQL	2.06	601
AL1 - 4	10.03.2022	1.016	BQL	2.08	456
AL1 - 5	14.03.2022	1.035	BQL	1.90	421
AL1 - 6	21.03.2022	1.051	BQL	1.78	535
AL1 - 7	24.03.2022	1.156	BQL	1.88	490
AL1 - 8	28.03.2022	1.089	BQL	2.20	396
Monthly Average		1.12	-	1.98	521
Standard Deviation		0.08	-	0.13	97.5

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 321.00 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 234.0 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 86.0 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.76 µg/ m<sup>3</sup>, 20.96 µg/ m<sup>3</sup> & 10.74 µg/ m<sup>3</sup> respectively. These were within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.98 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 2: Oil Jetty (AL2)

**Table 2 : Results of Air Pollutant Concentration at Oil Jetty**

Table 2 : Results of Air Pollutant Concentration at Oil Jetty										
Paramete	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	Table 1 :	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL2 - 1	01.03.2022	236	148	80	3.17	3.28	15.20	17.72	13.34	11.70
					3.22		18.77		13.11	
					3.45		19.19		8.65	
AL2 - 2	04.03.2022	272	172	92	2.56	2.74	17.78	17.56	7.56	7.30
					2.43		18.47		9.45	
					3.24		16.45		4.90	
AL2 - 3	07.03.2022	266	168	90	5.54	4.94	12.34	14.65	8.76	9.48
					4.61		15.30		9.24	
					4.67		16.33		10.45	
AL2 - 4	10.03.2022	282	199	75	3.78	3.30	18.31	16.65	8.89	9.18
					2.98		14.32		11.44	
					3.15		17.34		7.21	
AL2 - 5	14.03.2022	265	164	93	3.55	3.70	18.25	18.25	7.44	8.48
					3.46		20.76		8.44	
					4.09		15.74		9.56	
AL2 - 6	21.03.2022	359	253	98	5.16	4.86	15.61	14.49	10.19	8.74
					5.55		14.54		6.78	
					3.89		13.33		9.25	
AL2 - 7	24.03.2022	240	152	80	3.40	4.17	17.39	18.40	8.45	9.95
					4.12		16.35		10.88	
					5.01		21.45		10.54	
AL2 - 8	28.03.2022	382	278	96	5.65	4.67	17.77	17.28	9.19	8.49
					4.47		18.33		8.49	
					3.90		15.76		7.79	
Monthly Average		288	192	88		3.96		16.88		9.17
Standard Deviation		54	48	9		0.82		1.52		1.29

<b>Table 2 : Results of Air Pollutant Concentration at Oil Jetty</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>NAAQMS limit</b>					
<b>AL2 -1</b>	01.03.2022	1.11	BQL	1.34	675
<b>AL2 -2</b>	04.03.2022	1.44	BQL	1.87	666
<b>AL2 -3</b>	07.03.2022	1.26	BQL	2.11	456
<b>AL2 -4</b>	10.03.2022	1.18	BQL	1.68	670
<b>AL2 - 5</b>	14.03.2022	1.27	BQL	1.98	835
<b>AL2 - 6</b>	21.03.2022	1.16	BQL	1.24	589
<b>AL2 -7</b>	24.03.2022	1.13	BQL	1.94	423
<b>AL2 -8</b>	28.03.2022	1.43	BQL	1.45	587
<b>Monthly Average</b>		<b>1.25</b>	<b>-</b>	<b>1.70</b>	<b>612.62</b>
<b>Standard Deviation</b>		<b>0.128</b>	<b>-</b>	<b>0.32</b>	<b>131.57</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Oil Jetty area was mainly by motor vehicle emission produced from various types of vehicles Oil Jetty Area. The mean TSPM values at Oil Jetty were 288 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 192 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 88 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit, The mean concentration of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.96 µg/m<sup>3</sup>, 16.88 µg/m<sup>3</sup> and 9.17 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.25 µg/m<sup>3</sup>. Well below the permissible limit of 5.0 µg/m<sup>3</sup>. , NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.70 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 3: Kandla Colony - Estate Office (AL-3)

Table 3 : Results of Air Pollutant Concentration at Estate Office										
Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO2 [µg/m³]		NOx [µg/m³]		NH₃ [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL3 - 1	01.03.2022	259	177	78	3.44	3.95	12.33	14.22	12.33	12.48
					3.19		15.61		12.23	
					5.24		14.74		12.87	
AL3 - 2	04.03.2022	203	142	57	6.44	5.27	17.25	17.41	13.76	11.54
					4.78		18.11		12.32	
					4.59		16.88		8.55	
AL3 - 3	07.03.2022	352	259	89	3.48	4.12	15.22	14.85	9.12	10.53
					5.46		15.77		11.45	
					3.44		13.56		11.02	
AL3 - 4	10.03.2022	320	225	91	4.87	5.14	17.55	17.52	9.13	8.56
					4.77		18.68		8.02	
					5.80		16.34		8.54	
AL3 - 5	14.03.2022	240	156	80	5.34	4.96	16.53	16.66	7.35	9.22
					5.10		17.12		11.65	
					4.45		16.34		8.67	
AL3 - 6	21.03.2022	262	176	82	4.55	4.94	19.15	17.91	9.45	10.71
					4.67		16.61		11.33	
					5.61		17.98		11.34	
AL3 - 7	24.03.2022	262	168	90	4.78	4.96	14.54	15.88	10.67	9.82
					6.66		17.43		9.67	
					3.45		15.67		9.11	
AL3 - 8	28.03.2022	309	200	105	5.58	5.35	16.13	17.51	11.89	9.56
					4.45		17.81		8.18	
					6.02		18.61		8.60	
Monthly Average		276	188	84		4.84		16.50		10.30
Standard Deviation		48	38	14		0.52		1.37		1.28



<b>Table 3 : Results of Air Pollutant Concentration at Estate Office</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>NAAQMS limit</b>					
<b>AL3 -1</b>	01.03.2022	1.110	BQL	2.11	715
<b>AL3 -2</b>	04.03.2022	1.241	BQL	1.71	465
<b>AL3 -3</b>	07.03.2022	1.051	BQL	2.17	456
<b>AL3 -4</b>	10.03.2022	1.181	BQL	1.96	802
<b>AL3 - 5</b>	14.03.2022	1.065	BQL	1.85	651
<b>AL3 - 6</b>	21.03.2022	1.11	BQL	1.78	643
<b>AL3 - 7</b>	24.03.2022	1.085	BQL	1.81	734
<b>AL3 - 8</b>	28.03.2022	1.121	BQL	2.18	421
<b>Monthly Average</b>		<b>1.12</b>	<b>-</b>	<b>1.95</b>	<b>611</b>
<b>Standard Deviation</b>		<b>0.063</b>	<b>-</b>	<b>0.18</b>	<b>144.66</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit - NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Kandla Port Colony was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Oil Jetty were 276 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 188 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 84 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.84 µg/m<sup>3</sup>, 16.50 µg/m<sup>3</sup> and 10.30 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.95 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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## Location 4: Gopalpuri Hospital (AL-4)

**Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital**

Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
Paramete	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL4 -1	01.03.2022	178	120	55	3.6	3.99	10.67	11.51	7.54	8.21
					3.85		12.31		8.65	
					4.51		11.56		8.43	
AL4 -2	04.03.2022	189	119	67	4.01	3.28	12.43	12.59	6.76	7.80
					2.51		12.11		7.76	
					3.31		13.24		8.89	
AL4 -3	07.03.2022	230	144	83	3.12	3.55	13.41	14.31	7.67	8.06
					3.42		14.51		8.98	
					4.12		15.01		7.54	
AL4 -4	10.03.2022	273	178	92	3.02	3.25	10.87	12.5	7.45	8.66
					3.32		12.65		8.65	
					3.41		13.98		9.89	
AL4 - 5	14.03.2022	231	148	80	2.98	3.53	12.87	13.29	7.56	7.67
					3.41		12.23		8.15	
					4.21		14.76		7.31	
AL4 - 6	21.03.2022	310	211	96	3.21	3.28	14.15	13.19	6.89	7.81
					2.76		12.65		8.67	
					3.87		12.76		7.87	
AL4 - 7	24.03.2022	185	110	72	2.98	3.40	14.78	13.29	7.61	7.39
					3.45		13.12		6.98	
					3.76		11.98		7.57	
AL4 - 8	28.03.2022	205	122	80	2.96	3.57	12.65	13.54	8.61	9.46
					3.24		13.54		9.65	
					4.51		14.41		10.11	
Monthly Average		225	144	78		3.48		13.02		8.13
Standard Deviation		46	35	13		0.24		0.83		0.66

<b>Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO2 [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL4 -1</b>	01.03.2022	1.096	BQL	2.23	572
<b>AL4 -2</b>	04.03.2022	1.135	BQL	1.88	537
<b>AL4 -3</b>	07.03.2022	1.23	BQL	1.79	607
<b>AL4 -4</b>	10.03.2022	1.132	BQL	2.32	651
<b>AL4 - 5</b>	14.03.2022	1.243	BQL	1.78	741
<b>AL4 - 6</b>	21.03.2022	1.212	BQL	2.09	756
<b>AL4 - 7</b>	24.03.2022	1.312	BQL	1.81	634
<b>AL4 - 8</b>	28.03.2022	1.223	BQL	2.01	765
<b>Monthly Average</b>		<b>1.20</b>	<b>-</b>	<b>1.99</b>	<b>658</b>
<b>Standard Deviation</b>		<b>0.071</b>	<b>-</b>	<b>0.21</b>	<b>87</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 225 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 144 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 78 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.48 µg/m<sup>3</sup>, 13.02 µg/m<sup>3</sup> and 8.13 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.20 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.99 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 5: Coal Storage Area (AL-5)**

**Table 5 : Results of Air Pollutant Concentration at Coal Storage Area**

Table 5 : Results of Air Pollutant Concentration at Coal Storage Area										
Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.) 80	8 hr	24hr (Avg.) 80	8 hr	24hr (Avg.) 400
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL5 - 1	01.03.2022	396	292	102	3.65	4.16	19.32	17.59	10.89	8.91
					4.21		20.01		7.32	
					4.61		13.43		8.51	
AL5 - 2	04.03.2022	337	237	98	3.12	3.61	15.21	16.39	7.98	8.80
					4.01		16.33		9.67	
					3.71		17.63		8.76	
AL5 - 3	07.03.2022	524	392	130	4.21	3.95	17.35	15.51	9.46	8.52
					3.43		16.64		7.56	
					4.21		12.54		8.55	
AL5 - 4	10.03.2022	358	258	98	3.43	3.62	13.01	13.66	10.09	8.94
					3.31		14.21		8.65	
					4.12		13.76		8.09	
AL5 - 5	14.03.2022	442	309	111	3.09	3.81	15.43	17.29	10.43	11.03
					4.11		17.11		11.11	
					4.23		19.32		11.55	
AL5 - 6	21.03.2022	445	322	121	3.21	3.67	13.21	16.91	10.43	9.84
					3.67		18.21		9.34	
					4.13		19.32		9.76	
AL5 - 7	24.03.2022	432	313	117	3.78	3.79	12.32	14.52	7.87	8.57
					4.43		12.56		8.87	
					3.15		18.67		8.98	
AL5 - 8	28.03.2022	415	306	107	3.42	3.99	17.65	14.95	10.34	9.73
					4.22		13.12		9.87	
					4.32		14.09		8.98	
Monthly Average		416	304	111		3.82		15.85		9.29
Standard Deviation		57	46	12		0.19		1.41		0.86

<b>Table 5 : Results of Air Pollutant Concentration at Coal Storage Area</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>NAAQMS limit</b>					
<b>AL5 - 1</b>	01.03.2022	1.123	BQL	1.97	878
<b>AL5 - 2</b>	04.03.2022	1.223	BQL	2.12	544
<b>AL5 - 3</b>	07.03.2022	1.121	BQL	1.99	521
<b>AL5 - 4</b>	10.03.2022	1.243	BQL	1.81	588
<b>AL5 - 5</b>	14.03.2022	1.034	BQL	2.0	621
<b>AL5 - 6</b>	21.03.2022	1.143	BQL	2.26	609
<b>AL5 - 7</b>	24.03.2022	1.231	BQL	2.13	655
<b>AL5 - 8</b>	28.03.2022	1.012	BQL	2.01	543
<b>Monthly Average</b>		<b>1.14</b>	<b>-</b>	<b>2.04</b>	<b>620</b>
<b>Standard Deviation</b>		<b>0.09</b>	<b>-</b>	<b>0.13</b>	<b>114</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 416 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 304 µg/m<sup>3</sup>, which is well above the permissible limit. PM<sub>2.5</sub> values were 111 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.82 µg/m<sup>3</sup>, 15.85 µg/m<sup>3</sup> and 9.29 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.14 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 2.04 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 6: Tuna Port (AL-6)

**Table 6 : Results of Air Pollutant Concentration at Tuna Port**

Table 6 : Results of Air Pollutant Concentration atTuna Port										
Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO <sub>2</sub> [µg/m³]		NO <sub>x</sub> [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m 3]		400 [µg/m³]
AL6 -1	01.03.2022	221	141	70	4.55	4.78	16.77	14.84	11.33	10.55
					4.44		15.19		11.54	
					5.34		12.56		8.78	
AL6 - 2	04.03.2022	173	106	57	4.76	4.51	15.70	15.42	8.76	8.47
					4.12		16.18		9.18	
					4.66		14.37		7.46	
AL6 - 3	07.03.2022	229	152	67	5.78	5.59	15.45	18.18	8.11	8.83
					5.89		18.48		9.80	
					5.11		20.62		8.59	
AL6 - 4	10.03.2022	277	169	98	5.79	5.21	14.66	15.45	8.51	8.25
					4.17		16.80		7.90	
					5.69		14.89		8.35	
AL6 - 5	14.03.2022	296	196	90	3.64	4.45	18.12	16.78	12.57	11.59
					5.60		15.89		10.34	
					4.12		16.34		11.87	
AL6 - 6	21.03.2022	275	185	80	4.78	5.56	18.35	19.37	8.55	12.01
					6.26		18.54		13.44	
					5.64		21.23		14.06	
AL6 - 7	24.03.2022	247	150	87	5.80	5.17	18.57	17.93	7.53	9.93
					5.17		17.32		11.52	
					4.55		17.89		10.75	
AL6 - 8	28.03.2022	268	172	86	4.57	4.59	19.21	16.36	11.55	9.63
					4.52		14.66		8.57	
					4.68		15.22		8.78	
Monthly Average		248	159	79		4.98		16.79		9.91
Standard Deviation		40	28	14		0.46		1.58		1.40

<b>Table 6 : Results of Air Pollutant Concentration at Tuna Port</b>					
	<b>Date</b>	<b>C6H6 [µg/m3]</b>	<b>*NMHC</b>	<b>CO [mg/m3]</b>	<b>CO2 [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Samplin g</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m3</b>		<b>4.0 mg/m3</b>	<b>-</b>
<b>AL6 -1</b>	01.03.2022	1.123	BQL	2.08	554
<b>AL6 -2</b>	04.03.2022	1.213	BQL	1.89	623
<b>AL6 -3</b>	07.03.2022	1.056	BQL	1.96	585
<b>AL6 -4</b>	10.03.2022	1.214	BQL	2.0	532
<b>AL6 -5</b>	14.03.2022	1.188	BQL	1.69	711
<b>AL6 -6</b>	21.03.2022	1.008	BQL	1.88	687
<b>AL6 -7</b>	24.03.2022	1.087	BQL	1.79	677
<b>AL6 -8</b>	28.03.2022	1.154	BQL	2.09	511
<b>Monthly Average</b>		<b>1.13</b>	<b>-</b>	<b>1.92</b>	<b>610</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.14</b>	<b>76</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit - NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port were 248 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 159 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 79 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.98 µg/m<sup>3</sup>, 16.79 µg/m<sup>3</sup> and 9.91 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.13 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.92 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 7: Signal Building (Vadinar) (AL-7)

**Table 7 : Results of Air Pollutant Concentration at Signal Building**

Table 7 : Results of Air Pollutant Concentration at Signal Building										
Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL7 -1	01.03.2022	175	101	68	3.86	3.81	14.11	13.34	7.98	8.34
					3.25		13.98		9.01	
					4.01		12.98		8.56	
AL7 -2	04.03.2022	193	114	73	4.12	4.10	20.98	18.42	7.42	7.32
					3.67		21.12		8.31	
					4.02		18.65		6.98	
AL7 -3	08.03.2022	156	86	64	4.32	5.28	13.53	14.61	8.12	9.79
					3.99		15.21		9.45	
					4.98		17.54		10.01	
AL7 -4	11.03.2022	215	119	90	5.02	4.84	20.12	16.94	8.12	8.34
					4.32		18.91		7.89	
					3.78		17.12		8.43	
AL7 -5	14.03.2022	157	86	65	3.98	4.69	19.67	19.90	9.32	8.00
					4.32		20.21		8.67	
					3.89		17.89		8.23	
AL7 -6	21.03.2022	170	94	70	3.54	3.66	13.21	13.97	7.66	9.45
					5.09		14.32		10.21	
					4.76		15.89		10.47	
AL7 -7	24.03.2022	157	93	58	4.43	3.52	13.65	16.51	10.72	9.36
					3.43		15.67		8.93	
					4.12		14.92		8.42	
AL7 -8	28.03.2022	163	89	68	4.98	4.25	14.44	15.46	9.87	9.87
					5.09		15.03		10.23	
					3.98		16.65		8.65	
Monthly Average		173	98	69		4.21		16.49		8.82
Standard Deviation		21	13	9		0.33		2.51		0.71



<b>Table 7: Results of Air Pollutant Concentration at Signal buil vdr.</b>					
	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL7 -1</b>	01.03.2022	1.23	BQL	1.52	376
<b>AL7 -2</b>	04.03.2022	1.18	BQL	1.67	598
<b>AL7 -3</b>	08.03.2022	1.09	BQL	1.76	612
<b>AL7 -4</b>	11.03.2022	1.34	BQL	1.98	456
<b>AL7 -5</b>	14.03.2022	1.05	BQL	1.71	576
<b>AL7 -6</b>	22.03.2022	1.21	BQL	2.12	487
<b>AL7 -7</b>	25.03.2022	1.19	BQL	2.09	587
<b>AL7 -8</b>	28.03.2022	1.21	BQL	1.96	453
<b>Monthly Average</b>		<b>1.22</b>	<b>-</b>	<b>1.85</b>	<b>518</b>
<b>Standard Deviation</b>		<b>0.14</b>	<b>-</b>	<b>0.22</b>	<b>87</b>

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit - NMHC: 0.5 ppm)

The mean TSPM values at Vadinar Port were 173 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 98 µg/m<sup>3</sup>, which is below the permissible limit. PM<sub>2.5</sub> values were 69 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.21 µg/m<sup>3</sup>, 16.49 µg/m<sup>3</sup> and 8.82 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.22 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.85 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 8: Admin Building (Vadinar) (AL-8)

**Table 8: Results of Air Pollutant Concentration at Admin Building**

Table 8: Results of Air Pollutant Concentration at Admin Building										
Parameter	Date	TSPM [µg/m³]	PM10 [µg/m³]	PM2.5 [µg/m³]	SO <sub>2</sub> [µg/m³]		NO <sub>x</sub> [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		NS	100 [µg/m3]	60 [µg/m3]		80 [µg/m3]		80 [µg/m3]		400 [µg/m³]
AL8 -1	01.03.2022	120	74	43	3.63	3.73	16.67	17.34	7.67	7.10
					3.54		17.89		6.08	
					4.01		17.45		7.56	
AL8 -2	04.03.2022	189	111	75	3.65	3.55	15.43	16.50	8.01	8.07
					2.88		16.76		7.98	
					4.12		17.32		8.23	
AL8 -3	08.03.2022	190	108	79	3.81	3.23	15.87	15.62	7.21	7.83
					3.12		16.01		7.87	
					2.76		14.98		8.42	
AL8 -4	11.03.2022	168	96	69	4.01	4.03	12.54	14.80	7.98	8.87
					3.86		15.34		8.87	
					4.23		16.51		9.77	
AL8 -5	14.03.2022	206	113	90	3.19	3.46	13.53	14.40	7.62	8.22
					2.87		14.65		8.32	
					4.32		15.01		8.72	
AL8 -6	22.03.2022	198	107	88	4.09	4.66	18.65	19.51	9.12	8.66
					4.87		20.01		8.87	
					5.01		19.87		7.98	
AL8 -7	25.03.2022	197	109	85	3.56	3.85	17.65	17.62	8.22	7.92
					4.01		18.23		7.98	
					3.98		16.99		7.56	
AL8- 8	28.03.2022	197	114	80	4.12	4.47	19.21	19.30	9.12	8.74
					4.76		20.01		8.88	
					4.54		18.67		8.21	
Monthly Average		183	104	76		3.87		16.89		8.18
Standard Deviation		28	13	15		0.49		1.92		0.58

<b>Table 8 : Results of Air Pollutant Concentration at Admin Building</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C6H6 [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL8 -1</b>	01.03.2022	1.43	BQL	1.83	365
<b>AL8 -2</b>	04.03.2022	1.11	BQL	2.09	465
<b>AL8 -3</b>	08.03.2022	1.21	BQL	1.91	575
<b>AL8 -4</b>	11.03.2022	1.19	BQL	1.76	441
<b>AL8 -5</b>	14.03.2022	1.02	BQL	1.71	515
<b>AL8 -6</b>	22.03.2022	1.23	BQL	2.0	398
<b>AL8 -7</b>	25.03.2022	1.31	BQL	1.99	423
<b>AL8 -8</b>	28.03.2022	1.18	BQL	1.71	387
<b>Monthly Average</b>		<b>1.24</b>	<b>-</b>	<b>1.88</b>	<b>446</b>
<b>Standard Deviation</b>		<b>0.12</b>	<b>-</b>	<b>0.14</b>	<b>70.36</b>

\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Admin Building Vadinar was comparatively low among all the locations of Air Quality monitoring in Kandla Port and Vadinar Port. The mean TSPM values at Vadinar Port were 183 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 104 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 76.0 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.87 µg/m<sup>3</sup>, 16.89 µg/m<sup>3</sup> and 8.18 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Admin Building, Vadinar Port. The mean Benzene concentration was 1.24 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.88 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

### 3.3 Observations and Conclusion

During the monitoring period, the overall Ambient Air Quality of the port area was found to be well within the desired levels for various gaseous pollutants. However, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan, Estate Office, Tuna Port , Oil Jetty area, and Gopalpuri.

# **Drinking Water Monitoring**

#### **4.0 Drinking Water Quality Monitoring**

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

#### **4.1 Drinking Water Monitoring Methodology**

Drinking water samples were collected from 20 locations as prescribed in the tender document. Samples for physico-chemical analysis were collected in 1 liter carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling and Analysis was done as per standard methods - IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate , Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (cfu) .

#### **4.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 9 to Table No. 15

**Environmental Monitoring Report Of Deendayal Port Authority, MARCH-2022****Table 9: Drinking Water Quality Monitoring Parameters for Nirman Building 1 (23° 0' 27"E, 70° 13' 21"N) P & C building (23° 0' 33"E 70° 13' 20"N) & Main Gate (North) at Kandla (23° 0' 26.97"E, 70° 13' 21.87"N)**

Sr. No.	Parameter	Unit	Nirman Building	P & C building	Main Gate	Acceptable Limits as per	Permissible Limits in the absence of
1	pH	pH Unit	7.2	7.1	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved	mg/l	950	1120	1020	500	2000
3	Turbidity	NTU	0	0	1	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1720	2130	1820	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	561.2	606.35	546.21	250	1000
9	Total Hardness	mg/l	430	440	460	200	600
10	Calcium	mg/l	60.12	64.13	68.14	75	200
11	Salinity	%	1.01	1.095	0.98	NS*	NS*
12	Mg as Mg	mg/l	68.04	68.04	70.47	30	100
13	Fluorides as F	mg/l	0.74	0.69	0.81	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	254.4	222	206.4	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	0.0056	0.00574	0.006	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	7.18	6.89	7.88	45	No Relaxation
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
18	Sodium as Na	mg/l	202.5	201.8	232.5	NS*	NS*
19	Potassium as K	mg/l	3.18	4.07	5.38	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Environmental Monitoring Report Of Deendayal Port Authority, MARCH-2022****Table 10: Drinking Water Quality Monitoring Parameters for Canteen, (23° 2' 17.2674"E, 70° 13' 18.2814"N) West Gate - I(23° 59' 40.48"E, 70° 12' 50.96"N) & Wharf Area (22° 59' 52.2"E, 70° 13' 22.95"N) at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate - I	Wharf Area	Acceptable Limits as	Permissible Limits in the absence of
1	pH	pH Unit	7.4	7.5	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1160	970	1060	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	2160	1790	1950	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	626.39	586.30	616.37	250	1000
9	Total Hardness	mg/l	450	420	410	75	600
10	Calcium	mg/l	56.11	52.10	60.12	30	200
11	Salinity	%	1.13	1.06	1.11	200	NS*
12	Mg as Mg	mg/l	75.33	70.47	63.18	0.3	100
13	Fluorides as F	mg/l	0.82	0.41	0.52	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	246	217.2	214.8	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	0.006	0.006	0.006	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	8.66	9.5	9.92	45	No Relaxation
17	Iron as Fe	mg/l	1.13	1.06	1.11	0.3	No Relaxation
18	Sodium as Na	mg/l	217.8	240.9	251.7	NS*	NS*
19	Potassium as K	mg/l	4.28	5.3	5.76	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Environmental Monitoring Report Of Deendayal Port Authority, MARCH-2022****Table 11: Drinking Water Quality Monitoring Parameters for Sewa sadan - 3,( 23° 0' 22.55"E, 70° 13' 15.34"N) Workshop I (23° 0' 33.74"E, 70° 13' 20.05"N)&Custom Building (23° 1' 8.70"E, 70° 12' 52.0"N) at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan - 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.2	7.6	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	980	1120	1210	500	2000
3	Turbidity	NTU	0	0	1	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1730	2090	2230	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	546.21	581.29	611.36	250	1000
9	Total Hardness	mg/l	440	450	420	200	600
10	Calcium	mg/l	72.14	56.11	48.10	75	200
11	Salinity	%	0.98	1.05	1.10	NS*	NS*
12	Mg as Mg	mg/l	63.18	75.33	72.90	30	100
13	Fluorides as F	mg/l	0.55	0.85	0.92	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	231.6	252	265.2	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	0.0066	0.007	0.0073	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	12.32	10.77	11.33	45	100
17	Iron as Fe	mg/l	0.98	1.05	1.1	0.3	1.0
18	Sodium as Na	mg/l	249.8	315.6	183.8	NS*	NS*
19	Potassium as K	mg/l	5.17	5.92	2.08	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>6+</sup>- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



**Environmental Monitoring Report Of Deendayal Port Authority, MARCH-2022****Table 12: Drinking Water Quality Monitoring Parameters for Port Colony Kandla (23° 11' 14.9"E, 70° 12' 48.4"N) Hospital Kandla 23° 1' 5.02"E, 70° 12' 44.38"N) & A.O. Building (23° 3' 42.89"E, 70° 8' 41.5"N) at Gandhidham**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.3	7.5	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1130	1210	960	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odour	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	2040	2360	1750	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	656.46	646.43	576.28	250	1000
9	Total Hardness	mg/l	410	440	450	200	600
10	Calcium	mg/l	52.10	60.12	64.13	75	200
11	Salinity	%	1.18	1.16	1.04	NS*	NS*
12	Mg as Mg	mg/l	68.04	70.47	70.47	30	100
13	Fluorides as F	mg/l	0.81	0.73	0.86	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	184.8	195.6	202.8	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	0.0063	0.0067	0.007	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	8.87	12.32	12.742	45	100
17	Iron as Fe	mg/l	1.18	1.16	1.04	0.3	1.0
18	Sodium as Na	mg/l	228.1	236.9	356.8	NS*	NS*
19	Potassium as K	mg/l	3.15	4.65	6.18	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 13: Drinking Water Quality Monitoring Parameters for School Gopalpuri,( 23° 5' 1.03"E, 70° 7' 55.42"N) Guest House (23° 4' 43.14"E, 70° 7' 51.92"N) & E - Type Quarter(23° 4' 59.90"E, 70° 7' 56.72"N) at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.3	7.6	7.5	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1060	1220	1130	500	2000
3	Turbidity	NTU	0	1	1	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1850	2360	2100	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	616.37	531.18	516.14	250	1000
9	Total Hardness	mg/l	470	460	450	200	600
10	Calcium	mg/l	68.14	60.12	64.13	75	200
11	Salinity	%	1.11	0.95	0.93	NS*	NS*
12	Mg as Mg	mg/l	72.90	75.33	70.47	30	100
13	Fluorides as F	mg/l	0.63	0.69	0.74	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	206.4	198	174	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	0.0055	0.0057	0.0061	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	9.99	10.98	9.50	45	100
17	Iron as Fe	mg/l	1.11	0.95	0.93	0.3	1.0
18	Sodium as Na	mg/l	229.8	265.9	31.14	NS*	NS*
19	Potassium as K	mg/l	3.29	5.89	5.9	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Environmental Monitoring Report Of Deendayal Port Authority, MARCH-2022****Table 14:Drinking Water Quality Monitoring Parameters for F - Type Quarter, (23° 4' 38.45"E, 70° 8' 8.63"N) Hospital Gopalpuri (23° 4' 54.09"E, 70° 8' 7.5"N) & Tuna Port (23° 58' 23.06"E, 70° 5' 35.6"N)**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptabl e Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.4	7.3	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1080	1100	980	500	2000
3	Turbidity	NTU	1	0	0	1	5
4	Odor	-	Odourless	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	Colourless	5	15
6	Conductivity	µs/cm	1830	2140	1920	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	566.25	616.37	594.32	250	1000
9	Total Hardness	mg/l	410	430	420	200	600
10	Calcium	mg/l	68.14	72.14	76.15	75	200
11	Salinity	%	1.02	1.11	0.93	NS*	NS*
12	Mg as Mg	mg/l	58.32	60.75	55.89	30	100
13	Fluorides as F	mg/l	0.95	0.86	0.66	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	181.2	213.6	218.4	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	0.0062	0.0065	0.0068	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	10.77	8.51	7.60	45	100
17	Iron as Fe	mg/l	1.02	1.11	0.93	0.3	1.0
18	Sodium as Na	mg/l	244.9	273.8	281.4	NS*	NS*
19	Potassium as K	mg/l	5.05	5.38	4.19	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 15: Drinking Water Quality Monitoring Parameters for Vadinar Jetty(22° 25' 51.73"E, 69° 41' 36.62"N) & Port Colony (22° 30' 26.25"E, 69° 39' 45.03"N) at Vadinar**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	pH Unit	7.5	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1070	1030	500	2000
3	Turbidity	NTU	0	1	1	5
4	Odor	-	Odourless	Odourless	Agreeable	Agreeable
5	Color	Hazen Units	Colourless	Colourless	5	15
6	Conductivity	µs/cm	2010	1030	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	496.10	511.13	250	1000
9	Total Hardness	mg/l	460	450	200	600
10	Calcium	mg/l	64.13	56.11	75	200
11	Salinity	%	0.89	0.92	NS*	NS*
12	Mg as Mg	mg/l	72.90	75.33	30	100
13	Fluorides as F	mg/l	0.87	0.80	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	19.44	19.08	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	0.0059	0.0060	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	7.95	8.52	45	100
17	Iron as Fe	mg/l	0.89	0.92	0.3	1.0
18	Sodium as Na	mg/l	51.49	49.05	NS*	NS*
19	Potassium as K	mg/l	4.39	3.76	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	0.003
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	0.001
26	Lead	mg/l	BQL	BQL	0.01	0.01
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **4.3 Results & Discussion**

The colour of all drinking water samples was <5 Hazen unit and odour of the samples was also agreeable. All parameters are found to be within the specified limit of the Drinking water Standard.

#### **pH**

The limit of pH value for drinking water is specified as 7.1 to 7.6. pH value in the studied area varied from 7.1 to 7.6 pH unit. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Total Dissolved Solids (TDS)**

TDS values in the studied area varied between 950 - 1220 mg/l. None of the sampling points showed higher TDS values than the prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of March ranged from 1030-2360  $\mu\text{S}/\text{cm}$ . Electrical conductivity standards do not appear in BIS standards for drinking water.

#### **BOD**

BOD value in the studied area was found Below Quantification Limit (2.0 mg/l). Indian standards does not show any standard values for BOD in drinking water.

#### **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. Chloride value in the studied area varied between 496.1- 656.4 mg/l and is found to be within the Permissible limit of the Drinking Water Standard.

#### **Calcium**

Calcium value in the studied area varied between 48.09 - 76.15 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. If calcium is present beyond the maximum acceptable limit, it causes incrustation of pipes.

### **Magnesium**

Magnesium value in the studied area varied between 55.89 - 75.33 mg/l. All the locations had Magnesium within the prescribed limits of 30-100 mg/L.

### **Total Hardness**

Hardness value in the studied area varied between 410 - 470 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. The prescribed limit by Indian Standards is 200-600 mg/L.

### **Iron**

Iron value in the studied area was found Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards is 0.3 mg/L. The excess amount of iron causes slight toxicity; gives stringent taste to water.

### **Fluoride**

Fluoride value in the studied area varied between 0.42 - 0.95 mg/l and hence well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphates**

Sulphate value in the studied area varied between 19.08 - 265.2 mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

Nitrite values in all the water samples were found Below Quantification Limit (0.1 mg/l). There are no specified standard values for Nitrites in Drinking water. The minimum Nitrate value in drinking water of KPT was 0.0055 mg/l which is well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected ranged from 0.89 to 1.1%. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected ranged from 31.14 - 356.8 mg/l and Potassium salts ranged from 2.08 to 6.18 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter at all location shows that Bacteria is not present and hence Bacterial count is in line with the permissible limit of drinking water. This shows that all the drinking water samples were safe from any bacteriological contamination.

## **4.4 Conclusions**

These results are compared with acceptable limits as prescribed in IS 10500:2012 - Drinking Water Specification. It is seen from the analysis data that during the study period the water was safe for human consumption at all drinking water monitoring stations.

# **Noise Quality Monitoring**



## 5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 5.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 5.2 Results

**Table 16: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	6:00 am to 10:00 PM	10:00PM to 6:00 AM
1	Marine Bhavan	67.5	66.0
2	Nirman Building 1	65.2	61.7
3	Tuna Port	47.1	45.3
4	Main Gate North	64.4	61.2
5	West Gate I	55.2	54.9
6	Canteen Area	63.4	55.2
7	Main Road	60.7	53.2
8	ATM Building	69.8	68.4
9	Wharf Area /Jetty Area	74.4	62.8
10	Port & Custom Office	57.9	56.5
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	66.8	53.7
12	Nr. Port Colony, Vadinar	60.4	52.8
13	Nr. Vadinar Jetty	72.5	63.7

### 5.3 Conclusions

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 13 locations at Deendayal Port ranged from 47.1 dB(A) to 74.4 dB(A) and it was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from 45.30 dB to 68.40 dB(A) and it was within the permissible limits of 70 dB(A) for the industrial area for the night time.

# **Soil Quality Monitoring**

## **6.0 Soil Monitoring**

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

### **6.1 Methodology**

The soil samples were collected in the month of March 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

## 6.2 Results

**Table-17: Chemical Characteristics of Soil in the Study Area for Tuna port,** (22° 58' 10.18"E, 70° 6' 3.7"N) IFFCO plant (23° 26' 8.37"E, 70° 13' 4.4"N), Khori creek, (22° 58' 10.18"E, 70° 6' 3.7"N) Nakti Creek,( 23° 2' 1.10"E, 70° 9' 33.6"N) KPT admin site,( 22° 26' 30.9"E, 69° 40' 37.03"N) KPT colony(22° 23' 57.09"E, 69° 42' 49.42"N)

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	KPT Admin	KPT Colony
			Near main gate of	10 m away	Sand from creek at low tide			Vadinar
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	8.59	8.6	8.68	8.47	7.67	7.85
3	Electrical Conductivity	µs/cm	12,839.00	11,442.00	10,950.00	14,848.00	545	600
4	Moisture	%	22	28.37	21	24.88	4.99	10.65
5	Total Organic Carbon	%	0.96	0.71	0.98	0.84	1.74	0.62
6	Alkalinity	mg/kg	40.04	40.04	40.04	40.04	80.08	80.08
7	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
8	Chloride	mg/kg	3,545.00	2,481.50	2,836.00	3,190.50	35.5	28.4
9	Sulphate	mg/kg	3,891.18	1,650.89	1,292.27	4,950.89	BQL	BQL
10	Phosphorus	mg/kg	10.87	5.33	8.87	8.5	1.88	1.96
11	Potassium	mg/kg	192.3	155.01	160.36	178.48	31.3	33.61
12	Sodium	mg/kg	2,466.12	1,500.32	1,839.79	2,450.29	32.56	35.2
13	Calcium	mg/kg	284.57	432.86	232.46	492.9	637.27	581.1
14	Copper as Cu	mg/kg	43.4	18.1	20	15.4	85.5	76.2
15	Lead as Pb	mg/kg	7.8	5.4	5.7	5.8	1.4	ND
16	Nickel as Ni	mg/kg	17.4	35.4	40.9	30.2	42.1	42.2
17	Zinc as Zn	mg/kg	110.6	48.8	50.4	42.6	85.4	58.4
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg).

### **6.3 Discussion**

The data shows that value of pH ranges from 7.85 at KPT Colony (Vadinar) to 8.68 at Khorī Creek indicating that all soil samples are neutral to slight basic. Nakti creek samples showed maximum conductivity of 14,848.00  $\mu\text{mhos/cm}$ , while KPT Colony (Vadinar) location showed minimum conductivity of 10950.  $\mu\text{mhos/cm}$ . Conductivity at Vadinar Port was 545 and 600  $\mu\text{mhos/cm}$  at Admin site and Vadinar Port colony respectively.

Total organic Carbon ranged from 0.71 % to 0.98 at Deendayal Port. At Vadinar Port, organic Carbon range from 0.62 % to 1.74.

The concentration of Phosphorus and Potassium in the soil samples varies from 5.33 to 10.87 mg/kg and 155.1 to 192.3 mg/kg respectively at Deendayal Port. The mean concentration of Phosphorous at Vadinar site was 1.92 mg/kg and mean concentration of Potassium at Vadinar site was 32.46 mg/kg.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khorī Creek & Nakti Creek) are of saline nature as they are coastal soil; where as other locations are inland locations and have different chemical properties.

#### **Heavy Metals in the Soil**

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### **6.4 Conclusion**

The soils of Deendayal Port and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

# **Sewage Treatment Quality Monitoring**

## 7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guide lines of State Pollution Control Board and other statutory bodies.

### 7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

### 7.2 Results

#### Kandla STP

**Table 18: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

Date of Sampling		04.03.22			
Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			KPT STP I/L	KPT STP O/L	
1	pH	pH unit	7.45	7.2	6.5 - 8.5
2	Total Suspended	mg/l	398.4	37.7	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	304	99	100
5	BOD @ 27 °C	mg/l	101	28	30
6	Fecal Coliform	MPN Index /	-	865	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l		140	
8	MLVSS	%		49	

**Table 19: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	07.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			KPT STP I/L	KPT STP O/L	
1	pH	pH unit	7.43	7.18	6.5 - 8.5
2	Total Suspended Solids	mg/l	121.2	93.4	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	282	98	100
5	BOD @ 27 °C	mg/l	101	28	30
6	Fecal Coliform	MPN Index / 100 ml	-	780	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l	215		
8	MLVSS	%	56		

**Table 20: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	14.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			KPT STP I/L	KPT STP O/L	
1	pH	pH unit	7.55	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	105.4	77	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	253.5	97	100
5	BOD @ 27 °C	mg/l	89	28	30
6	Fecal Coliform	MPN Index / 100 ml	-	920	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l	45		
8	MLVSS	%	81		



**Table 21: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	21.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			KPT STP I/L	KPT STP O/L	
1	pH	pH unit	7.65	7.38	6.5 - 8.5
2	Total Suspended Solids	mg/l	224.4	85	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	332	100	100
5	BOD @ 27 °C	mg/l	110	30	30
6	Fecal Coliform	MPN Index / 100 ml	-	840	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l	32		
8	MLVSS	%	88		

**Table 22: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	04.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	pH unit	7.65	7.38	6.5 - 8.5
2	Total Suspended Solids	mg/l	224.4	85	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	332	96	100
5	BOD @ 27 °C	mg/l	110	27	30
6	Fecal Coliform	MPN Index / 100 ml	-	340	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l	32		
8	MLVSS	%	88		

**Table 23: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	07.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	pH unit	7.55	7.29	6.5 - 8.5
2	Total Suspended Solids	mg/l	280.4	70	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	303	91	100
5	BOD @ 27 °C	mg/l	106	26	30
6	Fecal Coliform	MPN Index / 100 ml	-	280	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l	30		
8	MLVSS	%	71		

**Table 24: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	14.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	pH unit	7.36	7.12	6.5 - 8.5
2	Total Suspended Solids	mg/l	380.4	88	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	303	98	100
5	BOD @ 27 °C	mg/l	106	28	30
6	Fecal Coliform	MPN	-	540	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l	198		
8	MLVSS	%	62		

**Table 25: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	21.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	pH unit	7.43	7.26	6.5 - 8.5
2	Total Suspended Solids	mg/l	268.8	59.4	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	290	100	100
5	BOD @ 27 °C	mg/l	102	30	30
6	Fecal Coliform	MPN Index / 100 ml	-	630	< 1000
<b>Aeration Tank</b>					
7	MLSS	mg/l	25		
8	MLVSS	%	90		

### Vadinar STP

**Table 26: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	04.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	pH unit	7.51	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	101.5	47.7	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	253	96	100
5	BOD @ 27 °C	mg/l	90	27	30
6	Fecal Coliform	MPN Index / 100 ml	-	7.8	< 1000

**Table 27: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	07.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	pH unit	7.76	7.41	6.5 - 8.5
2	Total Suspended	mg/l	105.4	54	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	240	98	100
5	BOD @ 27 °C	mg/l	82	28	30
6	Fecal Coliform	MPN Index / 100 ml		21	< 1000

**Table 28: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	14.03.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	pH unit	7.61	7.4	6.5 - 8.5
2	Total Suspended Solids	mg/l	100.4	39.1	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	233	98	100
5	BOD @ 27 °C	mg/l	78	26	30
6	Fecal Coliform	MPN Index / 100 ml		32	< 1000

**Table 29: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	21.03.22
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<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>		<b>GPCB Prescribed Limit</b>
			<b>Vadinar STP I/L</b>	<b>Vadinar O/L</b>	
1	pH	pH unit	7.5	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	93.5	44	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	230	100	100
5	BOD @ 27 °C	mg/l	76	28	30
6	Fecal Coliform	MPN Index / 100 ml	-	220	< 1000

### **7.3 Conclusions:**

The GPCB standards of BOD, TSS, PH, COD and Fecal Coliform for STP outlet are 30 mg/lit, 100 mg/lit 6.5 - 8.5 , 100 & < 1000 mg/lit respectively. All results are found within permissible limits.

# **Marine Water Quality Monitoring**

## **8.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of 'green thinking'. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A(g) states that the "fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures".

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at "integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources." The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 03<sup>rd</sup> & 04<sup>th</sup> March-2022 in harbor regions of KPT and on 03<sup>rd</sup> March-2022 at Vadinar during spring tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 10<sup>th</sup> &

11<sup>th</sup> March 2022 in harbor regions of KPT. 10<sup>th</sup> March -2022 in Vadinar during Neap tide period first quarter of Lunar Cycle..

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and two stations in Nakti creek and one station in Khori creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

### **Sampling Locations**

<b>Offshore monitoring requirement</b>	<b>Number of locations</b>
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khori creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### **8.1 Marine Water Quality and Results**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khori & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 30 to 37.



**Table 30: Marine Water Quality Monitoring Parameters for location near KPT colony**

Sr. No.	Parameters	Unit	Kandla Creek Near KPT colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.3	7.32	7.4	7.35
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31	32	31.3	32.0
5	Turbidity	NTU	34	31	36	32
6	Total Dissolved Solids	mg/l	15406	16523	20796	22487
7	Total Suspended Solids	mg/l	532	643	663.9	659.2
8	Total Solids	mg/l	16000	17233	21470.0	23220.0
9	DO	mg/l	4.1	4.2	4.3	4.2
10	COD	mg/l	78	80	82	80
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.75	0.69	0.82	0.71
13	Phosphate	mg/l	0.25	0.23	0.23	0.22
14	Sulphate	mg/l	2676	2304	2256	2340
15	Nitrate	mg/l	2.68	2.53	3.03	2.75
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	681.36	721.44	641.28	601.2
18	Magnesium	mg/l	1652.4	1603.8	1628.1	1628.1
19	Sodium	mg/l	9486	9013	9038	9181
20	Potassium	mg/l	370.6	315.9	338.1	341.8
21	Iron	mg/l	BQL	1.08	0.62	0.25
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 31: Marine Water Quality Monitoring Parameters for location near passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.4	7.26	7.45	7..38
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.8	31.3	31.8	31.9
5	Turbidity	NTU	30	28	29	35
6	Total Dissolved Solids	mg/l	18960	20901	19303	19608
7	Total Suspended Solids	mg/l	656	706	657.3	558.1
8	Total Solids	mg/l	19640	21620	20010.0	20280.0
9	DO	mg/l	4.3	4.4	4.6	4.7
10	COD	mg/l	82	82	78	76
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.65	0.6	0.75	0.65
13	Phosphate	mg/l	0.24	0.21	0.22	0.21
14	Sulphate	mg/l	2544	2520	2412	2544
15	Nitrate	mg/l	2.89	3.17	3.17	3.59
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	641.28	601.2	521.04	681.36
18	Magnesium	mg/l	1628.1	1628.1	1725.3	1676.7
19	Sodium	mg/l	9707	9001	9530	9408
20	Potassium	mg/l	388.6	318.9	378.6	370.8
21	Iron	mg/l	0.3	0.5	0.04	0.2
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	0.02	0.02

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Nitrite: 0.05mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 32: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.36	7.4	7.28	7.31
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.2	32.0	32.2	31.0
5	Turbidity	NTU	29	32	34	31
6	Total Dissolved	mg/l	20799	18680	24634	22504
7	Total Suspended	mg/l	599	709	599.5	614
8	Total Solids	mg/l	21460	19482	25316.0	23210.0
9	DO	mg/l	4.5	4.7	4.8	4.4
10	COD	mg/l	68	70	70	72
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.78	0.82	0.84	0.93
13	Phosphate	mg/l	0.19	0.2	0.21	0.2
14	Sulphate	mg/l	2220	2268	2100	2184
15	Nitrate	mg/l	3.94	3.59	3.87	4.01
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	561.12	641.28	721.44	641.28
18	Magnesium	mg/l	1749.6	1676.7	1676.7	1676.7
19	Sodium	mg/l	9059	8889	9030	9278
20	Potassium	mg/l	350.1	334.6	337.1	348.7
21	Iron	mg/l	0.05	0.06	0.21	1.36
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	0.04	4.28

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 33: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	KPT 4			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.41	7.36	7.41	7.46
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.0	30.8	32.2	31.4
5	Turbidity	NTU	38	36	30	28
6	Total Dissolved Solids	mg/l	20160	22448	29993	29941
7	Total Suspended Solids	mg/l	661	720	715.9	723.9
8	Total Solids	mg/l	20840	23268	30810	30666
9	DO	mg/l	4.6	4.3	4.5	4.6
10	COD	mg/l	86	88	82	80
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.93	0.89	0.89	0.71
13	Phosphate	mg/l	0.21	0.2	0.23	0.23
14	Sulphate	mg/l	1872	1944	2652	2700
15	Nitrate	mg/l	4.36	4.58	4.44	4.29
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	681.36	601.2	601.2	561.12
18	Magnesium	mg/l	1676.7	1749.6	1676.7	1652.4
19	Sodium	mg/l	9226	8808	9390	9725
20	Potassium	mg/l	356.2	320	356.8	387.1
21	Iron	mg/l	BQL	0.96	1.13	0.52
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	0.04	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 34: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.4	7.48	7.33	7.39
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.2	31.9	31.8	32.2
5	Turbidity	NTU	35	37	37	38
6	Total Dissolved Solids	mg/l	18698	21456	28575	23050
7	Total Suspended Solids	mg/l	674	789	704.4	733.2
8	Total Solids	mg/l	19420	22366	29340	23820
9	DO	mg/l	4.4	4.5	4.3	4.4
10	COD	mg/l	96	90	90	92
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.65	0.67	0.67	0.73
13	Phosphate	mg/l	0.22	0.21	0.19	0.2
14	Sulphate	mg/l	2100	2172	2628	2580
15	Nitrate	mg/l	5	4.86	5.07	4.93
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	721.44	761.52	521.04	480.96
18	Magnesium	mg/l	1579.5	1530.9	1701	1773.9
19	Sodium	mg/l	10145	10395	9831	9748
20	Potassium	mg/l	408.9	392.5	390.8	387.6
21	Iron	mg/l	0.84	0.13	1.12	0.46
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	0.02

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 35: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	31.9	Sampling not possible during Low Tide	31.0	Sampling not possible during Low Tide
2	Color	-	Colorless		Colorless	
3	Odor	-	Odorless		Odorless	
4	Salinity	ppt	20.8		18.1	
5	Turbidity	NTU	41		40	
6	Total Dissolved Solids	mg/l	25179		21035	
7	Total Suspended Solids	mg/l	614		678.5	
8	Total Solids	mg/l	25810		21812	
9	DO	mg/l	4.3		4.5	
10	COD	mg/l	98		96	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	0.82		0.85	
13	Phosphate	mg/l	0.21		0.21	
14	Sulphate	mg/l	2340		2376	
15	Nitrate	mg/l	5.07		4.65	
16	Nitrite	mg/l	BQL		BQL	
17	Calcium	mg/l	641.28		641.28	
18	Magnesium	mg/l	1676.7		1725.3	
19	Sodium	mg/l	10517		9631	
20	Potassium	mg/l	408		375.6	
21	Iron	mg/l	1.38		1.07	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		BQL	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		0.02	

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 36: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.42	7.38	7.45	7.39
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.4	31.9	31.6	32.0
5	Turbidity	NTU	42	40	42	43
6	Total Dissolved Solids	mg/l	29706	25972	22652	24202
7	Total Suspended Solids	mg/l	549	552	690.6	741.7
8	Total Solids	mg/l	30316	26601	23462	25105
9	DO	mg/l	4.5	4.6	4.6	4.7
10	COD	mg/l	60	62	68	66
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.69	0.75	0.93	0.89
13	Phosphate	mg/l	0.2	2520	0.22	0.2
14	Sulphate	mg/l	2652	2628	2508	2388
15	Nitrate	mg/l	4.15	3.94	3.17	2.89
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	601.2	521.04	561.12	601.2
18	Magnesium	mg/l	1652.4	1725.3	1798.2	1725.3
19	Sodium	mg/l	10598	10614	10236	10486
20	Potassium	mg/l	416.1	437	415.6	421.7
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	0.13	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 37: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr.Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	pH unit	7.4	7.38	7.44	7.4
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32	31.9	31.8	32.2
5	Turbidity	NTU	36.0	40	44	46
6	Total Dissolved Solids	mg/l	24560.0	23452	24955	25966
7	Total Suspended Solids	mg/l	620	580	710	686
8	Total Solids	721.44	25240	24130	25721	26712
9	DO	mg/l	4.0	3.9	4.8	4.5
10	COD	mg/l	72.0	70	74.0	76
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.86	0.77	0.76	0.82
13	Phosphate	mg/l	0.3	0.28	0.33	0.36
14	Sulphate	mg/l	2777.0	2492	2622	2596
15	Nitrate	mg/l	5.86	6.22	4.86	4.92
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	660	580	729.46	713.42
18	Magnesium	mg/l	1594.08	1545.48	1550.34	1511.46
19	Sodium	mg/l	10868.0	10879.0	10527.0	10486
20	Potassium	mg/l	441.8	442.0	440.8	438.6
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).



## **8.2 Discussion of Marine water samples**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit

Similar BOD is also under the BQL as analyzed for 5 days.

# **Marine Sediment Quality Monitoring**

## **9.0 Marine Sediments**

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

### **9.1 Results**

The Sediment Quality results are given in below from table no. 38 & 39.

**Table 38: Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	KPT - 1	KPT - 2	KPT - 3	KPT - 4	KPT - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	1.59	3.53	1.26	1.36	0.9	5.5	6.95
3	Organic Carbon	mg/kg	0.92	2.05	0.73	0.79	0.52	3.19	4.03
4	Inorganic Phosphate	mg/kg	112	110	126	130	126	115	134
5	Moisture	%	7.08	26.95	9.48	3.72	10.4	9.89	6.89
6	Aluminium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
7	Silica	mg/kg	8.00	8.80	10.30	9.60	7.80	8.20	9.06
8	Phosphate	mg/kg	2.58	BQL	1.41	3.29	3.83	BQL	0.93
9	Sulphate	mg/kg	443.16	670.92	360.39	157.33	327.68	864.14	1077.88
10	Nitrite	mg/kg	0.11	.10	0.11	0.12	.13	0.12	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	228.46	220.44	184.37	192.38	156.31	244.49	256.51
13	Magnesium	mg/kg	36.45	143.37	38.88	31.59	51.03	148.23	196.83
14	Sodium	mg/kg	396.04	4929.97	344.61	288.9	438.5	1139.94	1448.75
15	Potassium	mg/kg	23.35	104.88	19.53	14.05	34.98	148.03	254.96
16	Chromium	mg/kg	11.3	19.1	3.7	6.6	20.3	17.2	16.3
17	Nickel	mg/kg	5.1	35.4	BQL	1.9	14.5	28.5	110.5
18	Copper	mg/kg	2.4	12.6	BQL	BQL	1.3	36.7	40.6
19	Zinc	mg/kg	8.3	49.4	4.2	5	22.9	61.9	58.9
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	1.9	4.8	1.3	1.8	4.7	16.1	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

**Table 39 : Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	KPT - 1	KPT - 2	KPT - 3	KPT - 4	KPT - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	1.59	3.53	1.26	1.36	0.9	5.5	6.95
3	Organic Carbon	mg/kg	0.92	2.05	0.73	0.79	0.52	3.19	4.03
4	Inorganic Phosphate	mg/kg	110	106	130	128	1269	117	130
5	Moisture	%	7.08	26.95	9.48	3.72	10.4	6.20	5.80
6	Aluminium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
7	Silica	mg/kg	7.80	8.78	10.01	9.72	7.49	8.44	9.16
8	Phosphate	mg/kg	2.58	BQL	1.41	3.29	3.83	BQL	0.93
9	Sulphate	mg/kg	443.16	670.92	360.39	157.33	327.68	864.14	1077.88
10	Nitrite	mg/kg	0.12	0.11	0.13	0.12	0.11	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	228.46	220.44	184.37	192.38	156.31	244.49	256.51
13	Magnesium	mg/kg	36.45	143.37	38.88	31.59	51.03	148.23	196.83
14	Sodium	mg/kg	396.04	4929.97	344.61	288.9	438.5	1139.94	1448.75
15	Potassium	mg/kg	23.35	104.88	19.53	14.05	34.98	148.03	254.96
16	Chromium	mg/kg	11.3	19.1	3.7	6.6	20.3	17.2	16.3
17	Nickel	mg/kg	5.1	35.4	BQL	1.9	14.5	28.5	110.5
18	Copper	mg/kg	2.4	12.6	BQL	BQL	1.3	36.7	40.6
19	Zinc	mg/kg	8.3	49.4	4.2	5	22.9	61.9	58.9
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	1.9	4.8	1.3	1.8	4.7	16.1	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg,Cd: 1.0mg/kg,Hg: 1.0mg/kg, As: 1.0mg/kg)

## **9.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

The soil types is majority Sandy loamy. Also many of the parameters found below Quantification limit wise NO<sub>3</sub>, Cd, Hg, AS etc.

# **ECOLOGICAL MONITORING OF MARINE ENVIRONMENT**

## **10.1 INTRODUCTION:**

### **Sampling Stations:**

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 03<sup>rd</sup> March 2022 in harbour region of DPT at Kandla Creek, and on 04<sup>th</sup> March 2022 in creeks near by the port during spring tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 25<sup>th</sup> March, 2022 in harbour region of DPT at Kandla Creek and on 26<sup>th</sup> March, 2022 in creeks near by the port during neap tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period. The same sampling schedule was repeated during consecutive Neap tide and spring tide in same month.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during spring tide on 03/03/2022 and Neap tide period on 10/03/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin - a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

**TABLE #1 SAMPLING LOCATIONS**

<b>monitoring requirement</b>	<b>Number of locations</b>
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar
SPM	Jetty 1 near 1 <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

### **Sampling methodology adopted:**

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water



sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample were taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with nilyobolt cloth of 20µm mesh size.

#### **Samples Processing for chlorophyll estimation:**

Samples for the chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 1998).

#### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is general term for organisms have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplankton is free floating organisms that are capable of photosynthesis and zooplankton is the various free floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, **plankton** and **nekton** (Lalli and Parsons, 1997). **Plankton** consists of all organisms drifting in the water and is unable to swim against water currents, whereas **Nekton** includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

#### **Phytoplankton in the marine environment:**

Phytoplankton is free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio purifier and bio indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; diatoms and dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction

rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of biological pump in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives

such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

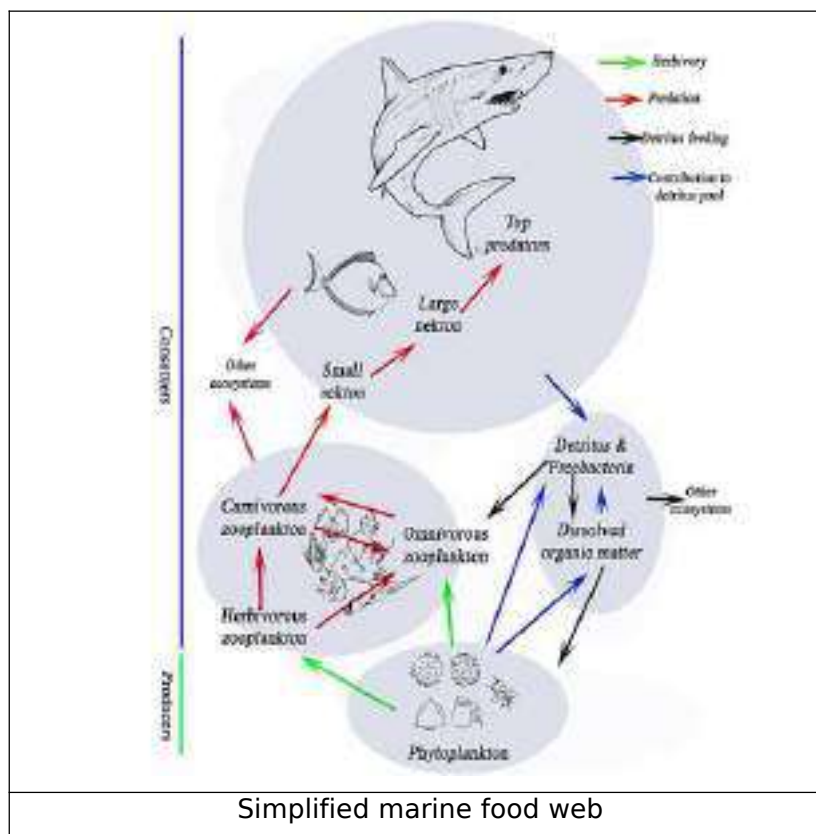
Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplankton is efficient grazers of the phytoplankton and is referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the

physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### **Spatial distribution of Plankton:**

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilometers in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist. Plankton may also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

**Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight. After the tow of about 15-30minutes, plankton net was pulled up and washed down to the tail and collected the plankton adhered to plankton net in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward. For quantitative evaluation 50 L water samples were collected from subsurface layer and filtered through 20µm mesh size net by using bucket and filtration assembly.

**Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

**Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

**Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a sub sample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of zooplankton that were encountered

**Cell counts by drop count method:**

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22 x 60mm was placed under the compound microscope provided with a mechanical

stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total number of plankton in the original volume of sample filtered was calculated as units/L.

### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment-water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42 $\mu$  in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes.

### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.



**Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bangal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

**DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A.E. (1988).

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species within a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H.R. *etal.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. The diversity measures that incorporate the two concepts may be termed heterogeneity measures (Magurran, 2004).

Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate specie richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is



the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness ( $S$ ) and evenness ( $J$ )

### **Simpson's diversity index**

Simpson's index ( $D$ ) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Low species diversity suggests:

Relatively few successful species in the habitat

The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment

Food webs which are relatively simple

Change in the environment would probably have quite serious effects

High species diversity suggests:

A greater number of successful species and a more stable ecosystem

More ecological niches are available and the environment is less likely to be hostile complex food webs

Environmental change is less likely to be damaging to the ecosystem as a whole

### **Species richness indices**

The species richness ( $S$ ) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness may be concomitant with severe or chronic human-induced perturbation (Fair weather 1990,) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness (**S**) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximized when all types are equally abundant (Rosenzweig, M. L. (1995).

### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index (**H**), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index (**H**) reproduces community parameters to a single number by using an equation.

$$H' = - \sum_{j=1}^s \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

## **10.2 RESULTS:**

### **CHLOROPHYLL-a:**

Water Samples for the chlorophyll estimation were collected from sub surface layer during high tide and low tide period of the tidal cycle for each sampling

locations and analysed for Chlorophyll - a and after acidification for Pheophytin - a. Chlorophyll - a value was used as algal biomass indicator (APHA,1998). Algal biomass was estimated by converting Chlorophyll value.

In the sub surface water chlorophyll-a was varying from 0.884 - 1.356 mg/m<sup>3</sup> with an average value 1.038 mg/m<sup>3</sup> of in harbour region of DPT in Kandla Creek during sampling done in spring tide period of March 2022. In the nearby creeks chlorophyll-a was varying from 0.662- 1.104mg/m<sup>3</sup> with an average value 0.853 mg/m<sup>3</sup>. Pheophytin - a level was below detectable limit- the all the sampling stations during spring tide.

In the sub surface water chlorophyll-a was varying from 0.308 - 0.866mg/m<sup>3</sup> with an average value 0.516mg/m<sup>3</sup>. In harbour region of DPT in Kandla Creek during sampling done in neap tide period of March 2022. In the nearby creeks chlorophyll-a was varying from 0.271 - 0.661mg/m<sup>3</sup> with an average value 0.482mg/m<sup>3</sup>. Pheophytin -a level was below detectable limit- the all the sampling stations.

In the sub surface water chlorophyll-a was varying from 0.662 - 1.104mg/m<sup>3</sup> with an average value 0.852mg/m<sup>3</sup>. In harbour region of DPT OOT in path finder Creek during sampling done in spring tide period of March 2022. In the sub surface water chlorophyll-a was varying from 0.101 - 0.307 mg/m<sup>3</sup>with an average value 0.237 mg/m<sup>3</sup>. In harbour region of DPT OOT in path finder Creek during sampling done in Neap Tide period of March 2022.

**TABLE 40 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING SPRING TIDE IN MARCH 2022**

Sr.No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll I method) mg/m <sup>3</sup>
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	1.356	BDL	90.85
		Low tide	0.898	BDL	60.16
2	KPT 2	High tide	0.984	BDL	65.93
		Low tide	1.207	BDL	80.87
3	KPT 3	High tide	0.884	BDL	59.23
		Low tide	0.899	BDL	60.23
CREEKS					
4	KPT-4 Khor-I	High tide	1.104	BDL	73.96
		Low tide	0.748	BDL	50.12
5	KPT-5 Nakti-I	High tide	0.748	BDL	50.12
		Low tide	1.000	BDL	67.0
6	KPT-6 Nakti-II	High tide	0.662	BDL	44.35
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.409	BDL	27.40
8		Low tide	0.203	BDL	13.60
9	SPM	High tide	0.458	BDL	30.69
10	SPM	Low tide	0.406	BDL	27.20

BDL: Below Detectable Limit.

**TABLE 41 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA, NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINARDURING NEAP TIDE IN MARCH 2022**

Sr.No.	Station	Tide	Chlorophyll-a (mg/m³ )	Pheophytin- a (mg/m³ )	Algal Biomass (Chlorophyll method) mg/m³
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.425	BDL	28.47
		Low tide	0.424	BDL	28.41
2	KPT 2	High tide	0.747	BDL	50.05
		Low tide	0.308	BDL	20.64
3	KPT 3	High tide	0.866	BDL	58.02
		Low tide	0.322	BDL	21.57
CREEKS					
4	KPT-4 Khor-I	High tide	0.660	BDL	44.22
		Low tide	0.425	BDL	28.47
5	KPT-5 Nakti-I	High tide	0.527	BDL	35.31
		Low tide	0.527	BDL	35.31
6	KPT-6 Nakti-II	High tide	0.271	BDL	18.16
PATHFINDER CREEK VADINAR					
7	VADINAR-I Jetty	High tide	0.306	BDL	20.50
8		Low tide	0.306	BDL	20.50
9	SPM	High tide	0.236	BDL	15.81
10	SPM	Low tide	0.101	BDL	6.76

BDL: Below Detectable Limit.

#### **PHYTOPLANKTON POPULATION:**

For the evaluation of the Phytoplankton population in DPT harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, blue green algae and dinoflagellates during spring tide period. Diatoms were represented by 25 genera. Blue green were represented by 3 genera and dinoflagellates were represented by 4 genera

during the sampling conducted in spring tide in March, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 74-267 units/ L during high tide period and 169-233 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 28 genera Blue green algae were represented 4 genera and dinoflagellates with 4 genera during the sampling conducted in Neap tide in March, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 251-326 units/ L during high tide period and 214-246 units/ L during low tide of Neap Tide.

For the evaluation of the Phytoplankton population in DPT OOT jetty area in Path Finder creek sampling was conducted from two sampling locations ;jetty area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green anlage and Dinoflagellates during spring tide period. Diatoms were represented by 24 genera, Blue Green algae by 2 genera and Dinoflagellates 4 genera each during the sampling conducted in spring tide in March, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area was varying from 188 units/ L during high tide period and 106 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the SPM area was varying from 192 units/ L during high tide period and 158 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 28 genera and Blue green algae 4 genera and dinoflagellates by 4 genera each during the sampling conducted in Neap tide in March, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 224- units/ L during high tide period and 219 units/ L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 167 units/ L during high tide period and 127 units/ L during low tide of Neap Tide.

**Species Richness Indices and Diversity Indices:** Margalef's diversity index (Species Richness)S

At the organism level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 3.02- 5.018 with an average of 4.216 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 3.884 - 4.801 with an average of 4.474 during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 3.979 - 5.791 with an average of 4.772 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 3.996 - 5.495 with an average of 4.795 during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 4.583 at OOT jetty area and 4.375 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 4.718 and 3.753 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 3.935 at OOT jetty area and 3.411 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 4.014 and SPM area was 3.823 during the consecutive low tide period.

**Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.978- 1.084 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.032 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.979-1.148 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.040 during consecutive low tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.818-1.146 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.958 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.918-1.054( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.009 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.012at OOT jetty area and 0.9759at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.058 and 0.898 at SPM during the consecutive low tide period.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.9852 at OOT jetty area and 1.183 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.009and at SPM area was1.154 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.



### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.840- 0.886 between selected sampling stations with an average of 0.855 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.823- 0.883 between selected sampling stations with an average of 0.846 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during neap tide also, which was varying from 0.732-0.874 with an average value of 0.806 between selected sampling stations during high tide period and 0.7982-0.8571 varying from with an average value of 0.836 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.822 at OOT jetty area and 0.826 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton

communities in the path finder creek near OOT jetty was 0.842 and 0.803 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.763 at OOT jetty area and 0.882 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.760 and at SPM area was 0.869 during the consecutive low tide period.

Low species diversity suggests a relatively few successful species in this habitat. The environment is quite stressful with relatively few ecological niches and only

a few organisms are really well adapted to that environment. Any change in the environment would probably have quite serious effects.

**Table 42 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT  
KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN MARCH  
2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	265	29/32	90.62	5.018	1.062	0.8468
	2	226	25/32	78.12	4.428	1.076	0.8713
	3	207	26/32	81.25	4.688	1.084	0.844
	4	238	25/32	78.12	4.386	1.006	0.8407
	5	267	22/32	68.75	3.759	0.988	0.8427
	6	74	14/32	43.75	3.02	0.9788	0.8863
LOW TIDE	1	228	27/32	84.38	4.789	1.047	0.8534
	2	225	27/32	84.38	4.801	0.9924	0.8235
	3	233	24/32	75	4.219	1.037	0.8381
	4	169	25/32	78.12	4.678	1.148	0.8838
	5	223	22/32	68.75	3.884	0.9797	0.8331

**Table 43 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT  
KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN MARCH  
2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	251	33/35	94.28	5.791	1.146	0.8749
	2	289	29/35	82.85	4.941	1.019	0.8467
	3	326	27/35	77.14	4.493	0.8189	0.7327
	4	266	27/35	77.14	4.657	0.9452	0.7852
	5	252	23/35	65.71	3.979	0.8657	0.7944
	6	86	14/35	40	2.918	0.7864	0.7674
LOW TIDE	1	246	28/35	80	4.904	1.007	0.8276
	2	214	27/35	77.14	4.845	1.045	0.8571
	3	235	31/35	88.57	5.495	1.054	0.8493
	4	243	27/35	77.14	4.733	1.024	0.8495
	5	246	23/35	65.71	3.996	0.9186	0.7982

**Table 44 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN MARCH 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	71-251	25/32	78.15
			BLUE GREEN	2-9	3/32	9.35
			DINOFLAGELLATE S	1-11	4/32	12.5
			TOTAL PHYTO PLANKTON	74-267	32	-
LOW TIDE	Sub surface	5	DIATOMS	148-221	25/32	78.15
			BLUE GREEN	3-8	3/32	9.35
			DINOFLAGELLATE S	1-11	4/32	12.5
			TOTAL PHYTO PLANKTON	169-233	32	-

**Table 45 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN MARCH 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	86-317	28/35	80
			BLUE GREEN	0-7	3/35	8.57
			DINOFLAGELLATES	0-9	4/35	11.43
			TOTAL PHYTO PLANKTON	86-323	35	-
LOW TIDE	Sub surface	5	DIATOMS	207-232	28/35	28/35
			BLUE GREEN	2-11	3/35	3/35
			DINOFLAGELLATES	1-4	4/35	4/35
			TOTAL PHYTO PLANKTON	212-243	35	35

**Table 46 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN MARCH 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	jetty	188	25/30	83.33	4.583	1.012	0.8229
	SPM	192	24/30	80	4.375	0.9759	0.826
LOW TIDE	jetty	106	23/30	76.66	4.718	1.058	0.8429
	SPM	158	20/30	66.66	3.753	0.898	0.8039

**Table 47 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN MARCH 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	224	36/36	100	6.468	0.9852	0.763
	SPM	167	31/36	86.11	5.862	1.183	0.8816
LOW TIDE	Jetty	219	33/36	91.66	5.938	1.009	0.7601
	SPM	127	28/36	77.77	5.574	1.154	0.8699

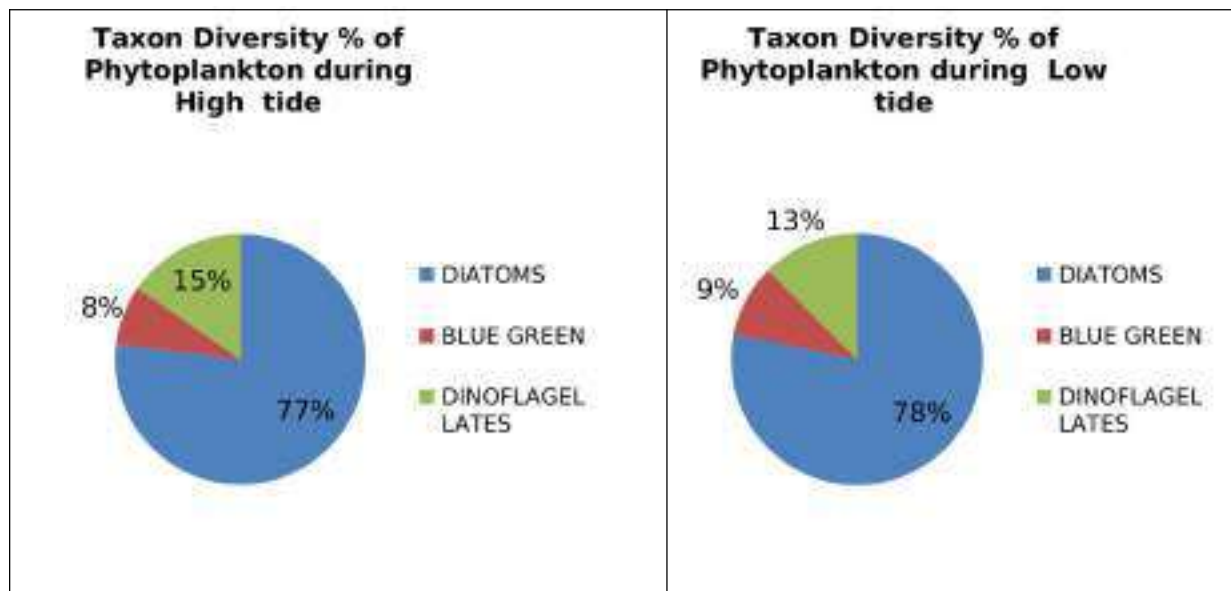
**Table 48 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPTDPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN MARCH 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN	0-6	2/30	6.67
			DIATOMS	176-185	24/30	80
			DINOFLAGELLATES	6-7	4/30	13.33
			TOTAL PHYTO PLANKTON	188-192	30	
LOW TIDE	Sub surface	2	BLUE GREEN	1-2	2/30	6.67
			DIATOMS	100-155	24/30	80
			DINOFLAGELLATES	1-5	4/30	13.33
			TOTAL PHYTO PLANKTON	106-158	30	

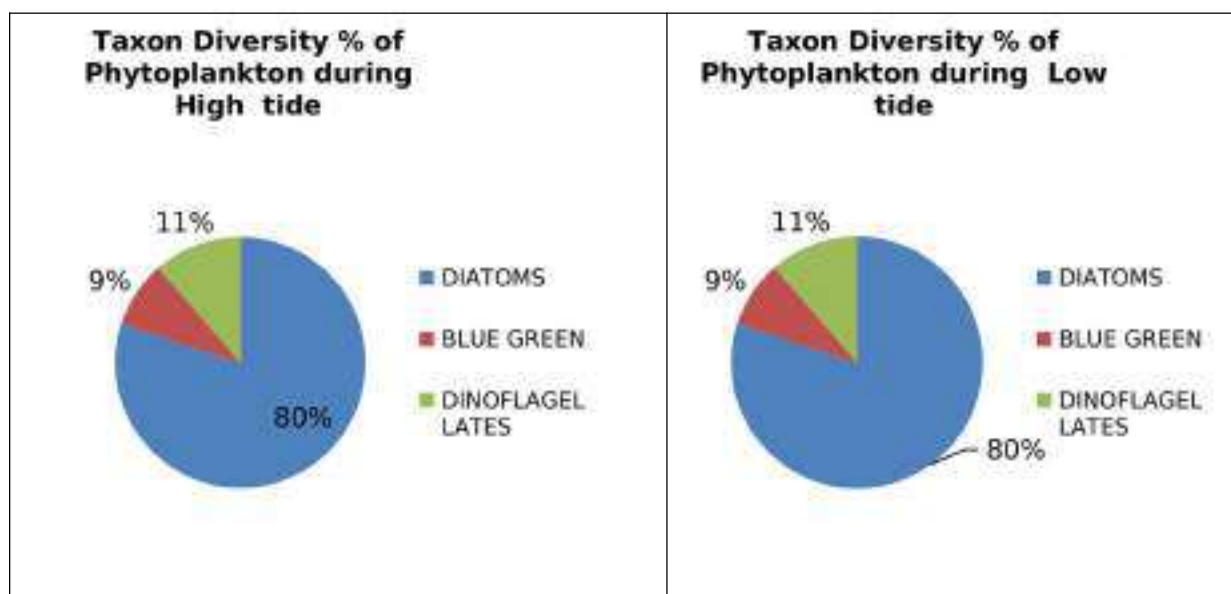
**Table 49 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPTDPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN MARCH 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN	8-12	4/36	11.11
			DIATOMS	147-210	28/36	77.78
			DINOFLAGELLATES	6-8	4/36	11.11
			TOTAL PHYTO PLANKTON	167-224	36	
LOW TIDE	Sub surface	2	BLUE GREEN	7-9	4/36	11.11
			DIATOMS	109-203	28/36	77.78
			DINOFLAGELLATES	7-11	4/36	11.11
			TOTAL PHYTO PLANKTON	127-219	36	

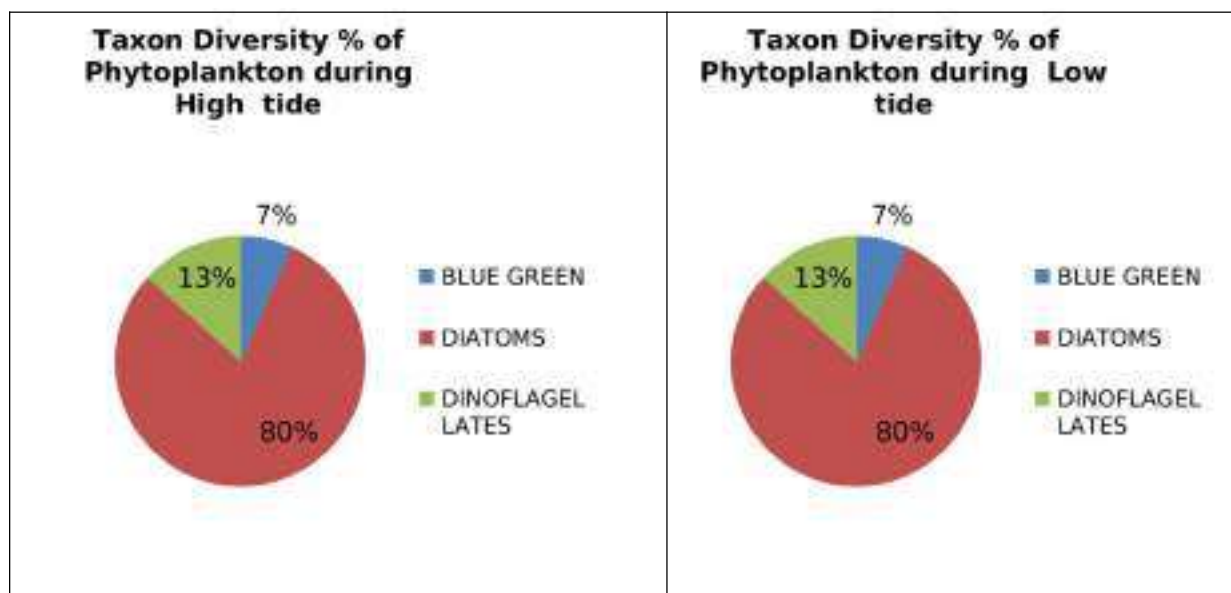
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Kandala creek and nearby creeks**



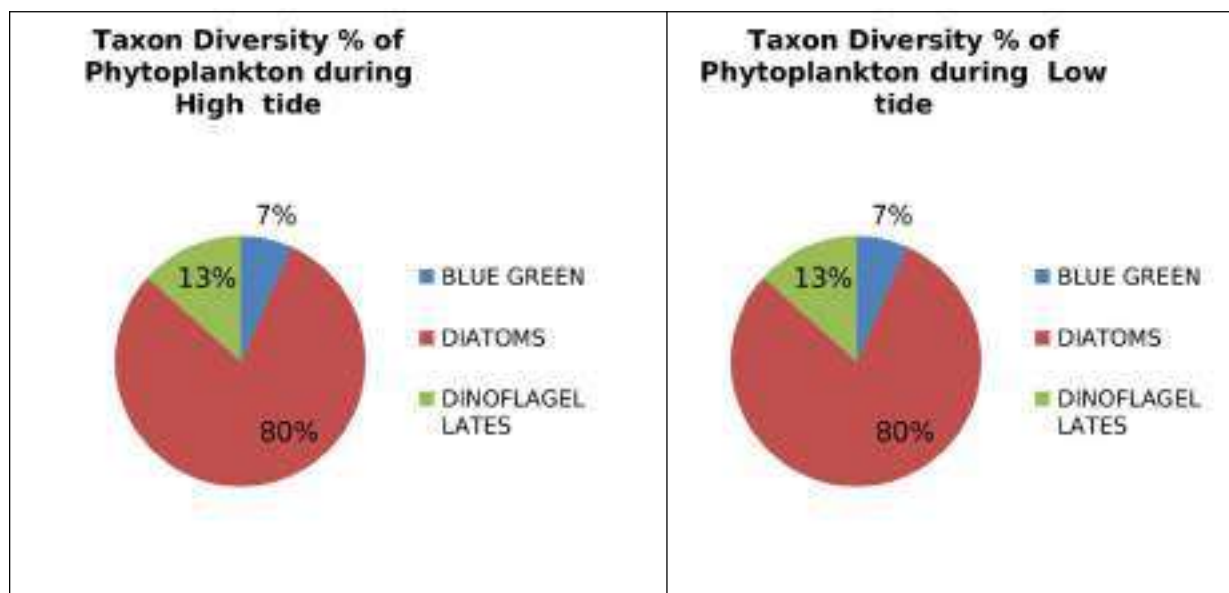
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Kandala creek and nearby creeks**



**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar**



**ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPT harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khori creek) during high tide period and low tide period of spring tide and Neap tide in March, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly 6 groups, and 8 larval forms; Tintinids, Copepods, Arrow worms, Mysids Urochordata, Foraminiferans, and 8 larval forms; The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly 7 groups, Tintinids, Copepods, Arrow worms, Mysids Urochordata, Hydroid Medusa and Foraminiferans and 8 larval forms

Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from 119-193  $\times 10^3$  N/  $m^3$  during high tide and 102-149  $\times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from 159-233  $\times 10^3$  N/  $m^3$  during high tide and 132-183  $\times 10^3$  N/  $m^3$  during low tide of Neap Tide period.



For the evaluation of the Zooplankton population in DPT OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM) During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek creeks during spring tide was represented by mainly Titinids, Copepods, Arrow worms, Urochordata, Foraminiferans and 9 larval forms. The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly four groups, Titinids, Copepods, Arrow worms, Urochordata, Foraminiferans and 8 larval forms, Zooplankton of the sampling stations at sub surface layer in the DPT OOT Jetty area of path finder creek was  $158 \times 10^3$  N/  $m^3$  during high tide and  $200 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area of path finder creek was  $169 \times 10^3$  N/  $m^3$  during high tide and  $184 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT OOT jetty area in path finder creek was recorded  $129 \times 10^3$  N/  $m^3$  during high tide and  $173 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area in path finder creek was recorded  $110 \times 10^3$  N/  $m^3$  during high tide and  $116 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap Tide .

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the stations Kandla creek region and nearby creeks was varying from 3.976-6.093 with an average of 4.924 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities varying from 3.459-5.112 with an average of 4.384 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness)  $S$  of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations was varying from 4.735-5.948 with an average of 5.208 during the sampling conducted in high tide and varying from 4.255-6.043 with an average of 5.407 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness)  $S$  of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 5.728 and 4.718 respectively. Margalef's diversity index (Species Richness)  $S$  of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 4.873 and 4.219 respectively.

Margalef's diversity index (Species Richness)  $S$  of Zooplankton communities near Jetty at Path finder creek was varying from 4.115-4.269 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness)  $S$  of Zooplankton communities near SPM at Path finder creek was varying from 4.68-4.418 respectively during the consecutive High tide and low tide period.

**Shannon-Wiener's index:**

Shannon-Wiener's Index ( $H$ ) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.9715-1.209 ( $H'(\log 10)$ ) between selected sampling stations with an average value of 1.0897 ( $H'(\log 10)$ ) during high tide period of spring tide. Shannon-Wiener's Index ( $H$ ) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.9645-1.25 ( $H'(\log 10)$ ) between selected sampling stations with an average value of 1.097 ( $H'(\log 10)$ ) during consecutive low tide period.

Shannon-Wiener's Index ( $H$ ) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 1.101-1.17 ( $H'(\log 10)$ ) between selected sampling stations with an average value of 1.1404 ( $H'(\log 10)$ ) during high tide period of Neap tide. Shannon-Wiener's Index ( $H$ ) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 1.06- 1.286 of ( $H'(\log 10)$ ) between selected sampling stations with an average value of 1.1894 ( $H'(\log 10)$ ) during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.168 and 1.045 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.143 and 0.9398 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.9748-1.089 during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 0.9864-0.9746 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.818-0.905 between selected sampling stations with an average of 0.871 during high tide period and was varying from 0.845-0.923 with an average value of 0.882 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of neap tide except few, which was varying from 0.864-0.884 between selected sampling stations with an average of 0.875 during high tide period and was varying from 0.831-0.928 with an average value of 0.894

between selected sampling stations during consecutive low tide. This species diversity suggests a relatively few successful species in this habitat during March 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.898 and 0.868 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.884 and 0.798 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.832-0.882 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.797 and 0.837 respectively.

**Table 50 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN MARCH 2022**

Tide	Sampling Station	Abundance In Nx103/ m3	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log10)	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	162	32/37	86.48	6.093	1.209	0.9055
	2	119	20/37	54.05	3.976	0.9715	0.8187
	3	193	28/37	75.67	5.13	1.109	0.8749
	4	168	26/37	70.27	4.879	1.1	0.883
	5	158	24/37	64.86	4.543	1.059	0.8736
	6	96	17/37	45.95	3.505	1.004	0.8658
LOW TIDE	1	124	20/37	54.05	3.942	1.047	0.8754
	2	147	26/37	70.27	5.01	1.16	0.8984
	3	133	26/37	70.27	5.112	1.25	0.9236
	4	149	23/37	85.19	4.397	1.067	0.8676
	5	102	17/37	45.94	3.459	0.9645	0.8455

**Table 51 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN MARCH 2022**

Tide	Sampling Station	Abundance In No x103/ m3	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log10)	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	217	33/35	94.28	5.948	1.17	0.8812
	2	187	30/35	85.71	5.544	1.157	0.8748
	3	211	28/35	80	5.045	1.119	0.8649
	4	233	27/35	77.14	4.77	1.155	0.8847
	5	159	25/35	71.43	4.735	1.101	0.8716
	6	94	17/35	48.57	3.522	1.004	0.8566
LOW TIDE	1	176	23/35	65.71	4.255	1.092	0.8753
	2	132	29/35	82.85	5.734	1.258	0.9286
	3	147	31/35	88.57	6.012	1.251	0.9125
	4	169	32/35	91.43	6.043	1.286	0.9221
	5	183	27/35	77.14	4.991	1.06	0.8316

**Table 52 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA ATKANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN MARCH 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	18-30	6/37	16.21
			Copepods	38-84	15/37	40.54
			Rotifers	0-4	1/37	2.7
			Arrow worms	0-4	1/37	2.7
			Mysids	1-6	2/37	5.41
			Urochordata	0-2	2/37	5.41
			Foraminiferans	0-1	2/37	5.41
			Larval forms	30-77	8/37	21.62
			Total Zooplankton N/ M3	96-193	37	
LOW TIDE	Sub surface	5	Tintinids	10-31	6/37	16.21
			Copepods	39-61	15/37	40.54
			Rotifers	0-4	1/37	2.7
			Arrow worms	0-4	1/37	2.7
			Mysids	0-4	2/37	5.41
			Urochordata	0-1	2/37	5.41
			Foraminiferans	0-4	2/37	5.41
			Larval forms	35-61	8/37	21.62
			Total Zooplankton N/M3	102-149	37	

**Table 53 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK AND , NEAR BY CREEKS DURING NEAP TIDE IN MARCH 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x103 Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	3-22	6/35	17.14
			Copepods	33-91	13/35	37.15
			Arrow worms	0-3	1/35	2.86
			Mysids	1-19	2/35	5.71
			Urochordata	0-6	2/35	5.71
			Medusa	0-2	1/35	2.86
			Foraminiferans	0-9	2/35	5.71
			Larval forms	44-96	8/35	22.86
			Total Zooplankton N/M3	94-233	35	
LOW TIDE	Sub surface	5	Tintinids	8-18	6/35	17.14
			Copepods	51-65	13/35	37.15
			Arrow worms	0-4	1/35	2.86
			Mysids	5-14	2/35	5.71
			Urochordata	0-6	2/35	5.71
			Medusa	0-2	1/35	2.86
			Foraminiferans	0-2	2/35	5.71
			Larval forms	45-93	8/35	22.86
			Total Zooplankton N/M3	132-183	35	



**Table 54 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN MARCH 2022**

Tide	Sampling Station	Abundance In x103N / m3	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log10)	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	158	30/32	93.75	5.728	1.168	0.898
	SPM	169	26/32	81.25	4.873	1.143	0.8842
LOW TIDE	Jetty	200	26/32	81.25	4.718	1.045	0.8686
	SPM	184	23/32	71.87	4.219	0.9398	0.798

**Table 55 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN MARCH 2022**

TOTAL Tide	Sampling Station	Abundance In Nx103/ m3	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log10)	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	129	21/27	77.77	4.115	0.9748	0.8327
	SPM	110	23/27	85.18	4.68	0.9864	0.7977
LOW TIDE	Jetty	173	23/27	85.18	4.269	1.089	0.8824
	SPM	116	22/27	81.48	4.418	0.9746	0.8375

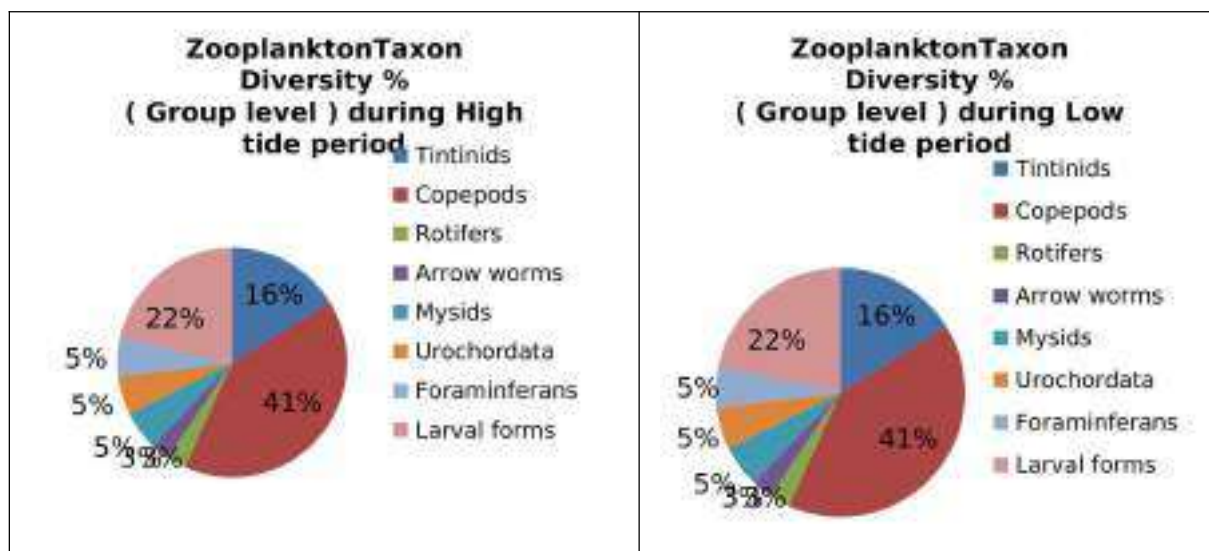
**Table 56 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN MARCH 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	8-16	3/32	9.36
			Copepods	70-85	14/32	43.75
			Arrow worms	3-6	1/32	3.13
			Urochortata	6-8	2/32	6.25
			Medusa	0-1	1/32	3.13
			Foraminiferans	2-9	2/32	6.25
			Larval forms	53-60	9/32	28.13
			Total Zooplankton NO/M3	158-169	32	
LOW TIDE	Sub surface	2	Tintinids	5-6	3/32	9.36
			Copepods	74-109	14/32	43.75
			Arrow worms	0-1	1/32	3.13
			Urochortata	10-11	2/32	6.25
			Medusa	0-1	1/32	3.13
			Foraminiferans	2-3	2/32	6.25
			Larval forms	72-90	9/32	28.13
			Total Zooplankton NO/M3	184-200	32	

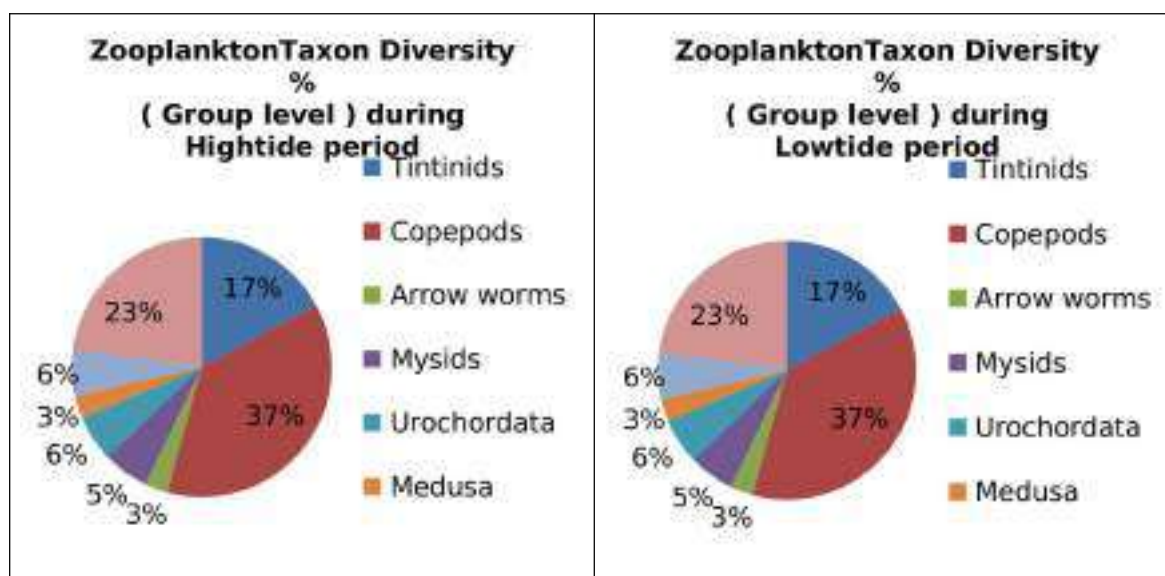
**Table 57 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN MARCH 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	1-8	4/27	14.82
			Copepods	38-39	12/27	44.45
			Arrow worms	0-1	1/27	3.7
			Urochordata	0-1	1/27	3.7
			Foraminiferans	1-3	1/27	3.7
			Larval forms	66-78	8/27	29.63
			Total Zooplankton NO/M3	110-125	27	-
LOW TIDE	Sub surface	2	Tintinids	4-12	4/27	14.82
			Copepods	43-51	12/27	44.45
			Arrow worms	0-1	1/27	3.7
			Urochordata	0-1	1/27	3.7
			Foraminiferans	1-5	1/27	3.7
			Larval forms	65-100	8/27	29.63
			Total Zooplankton NO/M3	115-169	27	-

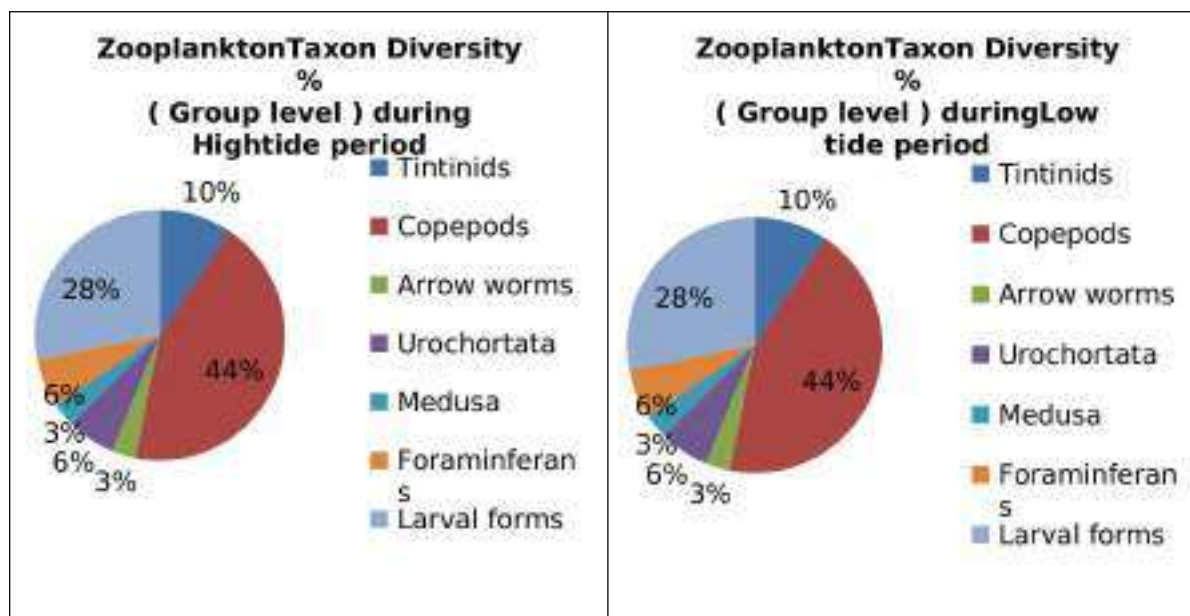
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Kandla Creek and nearby Creeks**



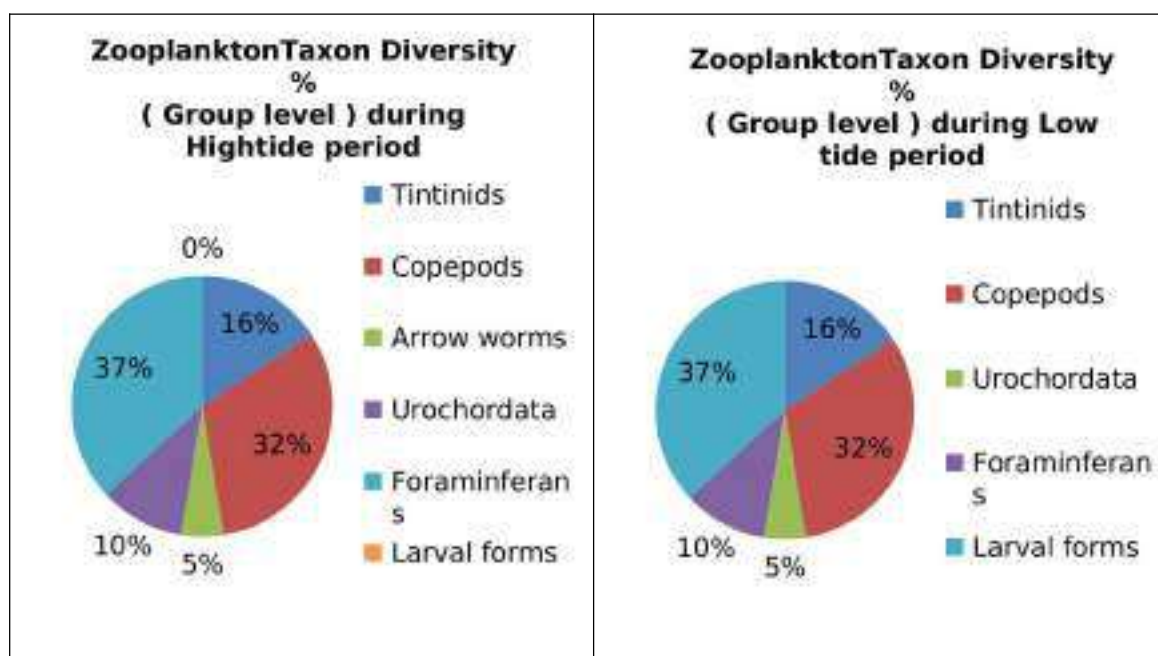
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Kandla Creek and nearby Creeks**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM**



**TABLE 58 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURINGSPRING TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	Lyngbya sp.	B1	Very sparse
					Oscillatoria sp.	B2	Very sparse
			Oscillatoriales	Phormidiaceae	Planktothrix sp.	B3	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	Coscinodiscus sp.	D1	Dominant
			Thalassiosirales	Thalassiosiraceae	Planktoniellasp	D2	Very sparse
					Thalassiosira sp	D3	Very sparse
			Triceratiales	Triceratiaceae	Odontella sp.	D4	Very sparse
					Triceratium sp.	D5	Sparse
			Biddulphiales	Biddulphiaceae	Biddulphiasp	D6	Abundant
			Hemiaulales	Belleracheaceae	Bellerachea sp	D7	Sparse
				Hemiaulaceae	Cerataulina sp.	D8	Abundant
					Eucampia sp	D9	Sparse
			Rhizosoleniales	Rhizosoleniaceae	Rhizosolenia sp.	D10	Scattered
			Chaetocerotales	Chaetocerotaceae	Chaetoceros sp	D11	Scattered
			Lithodesmiales	Lithodesmiaceae	Ditylum sp	D12	Sparse
		Bacillariophyceae	Naviculales	Naviculaceae	Navicula sp	D13	Very sparse
				Pleurosigmataceae	Gyrosigma sp	D14	Very sparse

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					Pleurosigma <i>sp</i>	D15	Sparse
				Pinnulariaceae	Pinnularia <i>sp</i>	D16	Very sparse
			Bacillariales	Bacillariaceae	Bacillaria <i>sp.</i>	D17	Sparse
					Nitzschia <i>sp</i>	D18	Very sparse
					Pseudo-nitzschia <i>sp</i>	D19	Very sparse
			Surirellales	Surirellaceae	Surirella <i>sp</i>	D20	Very sparse
		Fragilariophyceae	Thalassionematales	Thalassionemataceae	Thalassiothrix <i>sp.</i>	D21	Scattered
					Thalassionema <i>sp.</i>	D22	Very sparse
			Fragilariales	Fragilariaceae	Fragilaria <i>sp</i>	D23	Very sparse
					Synedrassp	D24	Sparse
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Noctiluca / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	Noctiluca <i>sp.</i>	DF1	Very sparse
		Dinophyceae	Peridinales	Protoperidiniaceae	Protoperidinium <i>sp.</i>	DF2	Sparse
			Gonyaulacales	Ceratiaceae	Ceratium furca	DF3	Very sparse
					Ceratium tripos	DF4	Very sparse

**TABLE 59 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING AND NEAP TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	Oscillatoria sp.	B1	Very sparse
			Oscillatoriales	Phormidiaceae	Planktothrix sp.	B2	Very sparse
			Stigonematales	Stigonemataceae	Stigonema sp.	B3	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	Coscinodiscus sp.	D1	Dominant
			Thalassiosirales	Thalassiosiraceae	Planktoniellasp	D2	Very sparse
					Thalassiosira sp	D3	Very sparse
			Triceratiales	Triceratiaceae	Odontella sp.	D4	Very sparse
					Triceratium sp.	D5	Very sparse
			Biddulphiales	Biddulphiaceae	Biddulphiasp	D6	Dominant
			Hemiaulales	Bellerocheaceae	Bellerochea sp	D7	Sparse
				Hemiaulaceae	Cerataulina sp.	D8	Very sparse
			Eucampia sp		D9	Sparse	
			Rhizosoleniales	Rhizosoleniaceae	Rhizosolenia sp.	D10	Scattered
			Chaetocerotales	Chaetocerotaceae	Chaetoceros sp.	D11	Sparse
			Lithodesmiales	Lithodesmiaceae	Ditylum sp	D12	Scattered
			Melosirales	Melosiraceae	Melosira sp	D13	Very sparse
		Bacillariophyceae	Bacillariales	Bacillariaceae	Bacillaria sp.	D14	Sparse
					Nitzschia sp	D15	Very sparse
					Pseudo-nitzschia	D16	Sparse
			Surirellales	Surirellaceae	Campylodiscus sp	D17	Very sparse
					Surirella sp	D18	Very sparse
			Naviculales	Naviculaceae	Navicula sp	D19	Very sparse
				Pleurosigmataceae	Gyrosigma sp.	D20	Very sparse
					Pleurosium sp.	D21	Sparse
				Pinnulariaceae	Pinnularia sp	D22	Very sparse
		Fragilariophyceae	Thalassionematales	Thalassionemataceae	Thalassiothrix sp.	D23	Abundant
					Thalassionema sp.	D24	Very sparse
			Fragilariales	Fragilariaceae	Asterionellopsis sp	D25	Very sparse
					Fragilaria sp	D26	Very sparse
					Synedrassp	D27	Sparse
					Tabellaria sp	D28	Very sparse
DINO FLAGELLAT ES	Dinoflagellata / Dinozoa		Noctiluca /	Noctilucales	Noctilucaceae	Noctiluca sp.	DF1
		Dinophyceae	Peridinales	Protoperidiniaceae	Protoperidinium sp.	DF2	Very sparse
			Gonyaulacales	Ceratiaceae	Ceratium furca	DF3	Very sparse
					Ceratium tripos	DF4	Very sparse



**TABLE 60 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
					<i>Oscillatoria sp.</i>	B2	Very sparse
DIATOMS	Bacillariophyta	Coccinodiscophyceae	Coccinodiscales	Coccinodiscaceae	<i>Coccinodiscus sp.</i>	D1	Dominant
					<i>Palmeria sp.</i>	D2	Very sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D3	Scattered
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp</i>	D4	Sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D6	Sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp</i>	D7	Sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D8	Very sparse
			Corethrales	Corethraceae	<i>Corethron sp.</i>	D9	Very sparse
			Thalassiosirales	Thalassiosiraceae	<i>Planktoniellasp</i>	D10	Very sparse
					<i>Thalassiosira sp</i>	D11	Abundant
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D12	Very sparse
					<i>Triceratium sp.</i>	D13	Very sparse
		Bacillariophyceae	Naviculales	Pleurosigmataceae	<i>Pleurosigma sp</i>	D14	Very sparse
				Pinnulariaceae	<i>Pinnularia sp</i>	D15	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D16	Sparse
					<i>Nitzschia sp</i>	D17	Sparse
					<i>Pseudo-nitzschia sp</i>	D18	Very sparse
			Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D19	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp</i>	D20	Very sparse
					<i>Synedra sp.</i>	D21	Scattered
			Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D22	Very sparse
			Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D23	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D24	Sparse
DINOFLAGELLATES	Dinoflagellata / Dinzoa	Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF2	Very sparse
					<i>Ceratium macroceros</i>	DF3	Very sparse
					<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE 61 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND NEAP TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Chlorococcales	Chroococcaceae	Merismopedia sp.	B1	Very sparse
			Nostocales	Oscillatoriaceae	Lyngbya sp.	B2	Very sparse
					Oscillatoria sp.	B3	Very sparse
			Stigonematales	Stigonemataceae	Stigonema sp.	B4	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	Coscinodiscus sp.	D1	Dominant
			Biddulphiales	Biddulphiaceae	Palmeria sp.	D2	Very sparse
					Biddulphiasep	D3	Sparse
			Hemiaulales	Bellerophyceae	Bellerophcea sp	D4	Sparse
				Hemiaulaceae	Cerataulina sp.	D5	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	Rhizosolenia sp.	D6	Sparse
			Chaetocerotales	Chaetocerotaceae	Chaetoceros sp	D7	Very sparse
			Lithodesmiales	Lithodesmiaceae	Ditylum sp	D8	Sparse
			Corethrales	Corethraceae	Corethron sp.	D9	Very sparse
			Melosirales	Melosiraceae	Melosira sp	D10	Very sparse
			Thalassiosirales	Thalassiosiraceae	Planktoniellasp	D11	Very sparse
			Triceratiales	Triceratiaceae	Odontella sp	D12	Sparse
					Triceratium sp	D13	Very sparse
		Bacillariophyceae	Naviculales	Naviculaceae	Navicula sp	D14	Very sparse
				Pleurosigmataceae	Gyrosigma sp.	D15	Very sparse
					Pleurosigma sp	D16	Very sparse
				Plagiotropidaceae	Plagiotropis sp.	D17	Very sparse
			Bacillariales	Bacillariaceae	Bacillaria sp.	D18	Sparse
					Nitzschia sp	D19	Scattered
					Pseudo-nitzschia sp	D20	Very sparse
			Surirellales	Surirellaceae	Campylodiscus sp	D21	Very sparse
			Achnanthales	Achnanthaceae	Achnanthes sp	D22	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	Fragilaria sp	D23	Very sparse
					Synedra sp.	D24	Abundant
			Striatellales	Striatellaceae	Striatellasp	D25	Very sparse
			Thalassionematales	Thalassionemataceae	Thalassiothrix sp.	D26	Very sparse
			Climacospheniales	Climacospheniaceae	Climacosphenia sp.	D27	Very sparse

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			Licmophorales	Licmophoraceae	Licmophora sp.	D28	Sparse
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Noctiluca / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	Noctiluca sp.	DF1	Very sparse
			Peridinales	Proto-peridiniaceae	Proto-peridinium sp.	DF2	Very sparse
		Dinophyceae	Gonyaulacales	Ceratiaceae	Ceratium furca	DF3	Sparse
					Ceratium tripos	DF4	Very sparse

**TABLE 62 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	Leprotintinnus sp.	T1	Very sparse
				Codonellidae	Tintinnopsis accuminata	T2	Very sparse
					Tintinnopsis failakkaensis	T3	Scattered
					Tintinnopsis gracilis	T4	Very sparse
					Tintinnopsis mortensenii	T5	Very sparse
					Tintinnopsis radix	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	Acrocalanus sp.	C1	Scattered
					Parvocalanus sp.	C2	Very sparse
				Eucalanidae	Pareucalanus sp.	C3	Very sparse
					Subeucalanus sp.	C4	Very sparse
				Clausocalanidae	Clausocalanus sp.	C5	Very sparse
				Centropagidae	Centropages sp.	C6	Very sparse
				Acartiidae	Acartia sp.	C7	Very sparse
			Cyclopoida	Temoridae	Temora sp.	C8	Very sparse
				Tortanidae	Tortanus sp.	C9	Very sparse
				Oithonidae	Oithona sp.	C10	Abundant
			Harpacticoida	Ectinosomatidae	Microsetella sp.	C11	Abundant
				Euterpidae	Euterpina sp.	C12	Sparse
				Canthocamptidae	Canthocamptus sp.	C13	Very sparse
			Poecilostomatoida	Corycaidae	Corycaeus sp.	C14	Very sparse
				Oncaeidae	Oncaea sp.	C15	Very sparse

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ROTIFERS	ROTIFERA	Rotifera Subclass: Eurotatoria	Superorder: Monogononta Order:Ploimida	Brachionidae	Brachionus plicatilis	R1	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	Sagitta sp.	A1	Very sparse
MYSIDS	ATHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Penaeidae	Metapenaeus sp.	M1	Very sparse
				Solenoceridae	Solenocera sp.	M2	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	Oikopleura sp.	U1	Very sparse
				Fritillariidae	Fritillaria sp.	U2	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L2	Sparse
BARNACLE LARVAE	ATHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophioplutes larvae/ Echinoplutes larvae	L5	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L6	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L7	Very sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L8	Very sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Globigerinidae	Globigerina sp.	F1	Very sparse
				Rotaliidae	Rotalia sp.	F2	Very sparse

**TABLE 63 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	Leprotintinnus sp.	T1	Sparse
				Codonellidae	Tintinnopsis accuminata	T2	Very sparse
					Tintinnopsis failakkaensis	T3	Sparse
					Tintinnopsis gracilis	T4	Very sparse
					Tintinnopsis mortensenii	T5	Very sparse
					Tintinnopsis radix	T6	Sparse
COPEPODS	ATHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	Acrocalanus sp.	C1	Scattered
					Parvocalanus sp.	C2	Very sparse
				Eucalanidae	Pareucalanus sp.	C3	Very sparse
					Subeucalanus sp.	C4	Sparse
				Clausocalanidae	Clausocalanus sp.	C5	Very sparse
				Centropagidae	Centropages sp.	C6	Very sparse
			Cyclopoida	Acartiidae	Acartia sp.	C7	Very sparse
				Temoridae	Temora sp.	C8	Very sparse
			Harpacticoida	Oithonidae	Oithona sp.	C9	Abundant
				Ectinosomatidae	Microsetella sp.	C10	Abundant
			Poecilostomatoida	Euterpinae	Euterpina sp.	C11	Sparse
				Oncaeidae	Oncaea sp.	C12	Sparse
				Corycaidae	Corycaeus sp.	C13	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	Sagitta sp.	A1	Sparse
MYSIDS	ATHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Penaeidae	Penaeus sp.	M1	Scattered
				Solenoceridae	Solenocera sp.	M2	Scattered
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	Oikopleura sp.	U1	Very sparse
				Fritillariidae	Fritillaria sp.	U2	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME 1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA	ARTHROPODA	Malacostraca			Brachyuran zoea larvae	L2	Very sparse

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LARVAE	(CRUSTACEA)	Decapoda					
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Scattered
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L5	Sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophioplutes larvae/ Echinoplutes larvae	L6	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L7	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L8	Very sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Globigerinidae	Globigerina sp.	F1	Very sparse
				Rotaliidae	Rotalia sp.	F2	Very sparse

**TABLE 64 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING SPRING TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	Leprotintinnus sp.	T1	Sparse
				Codonellidae	Tintinnopsis failakkaensis	T2	Very sparse
					Tintinnopsis radix	T3	Very sparse
COPEPODS	ATHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	Acrocalanus sp.	C1	Dominant
					Bestiolina sp.	C2	Very sparse
					Parvocalanus sp.	C3	Sparse
				Acartiidae	Acartia sp.	C4	Very sparse
				Centropagidae	Centropages sp.	C5	Sparse
				Clausocalanidae	Clausocalanus sp.	C6	Very sparse
				Temoridae	Temora sp.	C7	Very sparse
			Cyclopoida	Oithonidae	Oithona sp.	C8	Abundant
			Harpacticoida	Canthocamptidae	Canthocamptus sp	C9	Very sparse
				Ectinosomatidae	Microsetella sp.	C10	Sparse
				Euterpinidae	Euterpina sp.	C11	Abundant
			Poecilostomatoida	Oncaeidae	Oncaea sp.	C12	Very sparse
				Corycaeidae	Corycaeus sp.	C13	Very sparse
					Farranula sp.	C14	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	Sagitta sp.	A1	Sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	Oikopleura sp.	U1	Sparse
				Fritillariidae	Fritillaria sp.	U2	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME 1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
ASCIDIAN LARVAE	CHORDATA SUBPHYLUM: TUNICATA	Ascidacea			Ascidian tadpole larvae	L2	Very sparse
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca	Decapoda		Brachyuran zoea larvae	L3	Very sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L4	Scattered
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L5	Very sparse

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ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae/ Echinopluteus larvae	L6	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L7	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L9	Very sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Globigerinidae	Globigerina sp.	F1	Very sparse
				Rotaliidae	Rotalia sp.	F2	Very sparse

**TABLE 65 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF MARCH 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	Leprotintinnus sp.	T1	Very sparse
				Codonellidae	Tintinnopsis failakkaensis	T2	Sparse
					Tintinnopsis gracilis	T3	Very sparse
					Tintinnopsis radix	T4	Sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	Acrocalanus sp.	C1	Scattered
					Parvocalanus sp.	C2	Sparse
				Eucalanidae	Pareucalanus sp.	C3	Very sparse
				Centropagidae	Centropages sp.	C4	Very sparse
				Clausocalanidae	Clausocalanus sp.	C5	Very sparse
				Acartiidae	Acartia sp.	C6	Very sparse
			Cyclopoida	Oithonidae	Oithona sp.	C7	Abundant
			Harpacticoida	Canthocamptidae	Canthocamptus sp	C8	Very sparse
				Euterpinae	Euterpina sp.	C9	Very sparse



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			Poicilostomatatoida	Ectinosomatidae	Microsetella sp.	C10	Very sparse
				Oncaeidae	Oncaea sp.	C11	Very sparse
				Corycaeidae	Corycaeus sp.	C12	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	Sagitta sp.	A1	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM: UROCHORDATA	Appendicularia		Fritillariidae	Fritillaria sp.	U1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
ASCIDIAN LARVAE	CHORDATA SUBPHYLUM: TUNICATA	Ascidacea			Ascidian tadpole larvae	L2	Very sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae/ Echinopluteus larvae	L5	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L6	Abundant
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L7	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L8	Sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Rotaliidae	Rotalia sp.	F1	Sparse

**BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPT harbour region and nearby creek. The meiobenthic organisms during spring tide were represented by Polychaetes *Dasybranchus* sp., *Notomastus* sp, During neap tide Polychaetes *Nereis* sp., *Dasybranchus* sp and Few amphipods were detected.

**Table 66 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING SPRING TIDE IN MARCH 2022**

BENTHIC FAUNA	ABUNDANCE IN NO/M 2 DIFFERENT SAMPLING STATIONS					
	REPRESENTATION BY GROUP					
	DPT HARBOUR			CREEKS		
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family : Capitellidae <i>Dasybranchus</i> sp.	10	140	40	20	10	0
Family : Capitellidae <i>Notomastus</i> sp	10	20	10	40	20	0
Total Polychaetes N/M <sup>2</sup>	20	160	50	60	30	0
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	160	50	60	30	0

NS : No sample

**Table 67 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING NEAP TIDE IN MARCH 2022**

BENTHIC FAUNA	ABUNDANCE IN NO/M 2 DIFFERENT SAMPLING STATIONS					
	REPRESENTATION BY GROUP					
	DPT HARBOUR			CREEKS		
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family : Neridae Nereis sp.	0	0	0	0	10	0
Family : Capitellidae Dasybranchus sp	10	30	20	10	30	0
Total Polychaetes	10	30	20	10	40	0
Un identified Amphipods	10	20	10	20	30	0
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	50	30	40	110	0

# **Meteorological Observation**

## **11.1 Meteorological Data**

### **Temperature**

Temperature records indicate that the area experiences tropical coastal climate. The moderating effects of the nearby sea and the fairly high amount of relative humidity in the atmosphere have restricted the variability. The seasonal variations of temperature follow closely the course of the sun. January is invariably the coldest month and May and June the warmest. With the onset of monsoon in fourth night of June there is a reversal of the temperature curve and the temperature during the period of monsoon remains very nearly uniform at about 27°C. The slight rise in temperature in October falls gradually till it reaches the coldest month in January. The temperatures vary from 11.7°C to 44.0°C. The mean daily air temperatures along with the extremes for each day.

Automatic Weather station ( **ID KAZPHOEN424**) have been installed in Seva Sadan - 3 at the Deendayal Port which records the data on Temperature (°C), Humidity (%), Wind (mph), Dew Point (°C), Wind Direction (°), Pressure, Solar radiation, heat Index and UVI.

### **Temperature**

The mean day time temperature for Deendayal Port was 19.8 °C. The day-time maximum temperature was 32.8°C. The minimum mean night time temperature recorded was 25.8 °C.

### **Air Pressure**

The mean absolute air pressure for the month of March was 1013.21 hpa, whereas the mean relative pressure was 1013.31 hpa. The maximum absolute air pressure recorded for the month of March was 1021.9 hpa.

### **Heat Index**

The mean day-time heat index for the month of March was 30.03°C. The maximum heat index recorded was 42°C.

### **Solar Radiation**

The mean Solar Radiation in March was 118.58 w/m<sup>2</sup>. The maximum solar radiation recorded in the month of March was 530.7 w/m<sup>2</sup>.

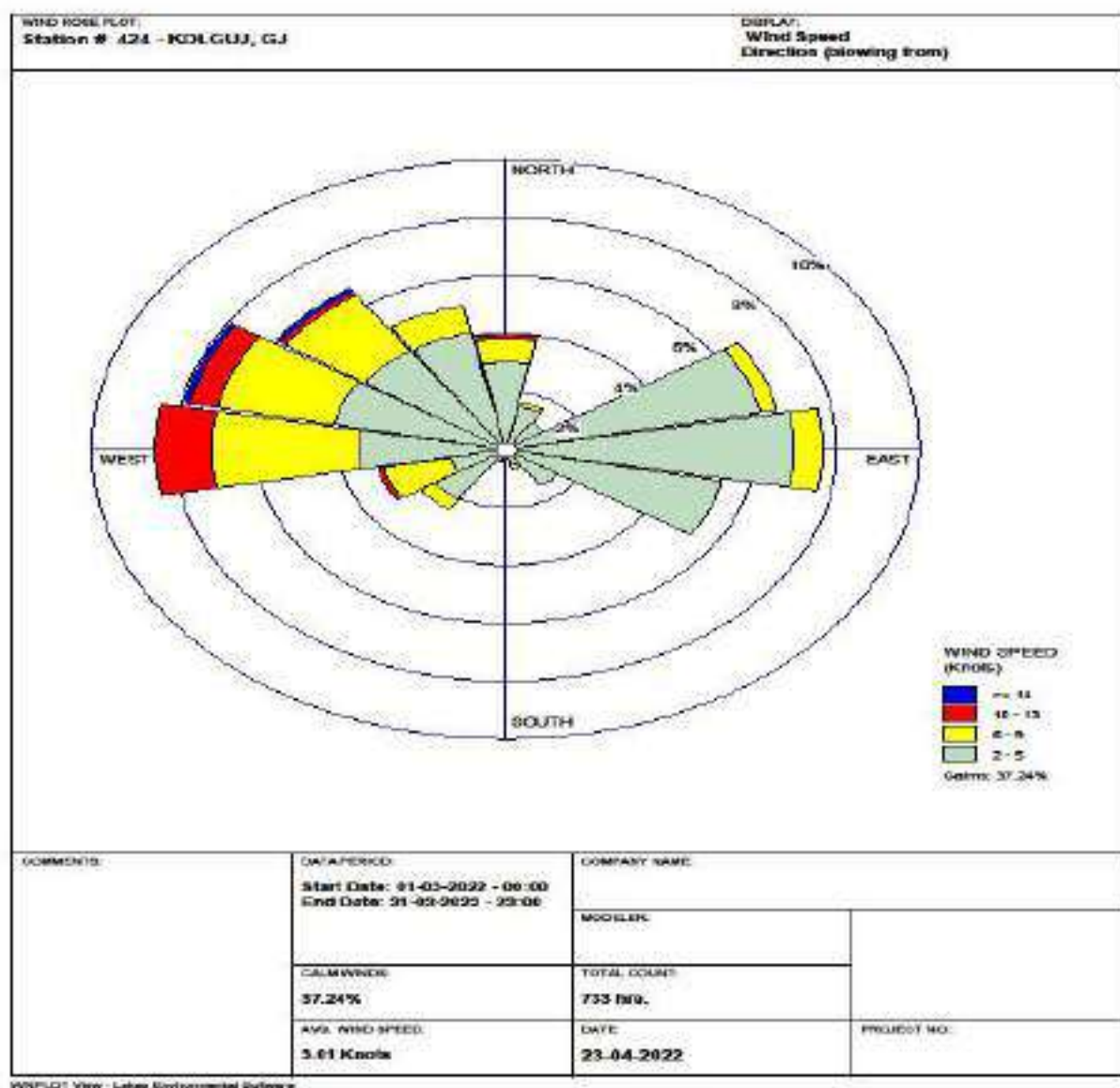
### **Humidity**

The mean day-time humidity was 44.54 % for the month of March and mean night time humidity was 58.77 %. Maximum humidity recorded during day-time was 98.0 % and maximum humidity recorded during night-time was 69.0%.

### **Wind Velocity and Wind Direction**

The mean wind velocity for the entire month of March was 5.20 km/hour. Maximum wind velocity recorded was 34.6 Km/hr . The wind direction was mostly SouthEast.

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## **12.0 Conclusive Summary and Remedial measures Suggested**

The AAQ monitoring at six locations of Deendayal Port Kandla indicates that the mean PM<sub>10</sub> values at all locations viz. Coal storage area, Marine Bhavan, Gopalpuri Hospital, Tuna Port, Kandla Colony and Oil Jetty area were found above the permissible standards (100 µg/m<sup>3</sup>) and PM<sub>2.5</sub> was above permissible limits at Coal storage, Marine Bhavan, Oil Jetty, Gopalpuri Hospital, Kandala colony, Tuna port (Limit 60 µg/m<sup>3</sup>).

The AAQ monitoring Vadinar at Admin building found above the permissible standards for both PM<sub>10</sub> (Limit 100 µg/m<sup>3</sup>) & PM<sub>2.5</sub> (Limit 60 µg/m<sup>3</sup>)

Drinking water at all the twenty locations was found potable and was within permissible limits of BIS standards (IS 10500).

Noise quality was also within the set permissible standards of an Industrial Area. The noise level observed during day time was >75 dB (A) and at night time was >70 dB (A) during the entire monitoring period.

The sewage treated water of Deendayal Port Colony (Gopalpuri) was in line with the standards set by the Gujarat Pollution Control Board.

### **Reasons for higher Values of PM<sub>10</sub>**

Large amount of coal is handled at Berth No. 6, 7, 8 and 9. The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.

Also, the coal laden trucks are not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.



## **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of March, 2022 were observed beyond the permissible limit at all locations mentioned above Except Vadinar Signal building for PM<sub>10</sub> . Given below are the remedial measures suggest to minimize the Air pollution at Deendayal Port.

Except for the higher values of PM<sub>10</sub> & PM<sub>2.5</sub> at Coal storage site, Oil Jetty, Tuna Port and Marine Bhavan locations, the monitoring results for the present month suggest that the overall Environment Quality of Deendayal Port is satisfactory.

During March, 2022 overall ambient air quality of the DPA is within GPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, and Marine Bhavan. To improve air quality the port is using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and unpaved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

Installed Mist Cannons system to suppresses dust generated in crushing and demolition sites, in material storage, cross-docking of Coal.

## **Solution towards the Green port:**

Practice should be initiated for using mask as preventative measure, to avoid inhalation of dust particle- Mask advised in sensitive areas.

Use of renewable energy like solar energy should be optimal and ensure to work continuously.

Display of Environmental Initiative Boards and create awareness towards public. Stay sanitized of public transport and all basic items at public interaction places as much as possible.

Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.

Limit the Activity and time of Exposure in Sensitive Area Prior planning.

Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.

New scanning technology and new high power Tugs are reducing operation timing and CO2 Emission are good creativity.

Initiate Natural Gas (CNG) as fuel by all buses and trucks.

Guidelines for Coal Handling by GPCB should be strictly followed.  
(<http://gpcb.gov.in/pdf/coal-handling-guidelines.pdf>)

### **13.0 SOURCE OF LITERATURE AND ADDITIONAL REFERENCE**

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## **ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY**



**REPORT : DCPL/DPA/21-22/24**  
**Mont : April**  
**Issue : 01**  
**Revision : 00**  
**Prepare : DETOX CORPORATION PVT. LTD., SURAT**

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## **ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTAL MONITORING REPORT- APRIL 2022**

### **1. EXECUTIVE SUMMARY**

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to identify non conformity in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### **A) Ambient Air**

The monitoring of Ambient Air quality at 6 locations at Deen Dayal Port Authority Kandla and 2 at Vadinar Port on 24 hourly basis for TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> in twice a Week at Gopalpuri, Tuna Port, Marine Bhavan building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The TSPM values in month of April 2022 were found 1295 µg/m<sup>3</sup> maximum at Coal Storage area on 14.04.2022 and minimum 73 µg/m<sup>3</sup> at Oil Jetty on 4<sup>th</sup> April 2022. The PM<sub>10</sub> values were found from 1198 µg/m<sup>3</sup> maximum at Coal Storage area on 14.04.2022 and minimum 51 µg/m<sup>3</sup> at Tuna Port on 7<sup>th</sup> April 2022, The PM<sub>2.5</sub> values were found from 109 µg/m<sup>3</sup> maximum at Coal Storage area on 21<sup>st</sup> April 2022 and minimum 21 µg/m<sup>3</sup> at Oil Jetty on 25<sup>th</sup> April 2022. The PM<sub>10</sub> values are found for five locations (Gopalpuri, Marine Bhavan building, Coal storage area, Estate building, Oil jetty) to above the permissible limit. The PM<sub>2.5</sub> values are found for four locations ( Marine Bhavan building, Oil jetty, Gopalpuri & Estate building) within permissible limit Except Coal Storage area. The PM<sub>10</sub> & PM<sub>2.5</sub> values are found for three locations ( Tuna Port, Vadinar Signal building & Admin building) within permissible limit.

The overall values of April for SO<sub>2</sub> were found maximum of 7.57 µg/m<sup>3</sup> and minimum of 1.29 µg/m<sup>3</sup> · NO<sub>x</sub> were found maximum 25.67 µg/m<sup>3</sup> and minimum 8.63 µg/m<sup>3</sup>, NH<sub>3</sub> were found maximum 13.66 µg/m<sup>3</sup> and minimum 5.17 µg/m<sup>3</sup>, C<sub>6</sub>H<sub>6</sub> were found maximum 1.25 µg/m<sup>3</sup> and minimum 1.00 µg/m<sup>3</sup>, CO were found

maximum 2.26 mg/m<sup>3</sup> and minimum of 1.41 mg/m<sup>3</sup> , CO<sub>2</sub> were found maximum 809 ppm and minimum of 320 ppm and there is reported result for NMHC were BQL (Below Quantification Limit).

## **B) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:**

The results obtained from the study for the month of April, 2022. Physic-chemical parameters were observed for Flora and Fauna of ecological parameters for Arabian Sea at Kachchh Creek. Net Primary Productivity and Chlorophyll-a were well for ecological parameters for Arabian Sea. However, considering the activities in DPA Harbour, it is seen that the marine ecosystem is not adversely affected by Port activities.

## **C) Drinking Water Quality**

Drinking water is water intended for human consumption for drinking and cooking purposes from any source. The drinking water being supplied to Deendayal Port is safe for drinking purpose. At all drinking water monitoring stations around port area are found to be as per the drinking water specifications given in IS 10500:2012 and also on the basis of analysis parameter.

The average results for 20 locations as per below. pH were found Min 7.23 to 7.61, TDS were found min 340 mg/l to Max found 910 mg/l, Chloride were found Min 210.0 mg/l to Max 611 mg/l, Total Hardness were found Min 410 mg/l to Max 480 mg/l and Calcium were found Min 48.09 mg/l to Max 72.14 mg/l. colour found colourless and odour were odourless. All water sample found for BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count is absent in all drinking water samples.

## **D) Monitoring Performance of Sewage Treatment Plant**

It is seen that the performance of STP at Deendayal Township, DPA STP Plant and Vadinar STP plant is satisfactory by overall. The treatment plant was well maintained during [April 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. The average results for 3 locations as per below. Two locations ( Gopalpuri & DPA STP) and one location at Vadinar. The pH were found 7.23 to Max 7.51, Total Suspended Solids were found 40.3 to 97.1 , Residual Chlorine were below Detection Limit (Less Than 0.5) , COD were found 10 to 80 and BOD @ 27 °C were found 4 to 20 mg/l.



## **E) Weather**

The data collected from Automatic weather station have been installed and other secondary sources to represent the metrological conditions of the project area has been reviewed and presented below for various attributes such as Temperature, Wind, Cloud cover, Relative Humidity, Rainfall, and Visibility. The predominant wind direction (blowing from) was the North West in the port area. Average values of wind speed was 8.19 m/s.

The Day maximum Temperature of 8<sup>th</sup> April 2022 was 41.6<sup>0</sup>C and min 26.0<sup>0</sup>C on 26<sup>th</sup> April 2022. Relative Humidity was recorded Mean at day 16.0 % on 8<sup>th</sup> April 2022 and on 16<sup>th</sup> & 29<sup>th</sup> April found the max 95.0%. Solar Radiation was recorded maximum 331.7 w/m<sup>2</sup> on 16<sup>th</sup> April 2022 The mean wind velocity for the entire month was 0.70 m/s. Maximum wind velocity recorded was 34.2 m/s on 26<sup>th</sup> April 2022 . The wind direction was mostly North West.

## **F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 13 locations at Deendayal Port ranged from minimum of 55.4 dB(A) at Tuna port and entrance gate Vadinar port and maximum of 73.5 dB(A) at Main road, all results was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from minimum 45.5 dB at Port & custom office and maximum of 69.1 dB(A) at Main road, all results was within the permissible limits of 70 dB(A) for the industrial area for the night time.

## **2.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 kms. From the mouth of Gulf of Kachchh. **Latitude: 23° 01" N Longitude: 70° 13"E**. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rose to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15 consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. The west coast port handled 72,225 million tonnes of cargo in 2008-09, over 11% more than 64,920 million tonnes handled in 2007-08. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. Although Deendayal Port Authority officials declined to elaborate given the ongoing election code of conduct, it is reliably learnt that the port will soon initiate the process of selecting developers for four clean cargo berths that together aim to handle 8 million tonnes of cargo. The four berths will be supported by a 14 m draft capable of handling 75,000 dwt vessels.

The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural upgradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32MMTPA Essar Oil Refinery in Jamnagar District.

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the

same, comparing results with respect to the prescribed standards by GBCB/CPCB/MoEF & CC. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd

# **Ambient Air Quality Monitoring**

### **3. Introduction**

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

#### **3.1 Ambient Air Quality Monitoring**

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

##### **Air Quality Monitoring Methodology**

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub>, NH<sub>3</sub>, NMHC & Benzene, and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours of the sampler. The reagents for SO<sub>2</sub> :- Mercuric Chloride, Potassium Chloride and EDTA used. For NO<sub>x</sub> :- Sodium Hydroxide and Sodium Arsenite. For NH<sub>3</sub> need Coc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO<sub>2</sub>, NO<sub>x</sub> . The EPM 2000 filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected twice a week from all the eight locations as per the EMP.

#### **3.2 Results**

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of April 2022 are given in Tables 1 to 6. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 7 to 8.

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**Note:AL1 To AL8 are Air Monitoring Location 1 to 8. Where AL1 Marine Bhavan, AL2 Oil Jetty, AL3 Estate Office, AL4 Gopalpuri Hospital, AL5 Coal Storage, AL6 Tuna Port, AL7 Signal Building (Vadinar) and AL8 Admin Building (Vadinar).**

**Location 1: Marine Bhavan (AL1)****Table 1 : Results of Air Pollutant Concentration at Marine Bhavan**

Table 1 : Results of Air Pollutant Concentration at Marine Bhavan										
Parameter	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL1 – 1	04.04.2022	149	77	67	2.14	2.00	20.30	19.13	8.06	9.09
					1.29		19.60		9.21	
					2.57		17.50		10.01	
AL1 – 2	07.04.2022	189	149	23	4.72	5.15	14.00	15.17	9.90	10.48
					5.57		12.60		8.98	
					5.15		18.90		12.55	
AL1 – 3	11.04.2022	333	257	58	7.29	5.86	27.31	25.67	13.01	13.09
					5.57		30.81		14.16	
					4.72		18.90		12.09	
AL1 – 4	14.04.2022	322	225	74	2.57	1.86	17.50	15.40	14.27	12.55
					1.72		12.60		10.82	
					1.29		16.10		12.55	
AL1 – 5	18.04.2022	338	234	78	3.00	4.00	21.00	21.24	6.68	7.83
					3.86		19.60		9.78	
					5.15		23.11		7.02	
AL1 - 6	21.04.2022	324	238	79	3.43	4.29	14.00	17.97	9.78	7.90
					5.15		22.40		8.86	
					4.29		17.50		5.06	
AL1 - 7	25.04.2022	268	225	43	2.14	2.29	14.00	17.27	11.28	11.55
					3.43		17.50		14.39	
					1.29		20.30		8.98	
AL1 – 8	28.04.2022	231	172	49	4.29	4.43	16.10	21.47	10.01	7.60
					5.15		29.41		7.02	
					3.86		18.90		5.76	
Monthly Average		269	197	59		3.74		19.16		10.01
Standard Deviation		73	60	20		1.51		3.53		2.22

Table 1 : Results of Air Pollutant Concentration at Marine Bhavan					
Parameter	Date	C6H6 [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL1 – 1	04.04.2022	1.1	BQL	2.12	474
AL1 – 2	07.04.2022	1.03	BQL	1.61	678
AL1 – 3	11.04.2022	1.2	BQL	1.41	647
AL1 – 4	14.04.2022	1.14	BQL	2.08	724
AL1 – 5	18.04.2022	1.08	BQL	1.94	643
AL1 – 6	21.04.2022	1.15	BQL	1.96	734
AL1 – 7	25.04.2022	1.2	BQL	1.64	578
AL1 – 8	28.04.2022	1.13	BQL	1.65	809
Monthly Average		1.13	-	1.80	661
Standard Deviation		0.06	-	0.26	103

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 269 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 197 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 99 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.74 µg/ m<sup>3</sup>, 19.16 µg/ m<sup>3</sup> & 10.01 µg/ m<sup>3</sup> respectively. These were within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.13 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.80 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 2: Oil Jetty (AL2)

Table 2 : Results of Air Pollutant Concentration at Oil Jetty

Table 2 : Results of Air Pollutant Concentration at Oil Jetty										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL2 -1	04.04.2022	110	52	27	3.00	3.80	14.00	12.13	12.20	11.47
					2.80		10.50		11.40	
					5.60		11.90		10.82	
AL2 -2	07.04.2022	160	100	22	1.40	2.80	9.80	9.57	6.33	7.75
					3.50		10.50		7.71	
					3.50		8.40		9.21	
AL2 -3	11.04.2022	348	260	54	6.00	5.86	27.31	22.87	7.37	9.02
					7.29		21.70		10.01	
					4.29		19.60		9.67	
AL2 -4	14.04.2022	269	207	61	3.00	2.29	15.40	14.23	10.47	10.32
					1.72		16.10		11.40	
					2.14		11.20		9.09	
AL2 – 5	18.04.2022	203	122	44	3.86	2.43	12.60	16.34	8.98	8.67
					1.29		23.11		7.71	
					2.14		13.30		9.32	
AL2 – 6	21.04.2022	234	140	61	4.29	4.43	20.30	16.80	6.91	8.94
					5.15		16.10		9.90	
					3.86		14.00		10.01	
AL2 – 7	25.08.2021	134	100	21	0.86	1.29	23.11	19.60	8.29	10.25
					1.72		18.20		10.82	
					1.29		17.50		11.63	
AL2 -8	28.04.2022	180	142	36	2.14	2.14	16.80	13.77	6.79	8.30
					1.29		11.90		9.32	
					3.00		12.60		8.78	
Monthly Average		205	140	41		3.13		15.66		9.34
Standard Deviation		78	66	17		1.48		4.22		1.23



**Table 2 : Results of Air Pollutant Concentration at Oil Jetty**

		C6H6 [ $\mu\text{g}/\text{m}^3$ ]		CO [ $\text{mg}/\text{m}^3$ ]	CO2 [ppm]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit	Date	5.0 $\mu\text{g}/\text{m}^3$	*NMHC	4.0 $\text{mg}/\text{m}^3$	-
AL2 -1	04.04.2022	1.24	BQL	2.1	704
AL2 -2	07.04.2022	1.04	BQL	2.03	634
AL2 -3	11.04.2022	1.07	BQL	1.79	534
AL2 -4	14.04.2022	1.07	BQL	2.09	489
AL2 -5	18.04.2022	1.17	BQL	2.07	734
AL2 -6	21.04.2022	1.13	BQL	2.06	579
AL2 -7	25.04.2022	1.07	BQL	1.77	564
AL2 -8	28.04.2022	1.06	BQL	1.91	671
Monthly Average		1.11	-	1.98	615
Standard Deviation		0.07	-	0.14	85

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Oil Jetty area was mainly by motor vehicle emission produced from various types of vehicles Oil Jetty Area. The mean TSPM values at Oil Jetty were 205  $\mu\text{g}/\text{m}^3$ . The mean PM<sub>10</sub> values were 140  $\mu\text{g}/\text{m}^3$ , which is above the permissible limit. PM<sub>2.5</sub> values were 41  $\mu\text{g}/\text{m}^3$ . The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were within the permissible limit, The mean concentration of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.13  $\mu\text{g}/\text{m}^3$ , 15.66  $\mu\text{g}/\text{m}^3$  and 9.34  $\mu\text{g}/\text{m}^3$  respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.11  $\mu\text{g}/\text{m}^3$ . Well below the permissible limit of 5.0  $\mu\text{g}/\text{m}^3$ . , NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.98  $\text{mg}/\text{m}^3$ , well below the permissible limit of 4.0  $\text{mg}/\text{m}^3$ .

**Environmental Monitoring Report Of Deendayal Port Authority, APRIL-2022****Location 3: Kandla Colony - Estate Office (AL-3)****Table 3 : Results of Air Pollutant Concentration at Estate Office**

Table 3 : Results of Air Pollutant Concentration at Estate Office										
Parameter	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit				100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3	
AL3 – 1	04.04.2022	167	129	34	0.86	1.72	16.80	14.70	13.01	12.28
					1.72		13.30		12.43	
					2.57		14.00		11.40	
AL3 – 2	07.04.2022	334	272	33	3.86	3.57	11.90	12.13	7.83	7.29
					2.57		10.50		6.91	
					4.29		14.00		7.14	
AL3 – 3	11.04.2022	271	159	92	3.00	3.43	15.40	15.87	9.32	7.83
					5.15		11.90		7.83	
					2.14		20.30		6.33	
AL3 – 4	14.04.2022	232	139	93	4.29	5.00	9.80	9.33	12.20	9.63
					6.00		8.40		9.09	
					4.72		9.80		7.60	
AL3 – 5	18.04.2022	288	175	90	3.43	3.43	23.11	20.07	10.24	11.28
					4.29		22.40		9.78	
					2.57		14.70		13.81	
AL3 – 6	21.04.2022	253	192	50	2.14	3.72	19.60	17.03	10.01	9.05
					3.86		16.80		11.05	
					5.15		14.70		6.10	
AL3 – 7	25.04.2022	388	337	42	5.15	3.43	21.70	20.07	12.20	11.51
					3.43		18.90		11.63	
					1.72		19.60		10.70	
AL3 – 8	28.04.2022	416	369	43	2.57	2.86	12.60	16.33	12.09	9.44
					4.29		16.80		9.21	
					1.72		19.60		7.02	
Monthly Average		294	221	60		3.40		15.69		9.79
Standard Deviation		82	92	27		0.91		3.68		1.78

**Table 3 : Results of Air Pollutant Concentration at Estate Office**

		C6H6 [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO2 [ppm ]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL3 -1	04.04.2022	1.21	BQL	1.89	564
AL3 -2	07.04.2022	1.01	BQL	2.01	786
AL3 -3	11.04.2022	1.01	BQL	2	544
AL3 -4	14.04.2022	1.01	BQL	1.96	679
AL3 - 5	18.04.2022	1.16	BQL	2.07	498
AL3 - 6	21.04.2022	1.06	BQL	1.94	653
AL3 - 7	25.04.2022	1.14	BQL	1.93	675
AL3 - 8	28.04.2022	1.1	BQL	1.83	756
Monthly Average		1.09	-	1.95	644
Standard Deviation		0.08	-	0.07	102

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit - NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Kandla Port Colony was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Kandla port Colony were 294 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 221 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 60 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 3.40 µg/m<sup>3</sup>, 15.69 µg/m<sup>3</sup> and 9.79 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.09 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.95 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 4: Gopalpuri Hospital (AL-4)

Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital

Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
Parameter	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL4 -1	04.04.2022	192	95	49	1.72	2.00	8.40	10.50	9.67	9.05
					2.14		15.40		8.86	
					2.14		7.70		8.63	
AL4 -2	07.04.2022	201	136	56	3.00	1.72	6.30	10.73	7.71	8.71
					0.86		12.60		9.32	
					1.29		13.30		9.09	
AL4 -3	11.04.2022	214	135	78	2.57	3.00	11.20	9.80	5.41	6.33
					3.43		5.60		6.56	
					3.00		12.60		7.02	
AL4 -4	14.04.2022	196	126	52	2.57	3.57	10.50	9.57	8.06	8.33
					4.29		8.40		9.44	
					3.86		9.80		7.48	
AL4 – 5	18.04.2022	254	191	56	2.57	3.00	16.80	12.37	10.82	9.67
					3.43		9.80		9.32	
					3.00		10.50		8.86	
AL4 – 6	21.04.2022	182	134	43	3.86	4.58	13.30	11.67	5.64	6.48
					4.72		10.50		6.33	
					5.15		11.20		7.48	
AL4 – 7	25.04.2022	187	132	51	3.00	3.57	19.60	18.67	8.83	7.82
					5.15		20.30		6.56	
					2.57		16.10		8.06	
AL4 – 8	28.04.2022	190	128	61	1.72	2.29	13.30	12.83	7.25	6.94
					3.00		11.20		6.56	
					2.14		14.00		7.02	
Monthly Average		202	135	56		2.97		12.02		7.92
Standard Deviation		23	26	10		0.95		2.93		1.23

Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital					
	Date	C6H6 [ $\mu\text{g}/\text{m}^3$ ]	*NMHC	CO [ $\text{mg}/\text{m}^3$ ]	CO2 [ppm]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 $\mu\text{g}/\text{m}^3$		4.0 $\text{mg}/\text{m}^3$	-
AL4 -1	04.04.2022	1.09	BQL	1.9	457
AL4 -2	07.04.2022	1	BQL	2.02	754
AL4 -3	11.04.2022	1.08	BQL	1.79	562
AL4 -4	14.04.2022	1.19	BQL	2.11	490
AL4 -5	18.04.2022	1.1	BQL	1.75	695
AL4 -6	21.04.2022	1.13	BQL	2.1	675
AL4 -7	25.04.2022	1.06	BQL	2.02	700
AL4 -8	28.04.2022	1.04	BQL	2.05	689
Monthly Average		1.09	-	1.97	628
Standard Deviation		0.06	-	0.14	110

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit - NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 202  $\mu\text{g}/\text{m}^3$ , The mean PM<sub>10</sub> values were 135  $\mu\text{g}/\text{m}^3$ , which is above the permissible limit. PM<sub>2.5</sub> values were 56  $\mu\text{g}/\text{m}^3$ . The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 2.97  $\mu\text{g}/\text{m}^3$ , 12.02  $\mu\text{g}/\text{m}^3$  and 7.92  $\mu\text{g}/\text{m}^3$  respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.09  $\mu\text{g}/\text{m}^3$ , well below the permissible limit of 5.0  $\mu\text{g}/\text{m}^3$ . HC's were below the detectable limit and Carbon Monoxide concentration was 1.97  $\text{mg}/\text{m}^3$ , well below the permissible limit of 4.0  $\text{mg}/\text{m}^3$ .

**Location 5: Coal Storage Area (AL-5)**

**Table 5 : Results of Air Pollutant Concentration at Coal Storage Area**

Table 5 : Results of Air Pollutant Concentration at Coal Storage Area										
Parameter	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL5 – 1	04.04.2022	351	304	40	3.86	4.00	23.11	21.47	9.44	8.86
					3.00		21.00		7.25	
					5.15		20.30		9.90	
AL5 – 2	07.04.2022	1128	1031	122	8.15	7.43	17.50	17.97	10.59	13.08
					6.86		18.90		14.73	
					7.29		17.50		13.93	
AL5 – 3	11.04.2022	1231	1185	132	9.00	7.57	24.51	23.57	9.90	8.60
					7.29		19.60		7.60	
					6.43		26.61		8.29	
AL5 – 4	14.04.2022	1295	1199	135	1.72	2.43	16.80	17.97	11.17	10.55
					2.57		17.50		10.70	
					3.00		19.60		9.78	
AL5 – 5	18.04.2022	959	848	93	4.29	4.15	21.70	19.60	11.51	10.63
					3.86		19.60		10.47	
					4.29		17.50		9.90	
AL5 – 6	21.04.2022	892	773	109	3.86	3.14	16.10	17.27	14.27	13.66
					3.00		15.40		13.70	
					2.57		20.30		13.01	
AL5 – 7	25.04.2022	572	493	79	4.29	5.00	11.90	14.93	10.01	9.59
					5.57		14.70		9.67	
					5.15		18.20		9.09	
AL5 – 8	28.04.2022	444	378	66	5.15	3.86	21.00	24.04	11.40	11.05
					3.43		23.11		10.70	
					3.00		28.01		11.05	
Monthly Average		859	776	97		4.70		19.60		10.75
Standard Deviation		364	354	34		1.89		3.20		1.84

**Table 5 : Results of Air Pollutant Concentration at Coal Storage Area**

		C6H6 [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL5 – 1	04.04.2022	1	BQL	2.15	696
AL5 – 2	07.04.2022	1.09	BQL	2.07	567
AL5 – 3	11.04.2022	1.21	BQL	2.02	678
AL5 – 4	14.04.2022	1.2	BQL	1.95	490
AL5 – 5	18.04.2022	1.04	BQL	2.26	521
AL5 – 6	21.04.2022	1.11	BQL	2.03	603
AL5 – 7	25.04.2022	1.21	BQL	2.1	562
AL5 – 8	28.04.2022	1.06	BQL	1.85	648
<b>Monthly Average</b>		<b>1.12</b>	<b>-</b>	<b>2.05</b>	<b>596</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.12</b>	<b>74</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 859 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 776 µg/m<sup>3</sup>, which is well above the permissible limit. The PM<sub>2.5</sub> values were 97 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 4.70 µg/m<sup>3</sup>, 19.60 µg/m<sup>3</sup> and 10.75 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 2.05 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 6: Tuna Port (AL-6)

Table 6 : Results of Air Pollutant Concentration at Tuna Port

Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL6 -1	04.04.2022	100	61	32	1.29	1.72	21.70	15.63	11.51	11.39
					2.14		14.00		12.66	
					1.72		11.20		10.01	
AL6 – 2	07.04.2022	80	51	27	2.14	2.57	9.10	9.80	6.79	6.98
					3.00		9.80		7.02	
					2.57		10.50		7.14	
AL6 – 3	11.04.2022	128	88	29	3.43	2.29	15.40	18.20	7.60	6.75
					1.29		18.90		5.64	
					2.14		20.30		7.02	
AL6 – 4	14.04.2022	141	89	36	3.00	3.43	8.40	8.63	10.01	9.44
					4.29		7.70		9.21	
					3.00		9.80		9.09	
AL6 – 5	18.04.2022	125	93	28	0.86	1.29	20.30	15.87	10.59	11.40
					1.29		14.00		12.20	
					1.72		13.30		11.40	
AL6 – 6	21.04.2022	108	67	38	4.29	4.00	28.01	23.34	9.78	11.01
					3.43		20.30		13.12	
					4.29		21.70		10.13	
AL6 – 7	25.04.2022	126	92	24	3.00	3.00	16.10	16.80	8.98	9.71
					2.57		17.50		9.78	
					3.43		16.80		10.36	
AL6 – 8	28.04.2022	118	71	36	2.57	3.00	16.10	15.63	10.70	10.13
					3.00		15.40		9.67	
					3.43		15.40		10.01	
Monthly Average		116	76	31		2.66		15.49		9.60
Standard Deviation		19	16	5		0.89		4.63		



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**Table 6 : Results of Air Pollutant Concentration at Tuna Port**

		C6H6 [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL6 -1	04.04.2022	1.14	BQL	1.96	567
AL6 - 2	07.04.2022	1.13	BQL	2.14	653
AL6 - 3	11.04.2022	1.17	BQL	1.79	489
AL6 - 4	14.04.2022	1.17	BQL	2.09	610
AL6 - 5	18.04.2022	1.19	BQL	2.04	680
AL6 - 6	21.04.2022	1.25	BQL	2.03	632
AL6 - 7	25.04.2022	1.11	BQL	1.7	458
AL6 - 8	28.04.2022	1.13	BQL	1.82	497
Monthly Average		1.16	-	1.95	573
Standard Deviation		0.04	-	0.16	83

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit - NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port were 116 µg/m<sup>3</sup>, The mean PM<sub>10</sub> values were 76 µg/m<sup>3</sup>, which is above the permissible limit. PM<sub>2.5</sub> values were 31 µg/m<sup>3</sup>. The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 2.66 µg/m<sup>3</sup>, 15.49 µg/m<sup>3</sup> and 9.60 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.16 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.95 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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### Location 7: Signal Building (Vadinar) (AL-7)

Table 7 : Results of Air Pollutant Concentration at Signal building Vadinar										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL7 -1	05.04.2022	147	95	45	1.29	2.00	7.70	9.80	5.87	7.67
					2.14		11.90		8.75	
					2.57		9.80		8.40	
AL7 -2	08.04.2022	165	110	41	3.86	3.72	18.20	14.70	6.56	8.09
					4.29		15.40		9.09	
					3.00		10.50		8.63	
AL7 -3	12.04.2022	119	80	36	2.57	2.14	9.80	17.97	5.06	6.41
					2.14		23.81		7.48	
					1.72		20.30		6.68	
AL7 -4	15.04.2022	161	101	58	2.57	3.00	19.60	14.47	8.52	8.52
					3.00		14.00		9.44	
					3.43		9.80		7.60	
AL7 -5	19.04.2022	133	85	46	4.29	3.86	15.40	16.33	8.29	8.75
					3.43		21.70		9.55	
					3.86		11.90		8.40	
AL7 -6	22.04.2022	160	96	55	3.86	3.00	9.10	10.27	4.83	5.18
					3.00		8.40		5.06	
					2.14		13.30		5.64	
AL7 -7	26.04.2022	154	98	48	2.57	1.86	14.70	15.88	11.97	10.13
					1.72		12.60		12.20	
					1.29		20.33		6.22	
AL7-8	29.04.2022	168	106	50	4.29	3.00	7.70	13.07	9.90	10.09
					3.43		17.50		10.13	
					1.29		14.00		10.24	
Monthly Average		151	96	48		2.82		14.06		8.10
Standard Deviation		17	10	7		1		3		2

**Table 7 : Results of Air Pollutant Concentration at Signal building Vadinar**

		C6H6 [ $\mu\text{g}/\text{m}^3$ ]		CO [ $\text{mg}/\text{m}^3$ ]	CO <sub>2</sub> [ppm]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit	Date	5.0 $\mu\text{g}/\text{m}^3$	*NMHC	4.0 $\text{mg}/\text{m}^3$	-
AL7 -1	05.04.2022	1.24	BQL	1.69	521
AL7 -2	08.04.2022	1.09	BQL	2.17	575
AL7 -3	12.04.2022	1.11	BQL	1.75	540
AL7 -4	15.04.2022	1.15	BQL	1.66	448
AL7 -5	19.04.2022	1.04	BQL	2.01	456
AL7 -6	22.04.2022	1.11	BQL	1.8	389
AL7 -7	26.04.2022	1.11	BQL	1.75	320
AL7 -8	29.04.2022	1.16	BQL	1.82	438
Monthly Average		1.13	-	1.83	461
Standard Deviation		0.06	-	0.17	83

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Vadinar Port were  $149 \mu\text{g}/\text{m}^3$ . The mean PM<sub>10</sub> values were  $96 \mu\text{g}/\text{m}^3$ , which is below the permissible limit. PM<sub>2.5</sub> values were  $48 \mu\text{g}/\text{m}^3$ . The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were  $2.82 \mu\text{g}/\text{m}^3$ ,  $14.06 \mu\text{g}/\text{m}^3$  and  $8.10 \mu\text{g}/\text{m}^3$  respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was  $1.13 \mu\text{g}/\text{m}^3$ , well below the permissible limit of  $5.0 \mu\text{g}/\text{m}^3$ . HC's were below the detectable limit and Carbon Monoxide concentration was  $1.83 \text{ mg}/\text{m}^3$ , well below the permissible limit of  $4.0 \text{ mg}/\text{m}^3$ .

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### Location 8: Admin Building (Vadinar) (AL-8)

Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar

Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar										
Parameters	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL8 -1	05.04.2022	159	93	51	1.29	2.43	11.20	11.67	9.09	8.63
					2.57		14.00		8.63	
					3.43		9.80		8.17	
AL8 -2	08.04.2022	150	105	44	4.29	1.86	14.70	14.70	7.48	7.83
					0.43		16.10		7.94	
					0.86		13.30		8.06	
AL8 -3	12.04.2022	142	99	37	1.72	1.72	15.40	13.77	5.06	5.75
					1.29		13.30		6.79	
					2.14		12.60		5.41	
AL8 -4	15.04.2022	154	97	40	3.43	3.86	11.20	10.03	8.86	9.02
					4.29		9.80		9.21	
					3.86		9.10		8.98	
AL8 -5	19.04.2022	146	89	39	2.57	3.00	7.70	8.63	7.83	7.98
					3.00		8.40		9.32	
					3.43		9.80		6.79	
AL8 -6	22.04.2022	136	87	45	2.14	2.57	12.60	11.43	8.52	8.56
					3.00		11.20		9.44	
					2.57		10.50		7.71	
AL8 -7	26.04.2022	128	80	43	3.86	4.29	7.00	8.63	10.36	8.82
					4.29		8.40		7.02	
					4.72		10.50		9.09	
AL8-8	29.04.2022	163	92	54	2.57	2.57	12.60	11.67	6.45	5.99
					2.14		11.90		5.99	
					3.00		10.50		5.53	
Monthly Average		147	93	44		2.79		11.32		7.82
Standard Deviation		12	8	6		1		2		1

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Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar

	Date	C6H6 [ $\mu\text{g}/\text{m}^3$ ]	*NMHC	CO [ $\text{mg}/\text{m}^3$ ]	CO2 [ppm]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 $\mu\text{g}/\text{m}^3$		4.0 $\text{mg}/\text{m}^3$	-
AL8 -1	05.04.2022	1.16	BQL	1.68	493
AL8 -2	08.04.2022	1.05	BQL	2.08	630
AL8 -3	12.04.2022	1	BQL	1.72	520
AL8 -4	15.04.2022	1.09	BQL	1.66	448
AL8 -5	19.04.2022	1.14	BQL	1.89	381
AL8 -6	22.04.2022	1.15	BQL	1.89	324
AL8 -7	26.04.2022	1.09	BQL	1.63	322
AL8 -8	29.04.2022	1.14	BQL	1.87	356
Monthly Average		1.10	-	1.80	434
Standard Deviation		0.06	-	0.16	109

\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> at Admin Building Vadinar was comparatively low among all the locations of Air Quality monitoring in Kandla Port and Vadinar Port. The mean TSPM values at Vadinar Port were 147  $\mu\text{g}/\text{m}^3$ . The mean PM<sub>10</sub> values were 93  $\mu\text{g}/\text{m}^3$ , which is above the permissible limit. PM<sub>2.5</sub> values were 44  $\mu\text{g}/\text{m}^3$ . The average values of SO<sub>2</sub>, NO<sub>x</sub> and NH<sub>3</sub> were 2.79  $\mu\text{g}/\text{m}^3$ , 11.32  $\mu\text{g}/\text{m}^3$  and 7.82  $\mu\text{g}/\text{m}^3$  respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Admin Building, Vadinar Port. The mean Benzene concentration was 1.10  $\mu\text{g}/\text{m}^3$ , well below the permissible limit of 5.0  $\mu\text{g}/\text{m}^3$ . NMHC's were below the detectable limit and

Carbon Monoxide concentration was 1.80 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

### **3.3 Observations and Conclusion**

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Total Suspended Particulate matter as TSPM, Particulate matter as PM<sub>10</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan, Estate Office, Tuna Port, Oil Jetty area, and Gopalpuri. The PM<sub>2.5</sub> values are found for four locations ( Marine Bhavan building, Oil jetty, Gopalpuri & Estate building) within permissible limit Except Coal Storage area

# **Drinking Water Monitoring**

#### **4.0 Drinking Water Quality Monitoring**

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

##### **4.1 Drinking Water Monitoring Methodology**

Drinking water samples were collected from 20 locations as prescribed in the tender document. Samples for physico-chemical analysis were collected in 1 liter carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS 3025 Part-1 and Analysis was done as per standard methods - IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate , Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (cfu) .

##### **4.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 9 to Table No. 15



**Environmental Monitoring Report Of Deendayal Port Authority, APRIL-2022****Table 9: Drinking Water Quality Monitoring Parameters for Nirman Building 1 (23° 0' 27"E, 70° 13' 21"N) P & C building (23° 0' 33"E 70° 13' 20"N) & Main Gate (North) at Kandla (23° 0' 26.97"E, 70° 13' 21.87"N)**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C building	Main Gate North	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.36	7.41	7.31	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	420.0	440.0	390.0	500	2000
3	Turbidity	NTU	1	1	0.5	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	S/m	686.0	700.0	718.0	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	310.69	315.70	305.68	250	1000
9	Total Hardness	mg/l	420.0	430.0	450.0	200	600
10	Calcium	mg/l	56.11	52.10	60.12	75	200
11	Salinity	%	0.56	0.57	0.55	NS*	NS*
12	Mg as Mg	mg/l	68.04	72.90	72.90	30	100
13	Fluorides as F	mg/l	0.42	0.49	0.35	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	265.2	273.6	277.2	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	6.90	8.52	8.87	45	No Relaxation
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
18	Sodium as Na	mg/l	201	219	249	NS*	NS*
19	Potassium as K	mg/l	3.04	4.38	5.14	NS*	NS*
20	Manganese	mg/l	<0.04	<0.04	<0.04	0.1	0.3
21	Hexavalent Chromium	mg/l	<0.03	<0.03	<0.03	NS*	NS*
22	Copper	mg/l	<0.05	<0.05	<0.05	0.05	1.5
23	Cadmium	mg/l	<0.002	<0.002	<0.002	0.003	NS*
24	Arsenic	mg/l	<0.01	<0.01	<0.01	0.01	0.05
25	Mercury	mg/l	<0.001	<0.001	<0.001	0.001	NS*
26	Lead	mg/l	<0.01	<0.01	<0.01	0.01	NS*
27	Zinc	mg/l	<0.1	<0.1	<0.1	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Environmental Monitoring Report Of Deendayal Port Authority, APRIL-2022****Table 10: Drinking Water Quality Monitoring Parameters for Canteen, (23° 2' 17.2674"E, 70° 13' 18.2814"N) West Gate - I(23° 59' 40.48"E, 70° 12' 50.96"N) & Wharf Area (22° 59' 52.2"E, 70° 13' 22.95"N) at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per	Permissible Limits in the absence of Alternate
1	pH	-	7.23	7.45	7.5	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	420.0	340.0	440.0	500	2000
3	Turbidity	NTU	1	0.3	0.4	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	S/m	745.0	620.0	779.0	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	310.69	295.66	320.71	250	1000
9	Total Hardness	mg/l	414.0	430.0	460.0	75	600
10	Calcium	mg/l	56.11	72.14	52.10	30	200
11	Salinity	%	0.56	0.53	0.58	200	NS*
12	Mg as Mg	mg/l	65.61	60.75	80.19	0.3	100
13	Fluorides as F	mg/l	0.28	0.34	0.56	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	222.0	235.2	252.0	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	9.50	10.28	8.73	45	No Relaxation
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
18	Sodium as Na	mg/l	228	255	242	NS*	NS*
19	Potassium as K	mg/l	4.83	5.03	4.46	NS*	NS*
20	Manganese	mg/l	<0.04	<0.04	<0.04	0.1	0.3
21	Hexavalent Chromium	mg/l	<0.03	<0.03	<0.03	NS*	NS*
22	Copper	mg/l	<0.05	<0.05	<0.05	0.05	1.5
23	Cadmium	mg/l	<0.002	<0.002	<0.002	0.003	NS*
24	Arsenic	mg/l	<0.01	<0.01	<0.01	0.01	0.05
25	Mercury	mg/l	<0.001	<0.001	<0.001	0.001	NS*
26	Lead	mg/l	<0.01	<0.01	<0.01	0.01	NS*
27	Zinc	mg/l	<0.1	<0.1	<0.1	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Environmental Monitoring Report Of Deendayal Port Authority, APRIL-2022****Table 11: Drinking Water Quality Monitoring Parameters for Sewa sadan - 3,( 23° 0' 22.55"E, 70° 13' 15.34"N) Workshop I (23° 0' 33.74"E, 70° 13' 20.05"N)&Custom Building (23° 1' 8.70"E, 70° 12' 52.0"N) at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.55	7.53	7.41	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	400.0	460.0	370.0	500	2000
3	Turbidity	NTU	1	1	0.5	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	S/m	702.0	820.0	692.0	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	305.68	310.69	315.70	250	1000
9	Total Hardness	mg/l	450.0	420.0	470.0	200	600
10	Calcium	mg/l	56.11	64.13	72.14	75	200
11	Salinity	%	0.55	0.56	0.57	NS*	NS*
12	Mg as Mg	mg/l	75.33	63.18	70.47	30	100
13	Fluorides as F	mg/l	0.67	0.78	0.52	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	255.6	262.8	211.2	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	12.32	11.40	12.74	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	302	298	209	NS*	NS*
19	Potassium as K	mg/l	6.18	5.96	3.68	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Environmental Monitoring Report Of Deendayal Port Authority, APRIL-2022****Table 12:Drinking Water Quality Monitoring Parameters for Port Colony Kandla(23° 11' 14.9"E, 70° 12' 48.4"N) Hospital Kandla 23° 1' 5.02"E, 70° 12' 44.38"N)& A.O. Building (23° 3' 42.89"E, 70° 8' 41.5"N) at Gandhidham**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.36	7.41	7.26	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	430.0	410.0	910.0	500	2000
3	Turbidity	NTU	1	0.3	1	1	5
4	Odour	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	S/m	775.0	720.0	1546.0	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	330.74	335.75	611.36	250	1000
9	Total Hardness	mg/l	430.0	440.0	480.0	200	600
10	Calcium	mg/l	56.11	68.14	60.12	75	200
11	Salinity	%	0.60	0.61	1.10	NS*	NS*
12	Mg as Mg	mg/l	70.47	65.61	80.19	30	100
13	Fluorides as F	mg/l	0.60	0.68	0.86	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	220.0	232.6	288.2	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	11.20	12.62	11.20	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	221	246	233	NS*	NS*
19	Potassium as K	mg/l	4.15	4.70	4.98	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 13: Drinking Water Quality Monitoring Parameters for School Gopalpuri,( 23° 5' 1.03"E, 70° 7' 55.42"N) Guest House (23° 4' 43.14"E, 70° 7' 51.92"N) & E - Type Quarter(23° 4' 59.90"E, 70° 7' 56.72"N) at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.36	7.4	7.51	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	450.0	600.0	360.0	500	2000
3	Turbidity	NTU	1	1	0.4	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	S/m	775.0	1048.0	642.0	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	210.47	275.61	305.68	250	1000
9	Total Hardness	mg/l	450.0	420.0	460.0	200	600
10	Calcium	mg/l	48.10	56.11	52.10	75	200
11	Salinity	%	0.38	0.50	0.55	NS*	NS*
12	Mg as Mg	mg/l	80.19	68.04	80.19	30	100
13	Fluorides as F	mg/l	0.72	0.66	0.70	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	272.0	296.0	198.0	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	9.80	12.40	9.60	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	341	298	30	NS*	NS*
19	Potassium as K	mg/l	6.78	5.90	5.08	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Environmental Monitoring Report Of Deendayal Port Authority, APRIL-2022****Table 14:Drinking Water Quality Monitoring Parameters for F - Type Quarter, (23° 4' 38.45"E, 70° 8' 8.63"N) Hospital Gopalpuri (23° 4' 54.09"E, 70° 8' 7.5"N) & Tuna Port (23° 58' 23.06"E, 70° 5' 35.6"N)**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.61	7.45	7.33	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	440.0	420.0	640.0	500	2000
3	Turbidity	NTU	0.4	1	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	S/m	756.0	745.0	1154.0	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	310.69	325.72	340.76	250	1000
9	Total Hardness	mg/l	450.0	480.0	460.0	200	600
10	Calcium	mg/l	64.13	48.10	60.12	75	200
11	Salinity	%	0.56	0.59	0.62	NS*	NS*
12	Mg as Mg	mg/l	70.47	87.48	75.33	30	100
13	Fluorides as F	mg/l	0.60	0.82	0.88	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	232.0	210.0	266.0	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	10.22	9.60	11.56	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	258	266	248	NS*	NS*
19	Potassium as K	mg/l	5.18	5.69	4.78	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 15: Drinking Water Quality Monitoring Parameters for Vadinar Jetty(22° 25' 51.73"E, 69° 41' 36.62"N) & Port Colony (22° 30' 26.25"E, 69° 39' 45.03"N) at Vadinar**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.41	7.51	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	450	430	500	2000
3	Turbidity	NTU	0.3	1.00	1	5
4	Odor	-	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	5	15
6	Conductivity	S/m	850	800	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	290.00	210.00	250	1000
9	Total Hardness	mg/l	470	450	200	600
10	Calcium	mg/l	56.11	60.12	75	200
11	Salinity	%	0.50	0.54	NS*	NS*
12	Mg as Mg	mg/l	80.19	72.90	30	100
13	Fluorides as F	mg/l	0.72	0.86	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	27.00	28.20	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	8.66	9.82	45	100
17	Iron as Fe	mg/l	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	49.7	47.2	NS*	NS*
19	Potassium as K	mg/l	5.7	5.2	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **4.3 Results & Discussion**

The colour of all drinking water samples was Colourless unit and odour of the samples was also agreeable. All parameters are found to be within the specified limit of the Drinking water Standard.

#### **pH**

The limit of pH value for drinking water is specified as 7.23 to 7.61. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Total Dissolved Solids (TDS)**

TDS values in the studied area varied between 340 - 910 mg/l. None of the sampling points showed higher TDS values than the prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of April ranged from 620-1546 S/m.

#### **BOD**

BOD value in the studied area was found Below Quantification Limit (2.0 mg/l). IS 10500 :2012 does not show any standard values for BOD in drinking water.

#### **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. Chloride value in the studied area varied between 210.0- 611.36 mg/l and is found to be within the Permissible limit of the Drinking Water Standard.

#### **Calcium**

Calcium value in the studied area varied between 48.10 - 72.14 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. If calcium is present beyond the maximum acceptable limit, it causes incrustation of pipes.

#### **Magnesium**



Magnesium value in the studied area varied between 60.75 - 87.48 mg/l. All the locations had Magnesium within the prescribed limits of 30-100 mg/L.

### **Total Hardness**

Hardness value in the studied area varied between 414 - 480 mg/l and is found to be within the Permissible limit of the Drinking Water Standard. The prescribed limit by Indian Standards is 200-600 mg/L.

### **Iron**

Iron value in the studied area was found Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards is 0.3 mg/L. The excess amount of iron causes slight toxicity; gives stringent taste to water.

### **Fluoride**

Fluoride value in the studied area varied between 0.28 - 0.88 mg/l and hence well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphates**

Sulphate value in the studied area varied between 27.0 - 296.0 mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

Nitrite values in all the water samples were found Below Quantification Limit (0.1 mg/l). There are no specified standard values for Nitrites in Drinking water. The minimum Nitrate value in drinking water of DPA was 6.90 To 12.74 mg/l which is well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected ranged from 0.38 to 1.10 %. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected ranged from 47.2 - 341.0 mg/l and Potassium salts ranged from 3.04 to 6.78 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter at all location shows that Bacteria is not present and hence Bacterial count is in line with the permissible limit of drinking water. This shows that all the drinking water samples were safe from any bacteriological contamination.

## **4.4 Conclusions**

These results are compared with acceptable limits as prescribed in IS 10500:2012 - Drinking Water Specification. It is seen from the analysis data that during the study period the water was safe for human consumption as per analyzed parameters only at all drinking water monitoring stations.

# **Noise Quality Monitoring**

## 5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 5.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 5.2 Results

**Table 16: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	6:00 am to 10:00 PM	10:00PM to 6:00 AM
1	Marine Bhavan	58.8	55.2
2	Nirman Building 1	56.4	54.1
3	Tuna Port	55.4	52.9
4	Main Gate North	62.5	59.1
5	West Gate I	73.3	67.2
6	Canteen Area	59.0	57.5
7	Main Road	73.5	69.1
8	ATM Building	66.1	60.1
9	Wharf Area /Jetty Area	73.2	65.7
10	Port & Custom Office	59.4	45.5
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	55.4	54.5
12	Nr. Port Colony, Vadinar	56.4	54.4
13	Nr. Vadinar Jetty	57.4	53.1

### 5.3 Conclusions

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 13 locations at Deendayal Port ranged from 56.4 dB(A) to 73.5 dB(A) and it was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from 45.5 dB to 69.1 dB(A) and it was within the permissible limits of 70 dB(A) for the industrial area for the night time.

# **Soil Quality Monitoring**

## **6.0 Soil Monitoring**

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

### **6.1 Methodology**

The soil samples were collected in the month of April 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

**6.2 Results**

**Table-17: Chemical Characteristics of Soil in the Study Area for Tuna port,** (22° 58' 10.18"E, 70° 6' 3.7"N) IFFCO plant (23° 26' 8.37"E, 70° 13' 4.4"N), Khori creek, (22° 58' 10.18"E, 70° 6' 3.7"N) Nakti Creek,( 23° 2' 1.10"E, 70° 9' 33.6"N) DPA admin site,( 22° 26' 30.9"E, 69° 40' 37.03"N) DPA colony(22° 23' 57.09"E, 69° 42' 49.42"N)

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main	Sand from creek at low tide			Vadinar
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	8.03	7.96	8.36	8.60	7.82	7.96
3	Electrical Conductivity	S/m	21,900.00	12,800.00	28,020.00	24,090.0	678.0	490.0
4	Moisture	%	22.31	13.69	49.66	17.12	8.01	8.27
5	Total Organic Carbon	%	0.61	1.03	0.46	0.66	0.36	0.71
6	Alkalinity	mg/kg	18.02	28.03	30.03	18.02	20.02	28.03
7	Total Nitrogen	%	0.05	0.09	0.04	0.06	0.03	0.06
8	Chloride	mg/kg	5,636.6	5,494.8	10,812.3	4,608.5	283.6	212.7
9	Sulphate	mg/kg	780.13	837.61	2,997.73	713.45	128.52	24.2
10	Phosphorus	mg/kg	5.05	5.44	9.67	3.03	5.91	1.33
11	Potassium	mg/kg	187.31	158.40	198.77	140.88	19.47	34.54
12	Sodium	mg/kg	1,921.65	1,993.81	2,879.74	1,630.91	35.52	76.98
13	Calcium	mg/kg	232.46	212.42	1,683.36	228.46	941.88	777.55
14	Copper as Cu	mg/kg	BQL	26.80	17.50	BQL	93.40	72.40
15	Lead as Pb	mg/kg	BQL	5.80	BQL	BQL	BQL	BQL
16	Nickel as Ni	mg/kg	BQL	45.50	10.80	BQL	46.80	41.70
17	Zinc as Zn	mg/kg	BQL	67.20	21.50	BQL	58.20	59.60
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg).

### **6.3 Discussion**

The data shows that value of pH ranges from 7.82 at DPA Colony (Vadinar) to 8.60 at Natki Creek indicating that all soil samples are neutral to slight basic. Khari Creek samples showed maximum conductivity of 28020.00  $\mu\text{mhos/cm}$ , while DPA Colony (Vadinar) location showed minimum conductivity of 490. S/m. Conductivity at Vadinar Port was 678 S/m at Admin site and Vadinar Port colony respectively.

Total organic Carbon ranged from 0.46 % to 1.03 % at Deendayal Port. At Vadinar Port, organic Carbon range from 0.36 % to 0.71 %.

The concentration of Phosphorus and Potassium in the soil samples varies from 3.03 to 9.67 mg/kg and 140.88 to 198.77 mg/kg respectively at Deendayal Port. The mean concentration of Phosphorous at Vadinar site was 3.62 mg/kg and mean concentration of Potassium at Vadinar site was 27.00 mg/kg.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) are of saline nature as they are coastal soil; where as other locations are inland locations and have different chemical properties.

#### **Heavy Metals in the Soil**

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### **6.4 Conclusion**

The soils of Deendayal Port and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.



# **Sewage Treatment Quality Monitoring**

## 7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guide lines of State Pollution Control Board and other statutory bodies.

### 7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

### 7.2 Results

#### Kandla STP

**Table 18: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

Date of Sampling		06.04.22			
Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.72	7.51	6.5 - 8.5
2	Total Suspended	mg/l	126.8	90.2	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	90	30	100
5	BOD @ 27 °C	mg/l	24	8	30
Aeration Tank					
7	MLSS	mg/l	11		
8	MLVSS	%	98		

**Table 19: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	13.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.61	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	109.4	61.5	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	80	20	100
5	BOD @ 27 °C	mg/l	22	8	30
<b>Aeration Tank</b>					
7	MLSS	mg/l	14		
8	MLVSS	%	96		

**Table 20: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	20.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.65	7.41	6.5 - 8.5
2	Total Suspended Solids	mg/l	126.8	54.7	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	120	60	100
5	BOD @ 27 °C	mg/l	38	18	30
<b>Aeration Tank</b>					
7	MLSS	mg/l	10		
8	MLVSS	%	98		

**Table 21: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	27.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.46	7.23	6.5 - 8.5
2	Total Suspended Solids	mg/l	232	97.1	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	108	69	100
5	BOD @ 27 °C	mg/l	26.0	18.0	30
<b>Aeration Tank</b>					
7	MLSS	mg/l	20		
8	MLVSS	%	94.0		

**Table 22: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	06.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.65	7.41	6.5 - 8.5
2	Total Suspended Solids	mg/l	153.4	59.3	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	120	80	100
5	BOD @ 27 °C	mg/l	38	20	30
<b>Aeration Tank</b>					
7	MLSS	mg/l	39		
8	MLVSS	%	101		

**Table 23: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	13.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.56	7.23	6.5 - 8.5
2	Total Suspended Solids	mg/l	170.6	75.5	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	110	60	100
5	BOD @ 27 °C	mg/l	30	18	30
<b>Aeration Tank</b>					
7	MLSS	mg/l	40.0		
8	MLVSS	%	84.0		

**Table 24: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	20.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.53	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	131.4	68.6	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	110.0	10.0	100
5	BOD @ 27 °C	mg/l	30.0	4.0	30
<b>Aeration Tank</b>					
7	MLSS	mg/l	32.0		
8	MLVSS	%	89.0		

**Table 25: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	27.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.56	7.37	6.5 - 8.5
2	Total Suspended Solids	mg/l	135.6	88.8	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	127.0	39.0	100
5	BOD @ 27 °C	mg/l	38.0	10.0	30
<b>Aeration Tank</b>					
7	MLSS	mg/l	18.0		
8	MLVSS	%	95.0		

**Vadinar STP**

**Table 26: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	06.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.70	7.50	6.5 - 8.5
2	Total Suspended Solids	mg/l	101.8	43.0	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	80	40	100
5	BOD @ 27 °C	mg/l	18	12	30

**Table 27: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	13.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.41	7.23	6.5 - 8.5
2	Total Suspended Solids	mg/l	86.9	40.3	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	40.0	10.0	100
5	BOD @ 27 °C	mg/l	8.0	4.0	30

**Table 28: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	20.04.22
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.41	7.23	6.5 - 8.5
2	Total Suspended Solids	mg/l	86.9	40.3	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	78.0	39.0	100
5	BOD @ 27 °C	mg/l	21.0	10.0	30

**Table 29: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	27.04.22
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<b>Sr. No.</b>	<b>Parameters</b>	<b>Unit</b>	<b>Results</b>		<b>GPCB Prescribed Limit</b>
			<b>Vadinar STP I/L</b>	<b>Vadinar O/L</b>	
1	pH	-	7.71	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	101.8	43	100
3	Residual Chlorine	mg/l	<0.5	<0.5	-
4	COD	mg/l	69.0	29.0	100
5	BOD @ 27 °C	mg/l	16.0	7.0	30

### **7.3 Conclusions:**

The GPCB specification for pH ,TSS, Residual Chlorine , COD and BOD for STP outlet are 6.5 to 8.5 , 100 mg/lit, 0.5 mg/l, 100 mg/lit and 30 mg/lit respectively. All parameters for STP outlet are within limit. It is suggested to do treatment on regular basis to avoid flow of contamination / Polluent water into the sea.



# **Marine Water Quality Monitoring**

## **8.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of 'green thinking'. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A(g) states that the "fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures".

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at "integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources." The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 03<sup>rd</sup> & 04<sup>th</sup> April-2022 in harbor regions of DPA and on 03<sup>rd</sup> April-2022 at Vadinar during spring tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 10<sup>th</sup> & 11<sup>th</sup> April 2022 in harbor regions of DPA. 10<sup>th</sup> April -2022 in Vadinar during Neap tide period first quarter of Lunar Cycle..

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbour area and two stations in Nakti creek and one station in Khorī creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

### **Sampling Locations**

<b>Offshore monitoring requirement</b>	<b>Number of locations</b>
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khorī creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### **8.1 Marine Water Quality and Results**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khorī & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 30 to 37.

**Table 30: Marine Water Quality Monitoring Parameters for location near DPA colony**

Sr. No.	Parameters	Unit	Kandla Creek Near DPA colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.36	7.41	7.41	7.36
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.2	31.8	31.7	32.2
5	Turbidity	NTU	33	34	34.0	35.0
6	Total Dissolved Solids	mg/l	40732	41282	41282.0	48372.0
7	Total Suspended Solids	mg/l	680.9	872.5	872.5	766.8
8	Total Solids	mg/l	46378	45280	42200.0	50100.0
9	DO	mg/l	4.4	4.5	4.5	4.3
10	COD	mg/l	80	76	78	82
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.68	0.7	0.72	0.70
13	Phosphate	mg/l	0.24	0.2	0.20	0.24
14	Sulphate	mg/l	2600	2480	2210	2190
15	Nitrate	mg/l	2.77	2.68	3.12	2.88
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	601.2	681.36	681.36	641.28
18	Magnesium	mg/l	1725.3	1701	1628.1	1676.7
19	Sodium	mg/l	9436	9150	9231.0	9118.0
20	Potassium	mg/l	367.8	327	340.0	336.9
21	Iron	mg/l	0.81	0.31	0.89	2.00
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 31: Marine Water Quality Monitoring Parameters for location near passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.26	7.30	7.31	7.42
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32	31.9	31.8	31.1
5	Turbidity	NTU	35	37	37.0	38.0
6	Total Dissolved Solids	mg/l	48372	40680	40680.0	34170.0
7	Total Suspended Solids	mg/l	766.8	751.9	751.9	659.5
8	Total Solids	mg/l	49660	42940	42300.0	35120.0
9	DO	mg/l	4.3	4.4	4.4	4.2
10	COD	mg/l	78	74	72.0	70.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.74	0.72	0.77	0.74
13	Phosphate	mg/l	0.20	0.22	0.30	0.28
14	Sulphate	mg/l	2555	2620	2410	2488
15	Nitrate	mg/l	2.89	2.9	3.07	3.42
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	641.28	561.12	561.12	601.2
18	Magnesium	mg/l	1676.7	1749.6	1773.9	1652.4
19	Sodium	mg/l	9638	9149	9524.0	9198.0
20	Potassium	mg/l	389.6	315.6	371.8	349.8
21	Iron	mg/l	0.69	0.45	1.58	2.19
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Nitrite: 0.05mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 32: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.40	7.50	7.51	7.46
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.2	31.8	32.0	31.9
5	Turbidity	NTU	38	39	39.0	32.0
6	Total Dissolved Solids	mg/l	34170	51520	51520.0	37282.0
7	Total Suspended Solids	mg/l	659.5	811.7	811.7	711.6
8	Total Solids	mg/l	35020	52960	52400.0	38180.0
9	DO	mg/l	4.2	4.3	4.3	4.6
10	COD	mg/l	82	80	72.0	74.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.76	0.78	0.80	0.78
13	Phosphate	mg/l	0.32	0.30	0.18	0.20
14	Sulphate	mg/l	2700	2560	2160	2210
15	Nitrate	mg/l	3.01	2.98	3.96	4.00
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	521.04	601.2	521.04	601.2
18	Magnesium	mg/l	1798.2	1628.1	1725.3	1628.1
19	Sodium	mg/l	9076	8992	9248.0	9639.0
20	Potassium	mg/l	303.7	294.8	343.4	375.9
21	Iron	mg/l	0.13	1.66	0.31	1.77
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 33: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	DPA 4			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.35	7.41	7.38	7.36
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32	31.6	32.0	31.8
5	Turbidity	NTU	32	34	34.0	39.0
6	Total Dissolved Solids	mg/l	37282	43942	43942.0	36930.0
7	Total Suspended Solids	mg/l	711.6	816.9	816.9	763.6
8	Total Solids	mg/l	38520	54440	44850.0	37720.0
9	DO	mg/l	4.6	4.5	4.5	4.3
10	COD	mg/l	86	88	86.0	88.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.60	0.62	0.88	0.82
13	Phosphate	mg/l	0.19	0.18	0.26	0.28
14	Sulphate	mg/l	2700	2680	2744	2690
15	Nitrate	mg/l	2.66	2.72	3.92	4.20
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	641.28	681.36	561.12	681.36
18	Magnesium	mg/l	1676.7	1628.1	1773.9	1725.3
19	Sodium	mg/l	9130	8875	9710.0	9904.0
20	Potassium	mg/l	314	284	383.4	394.1
21	Iron	mg/l	0.17	1.17	2.82	0.65
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	0.25

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 34: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.51	7.45	7.28	7.31
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.7	31.8	31.0	32.2
5	Turbidity	NTU	39	40	40.0	41.0
6	Total Dissolved Solids	mg/l	36930	37440	37440.0	41330.0
7	Total Suspended Solids	mg/l	763.6	843.8	843.8	795.2
8	Total Solids	mg/l	37900	39540	38320.0	42200.0
9	DO	mg/l	4.3	4.4	4.4	4.7
10	COD	mg/l	90	92	92.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.80	0.82	0.92	0.90
13	Phosphate	mg/l	0.41	0.40	0.19	0.16
14	Sulphate	mg/l	2860	2900	2780	2710
15	Nitrate	mg/l	3.46	3.56	5.26	4.98
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	601.2	561.12	721.44	681.36
18	Magnesium	mg/l	1749.6	1749.6	1628.1	1628.1
19	Sodium	mg/l	10280	10418	9805.0	9669.0
20	Potassium	mg/l	392.3	404.1	393.8	380.3
21	Iron	mg/l	1.1	1.52	1.20	1.34
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).



**Table 35: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.45	Sampling not possible during Low Tide	31.0	Sampling not possible during Low Tide
2	Color	-	Colorless		Colorless	
3	Odor	-	Odorless		Odorless	
4	Salinity	ppt	31.4		18.1	
5	Turbidity	NTU	41		40	
6	Total Dissolved Solids	mg/l	41330		21035	
7	Total Suspended Solids	mg/l	795.2		678.5	
8	Total Solids	mg/l	42240		21812	
9	DO	mg/l	4.7		4.5	
10	COD	mg/l	94		96	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	0.84		0.85	
13	Phosphate	mg/l	0.43		0.21	
14	Sulphate	mg/l	2820		2376	
15	Nitrate	mg/l	4.01		4.65	
16	Nitrite	mg/l	BQL		BQL	
17	Calcium	mg/l	641.28		641.28	
18	Magnesium	mg/l	1676.7		1725.3	
19	Sodium	mg/l	10446		9631	
20	Potassium	mg/l	405.7		375.6	
21	Iron	mg/l	1.39		1.07	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		BQL	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		0.02	

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 36: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr. Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.41	7.36	7.38	7.41
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	31.5	31.8	31.8	32.0
5	Turbidity	NTU	37	36	36.0	34.0
6	Total Dissolved Solids	mg/l	35495	41380	41380.0	34860.0
7	Total Suspended Solids	mg/l	725.9	666.8	666.8	689.7
8	Total Solids	mg/l	36340	43060	42120.0	36620.0
9	DO	mg/l	4.5	4.6	4.6	4.4
10	COD	mg/l	80	82	80.0	82.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.86	0.88	0.72	0.76
13	Phosphate	mg/l	0.32	0.30	0.18	0.20
14	Sulphate	mg/l	2610	2580	2468	2392
15	Nitrate	mg/l	4.88	4.92	3.52	2.98
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	681.36	601.2	561.12	601.2
18	Magnesium	mg/l	1603.8	1628.1	1701	1701
19	Sodium	mg/l	10551	10739	10346.0	10450.0
20	Potassium	mg/l	418	422.4	430.5	420.3
21	Iron	mg/l	0.56	0.79	0.56	0.79
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 37: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr.Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.28	7.25	7.44	7.4
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	ppt	32	32.1	32.2	32.4
5	Turbidity	NTU	34	35	42	43
6	Total Dissolved Solids	mg/l	34860	37750	34920	35216
7	Total Suspended Solids	mg/l	689.7	641.6	688	692
8	Total Solids	721.44	37940	38440	36210.0	36426
9	DO	mg/l	4.4	4.3	4.8	4.5
10	COD	mg/l	88	90	80.0	84
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.9	0.92	0.74	0.79
13	Phosphate	mg/l	0.32	0.28	0.30	0.32
14	Sulphate	mg/l	2789	2492	2770	2710
15	Nitrate	mg/l	5.96	6.22	4.93	5.01
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	561.12	521.04	641.28	681.36
18	Magnesium	mg/l	1628.1	1725.3	1676.7	1628.1
19	Sodium	mg/l	10682	10708	10538.0	10678
20	Potassium	mg/l	409.8	421.4	434.9	438.6
21	Iron	mg/l	0.7	0.83	0.7	0.83
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

## **8.2 Results & Discussion for Marine water samples**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters

during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit .

### **pH**

The limit of pH value for drinking water is specified as 7.25 to 7.51.

### **Total Dissolved Solids (TDS)**

TDS values in the studied area varied between 34170 to 51520 mg/l.

### **Calcium**

Calcium value in the studied area varied between 521.04 to 721.44 mg/l.

### **Magnesium**

Magnesium value in the studied area varied between 1603.80 to 1798.20 mg/l.

### **Iron**

Iron value in the studied area was found 0.13 to 2.82 mg/l).

### **Sulphates**

Sulphate value in the studied area varied between 2160.0 – 2900.0 mg/l.

### **Salinity**

Salinity in marine water in the present samples collected ranged from 31.0 to 32.4 %.

### **Sodium and Potassium Salts**

Sodium values in the samples collected ranged from 8875.0 to 10739.0 mg/l and Potassium salts ranged from 284.0 to 438.6 mg/l.

### **Heavy Metals in Drinking Water**

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

# **Marine Sediment Quality Monitoring**

## **9.0 Marine Sediments**

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

### **9.1 Results**

The Sediment Quality results are given in below from table no. 38 & 39.

**Table 38: Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	DPA - 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	1.31	4.26	1.43	0.72	0.57	5.48	2.86
3	Organic Carbon	mg/kg	0.76	2.47	0.83	0.42	0.33	3.18	1.66
4	Inorganic Phosphate	mg/kg	110.00	112.00	122.00	132.00	144.00	142.00	156.00
5	Moisture	%	11.02	33.21	7.35	4.73	8.85	28.89	29.69
6	Aluminium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
7	Silica	mg/kg	30.20	24.20	32.00	28.00	34.20	49.20	48.88
8	Phosphate	mg/kg	2.58	BQL	1.41	3.29	3.83	1.04	2.72
9	Sulphate	mg/kg	282.56	867.09	198.77	190.91	194.90	938.80	570.04
10	Nitrite	mg/kg	0.11	0.12	0.10	0.11	0.13	0.11	0.12
11	Nitrate	mg/kg	11.10	12.22	10.22	11.62	14.20	11.85	13.02
12	Calcium	mg/kg	164.33	236.41	220.44	172.34	112.22	244.49	252.50
13	Magnesium	mg/kg	51.03	116.64	34.02	51.03	48.60	182.25	128.79
14	Sodium	mg/kg	640.40	1315.14	385.49	405.60	405.65	1145.33	1194.03
15	Potassium	mg/kg	43.96	136.25	23.69	27.58	26.82	217.63	162.70
16	Chromium	mg/kg	18.10	48.70	8.00	5.00	8.00	44.90	13.50
17	Nickel	mg/kg	10.00	38.30	BQL	BQL	5.60	28.90	5.70
18	Copper	mg/kg	7.20	14.20	BQL	BQL	BQL	14.00	B
19	Zinc	mg/kg	16.90	59.30	BQL	BQL	25.70	38.40	5.70
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	5.20	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).



**Table 39 : Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	DPA - 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	2.33	5.14	2.00	1.38	1.67	8.57	14.15
3	Organic Carbon	mg/kg	1.35	2.98	1.16	0.80	0.97	4.97	8.21
4	Inorganic Phosphate	mg/kg	112.00	109.00	115.00	130.00	136.00	152.00	157.00
5	Moisture	%	9.22	24.86	11.12	7.93	17.60	28.11	36.89
6	Aluminium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
7	Silica	mg/kg	28.88	22.60	30.00	24.00	30.20	52.60	56.20
8	Phosphate	mg/kg	3.90	1.38	1.16	1.23	BQL	BQL	0.93
9	Sulphate	mg/kg	241.00	433.27	296.55	402.90	285.38	864.14	1077.88
10	Nitrite	mg/kg	0.11	0.12	0.11	0.10	0.12	0.12	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	13.32	14.20
12	Calcium	mg/kg	180.36	200.40	176.35	192.38	160.32	260.52	212.42
13	Magnesium	mg/kg	60.75	75.33	63.18	53.46	94.77	114.21	167.67
14	Sodium	mg/kg	360.43	474.10	379.45	408.00	326.90	816.95	1335.31
15	Potassium	mg/kg	21.87	85.61	32.25	25.83	35.97	144.95	195.05
16	Chromium	mg/kg	42.90	40.70	8.60	67.30	14.80	53.00	59.50
17	Nickel	mg/kg	33.00	31.80	5.20	47.10	8.70	39.70	44.30
18	Copper	mg/kg	21.90	12.20	BQL	28.60	BQL	32.10	27.00
19	Zinc	mg/kg	53.80	47.60	14.30	67.60	14.60	70.30	62.50
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	5.30	BQL	BQL	5.40	BQL	31.10	5.50
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg,Cd: 1.0mg/kg,Hg: 1.0mg/kg, As: 1.0mg/kg)

## **9.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

The soil types is majority Sandy loamy. Also many of the parameters found below Quantification limit wise NO<sub>3</sub>, Cd, Hg, AS etc.

# **ECOLOGICAL MONITORING OF MARINE ENVIRONMENT**

**10.1 INTRODUCTION:****Sampling Stations:**

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 03<sup>rd</sup> April 2022 in harbour region of DPA at Kandla Creek, and on 04<sup>th</sup> April 2022 in creeks near by the port during spring tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 25<sup>th</sup> April, 2022 in harbour region of DPA at Kandla Creek and on 26<sup>th</sup> April, 2022 in creeks near by the port during neap tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period. The same sampling schedule was repeated during consecutive Neap tide and spring tide in same month.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during spring tide on 03/03/2022 and Neap tide period on 10/03/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin - a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

**TABLE #1 SAMPLING LOCATIONS**

<b>monitoring requirement</b>	<b>Number of locations</b>
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar
SPM	Jetty 1 near 1 <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

**Sampling methodology adopted:**

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water

sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample were taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with nilyobolt cloth of 20µm mesh size.

#### **Samples Processing for chlorophyll estimation:**

Samples for the chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 1998).

#### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is general term for organisms have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplankton is free floating organisms that are capable of photosynthesis and zooplankton is the various free floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, **plankton** and **nekton** (Lalli and Parsons, 1997). **Plankton** consists of all organisms drifting in the water and is unable to swim against water currents, whereas **Nekton** includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

#### **Phytoplankton in the marine environment:**

Phytoplankton is free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio purifier and bio indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; diatoms and dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction

rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of biological pump in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives

such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

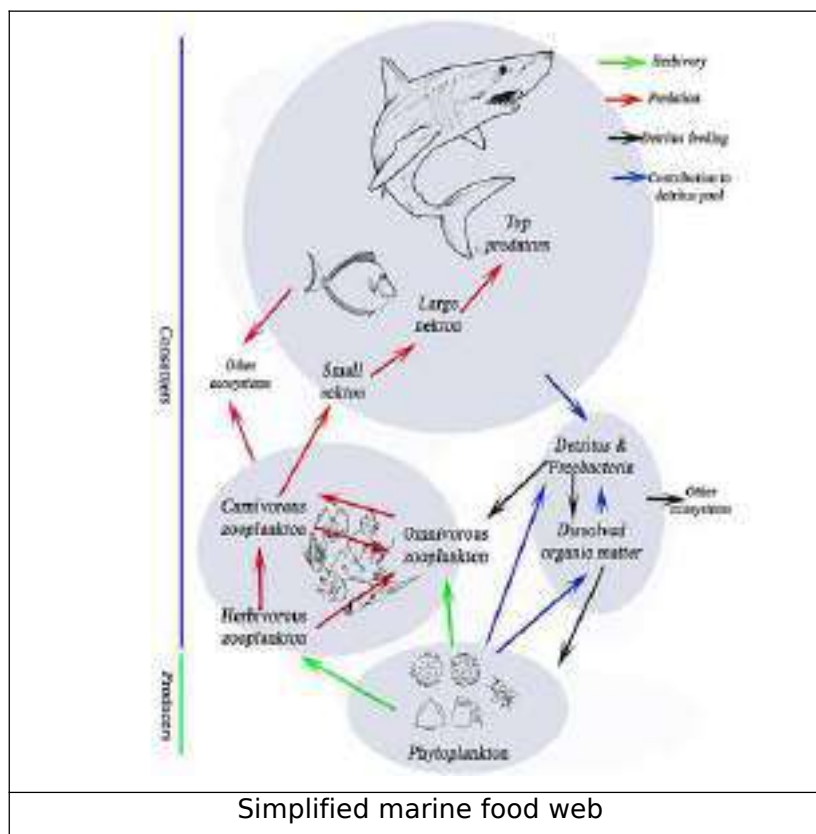
Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplankton is efficient grazers of the phytoplankton and is referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the



physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### **Spatial distribution of Plankton:**

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilometers in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist. Plankton may also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

**Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight. After the tow of about 15-30minutes, plankton net was pulled up and washed down to the tail and collected the plankton adhered to plankton net in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward. For quantitative evaluation 50 L water samples were collected from subsurface layer and filtered through 20µm mesh size net by using bucket and filtration assembly.

**Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

**Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

**Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a sub sample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of zooplankton that were encountered

**Cell counts by drop count method:**

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22 x 60mm was placed under the compound microscope provided with a mechanical

stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total number of plankton in the original volume of sample filtered was calculated as units/L.

### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment-water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42 $\mu$  in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes.

### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

**Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

**DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A.E. (1988).

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species within a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H.R. *etal.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. The diversity measures that incorporate the two concepts may be termed heterogeneity measures (Magurran, 2004).

Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate species richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is

the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness (*S*) and evenness (*J*)

### **Simpson's diversity index**

Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Low species diversity suggests:

Relatively few successful species in the habitat

The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment

Food webs which are relatively simple

Change in the environment would probably have quite serious effects

High species diversity suggests:

A greater number of successful species and a more stable ecosystem

More ecological niches are available and the environment is less likely to be hostile complex food webs

Environmental change is less likely to be damaging to the ecosystem as a whole

### **Species richness indices**

The species richness (**S**) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness may be concomitant with severe or chronic human-induced perturbation (Fair weather 1990,) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness (**S**) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximized when all types are equally abundant (Rosenzweig, M. L. (1995).

### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index (**H**), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index (**H**) reproduces community parameters to a single number by using an equation.

$$H' = - \sum_{j=1}^s \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

## **10.2 RESULTS:**

### **CHLOROPHYLL-a:**

Water Samples for the chlorophyll estimation were collected from sub surface layer during high tide and low tide period of the tidal cycle for each sampling locations and analysed for Chlorophyll -a and after acidification for Pheophytin -a. Chlorophyll- a value was used as algal biomass indicator (APHA,1998) Algal biomass was estimated by converting Chlorophyll value.

In the sub surface water chlorophyll-a was varying from 0.409- 0.865 mg/m<sup>3</sup> with an average value 0.594 mg/m<sup>3</sup> of in harbour region of DPA in Kandla Creek during sampling done in spring tide period of April 2022. In the nearby creeks chlorophyll-a was varying from 0.322- 1.103mg/m<sup>3</sup>.with an average value 0.740 mg/m<sup>3</sup>.Pheophytin -a level was below detectable limit- the all the sampling stations during springtide.

In the sub surface water chlorophyll-a was varying from 0.307 -0.882mg/m<sup>3</sup>with an average value 0.639 mg/m<sup>3</sup>.in harbour region of DPA in Kandla Creek during sampling done in neap tide period of April 2022. In the nearby creeks chlorophyll-a was varying from 0.271 0.574 mg/m<sup>3</sup> with an average value 0.461 mg/m<sup>3</sup>.Pheophytin -a level was below detectable limit- the all the sampling stations.

In the sub surface water chlorophyll-a was varying from 0.731 - 0.835 mg/m<sup>3</sup>with an average value 0.761 mg/m<sup>3</sup>.in harbour region of DPA OOT in path finder Creek during sampling done in spring tide period of April 2022. In the sub surface water chlorophyll-a was varying from 0.630- 1.039 mg/m<sup>3</sup> with an average value 0.809 mg/m<sup>3</sup>.in harbour region of DPA OOT in path finder Creek during sampling done in Neap Tide period of April 2022.5.23

**TABLE 40 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINARDURING SPRING TIDE IN APRIL 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	DPA1 - Oil Jetty	High tide	0.645	BDL	43.21
		Low tide	0.409	BDL	27.40
2	DPA 2 - Passenger Jetty	High tide	0.865	BDL	57.95
		Low tide	0.544	BDL	36.45
3	DPA 3 - Coal Berth	High tide	0.542	BDL	36.31
		Low tide	0.558	BDL	37.39
CREEKS					
4	DPA-4 Khor-I	High tide	0.662	BDL	44.35
		Low tide	0.630	BDL	42.21
5	DPA-5 Nakti-I	High tide	1.103	BDL	73.90
		Low tide	0.985	BDL	65.99
6	DPA-6 Nakti-II	High tide	0.322	BDL	21.57
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.731	BDL	48.97
8		Low tide	0.732	BDL	49.04
9	SPM	High tide	0.835	BDL	55.94
10	SPM	Low tide	0.748	BDL	50.11

BDL: Below Detectable Limit.



**TABLE 41 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA ,NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN APRIL 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	DPA1 - Oil Jetty	High tide	0.882	BDL	59.09
		Low tide	0.307	BDL	20.57
2	DPA 2 - Passenger Jetty	High tide	0.678	BDL	45.42
		Low tide	0.543	BDL	36.38
3	DPA 3 - Coal Berth	High tide	0.559	BDL	37.45
		Low tide	0.866	BDL	58.02
CREEKS					
4	DPA-4 Khor-I	High tide	0.560	BDL	37.52
		Low tide	0.441	BDL	29.54
5	DPA-5 Nakti-I	High tide	0.458	BDL	30.69
		Low tide	0.272	BDL	18.22
6	DPA-6 Nakti-II	High tide	0.575	BDL	38.53
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	1.039	BDL	69.61
8		Low tide	0.733	BDL	49.11
9	SPM	High tide	0.630	BDL	42.21
10	SPM	Low tide	0.834	BDL	55.88

BDL: Below Detectable Limit.

#### **PHYTOPLANKTON POPULATION:**

For the evaluation of the Phytoplankton population in DPA harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms blue green algae and dinoflagellates during spring tide period. Diatoms were represented by 24 genera. Blue green were represented by 2 genera and dinoflagellates were represented by 3 genera during the sampling conducted in spring tide in April, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 82-225 units/ L during high tide period and 167-182 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and Dinoflagellates

during Neap tide period. Diatoms were represented by 23 genera, Blue green algae were represented 3 genera and dinoflagellates with 4 genera during the sampling conducted in Neap tide in April, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 59-240 units/ L during high tide period and 114-199units/ L during low tide of Neap Tide.

For the evaluation of the Phytoplankton population in DPA OOT jetty area in Path Finder creek sampling was conducted from two sampling locations ;jetty area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 27 genera, Blue Green algae by 5 genera and Dinoflagellates 5 genera each during the sampling conducted in spring tide in April, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area was varying from 434 units/ L during high tide period and 437 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the *SPM area* was varying from 414units/ L during high tide period and 410 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 21 genera and Blue green algae 6 genera and dinoflagellates by 5 genera each during the sampling conducted in Neap tide in April, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 197- units/ L during high tide period and 130 units/ L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 139 units/ L during high tide period and 157 units/ L during low tide of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness)S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 4.312-

4.931 with an average of 4.684 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness)  $S$  of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.498- 4.652 with an average of 4.034 during the consecutive low tide period.

Margalef's diversity index (Species Richness)  $S$  of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 3.105- 4.744 with an average of 3.919 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness)  $S$  of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.834- 4.434 with an average of 3.371 during consecutive low tide.

Margalef's diversity index (Species Richness)  $S$  of phytoplankton communities in the stations was 5.599 at OOT jetty area and 4.979 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness)  $S$  of phytoplankton communities in the path finder creek near OOT jetty was 4.605 and 4.654 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness)  $S$  of phytoplankton communities in the stations was 4.732 at OOT jetty area and 4.053 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness)  $S$  of phytoplankton communities in the path finder creek near OOT jetty was 2.671 and SPM area was 4.747 during the consecutive low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index ( $H$ ) of phytoplankton communities in the sampling stations was in the range of 0.934- 1.231 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.016 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index ( $H$ ) of phytoplankton communities in the sampling stations was in the range of 0.663-1.019 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.891 during consecutive low tide at Kandla creek and nearby creeks. Shannon-Wiener's Index ( $H$ ) of phytoplankton communities in the sampling stations was in the range of 0.891- 1.01 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.947 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index ( $H$ ) of phytoplankton communities in the sampling stations was in the range of 0.755- 1.027 ( $H'(\log_{10})$ ) between selected sampling

stations with an average value of 0.883 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.062 at OOT jetty area and 1.08 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.893 and 1.022 at SPM during the consecutive low tide period.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.990 at OOT jetty area and 0.995 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.768 and at SPM area was 1.064 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.782- 0.946 between selected sampling stations with an average of 0.824 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.682- 0.823 between selected sampling stations with an average of 0.760 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during neap tide also, which was varying from 0.811- 0.874 with an average value of 0.832 between selected

sampling stations during high tide period and 0.753- 0.8601 varying from with an average value of 0.803 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.843 at OOT jetty area and 0.874 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.796 and 0.853 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.831 at OOT jetty area and 0.851 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.756 and at SPM area was 0.867 during the consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat. The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment. Any change in the environment would probably have quite serious effects.

**Table 42 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT  
KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN APRIL  
2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	195	27/29	93.10	4.931	0.971	0.7877
	2	211	27/29	93.10	4.858	0.9547	0.7818
	3	153	24/29	82.76	4.572	0.9335	0.7897
	4	180	26/29	89.66	4.814	1.025	0.8241
	5	225	26/29	89.66	4.616	0.9789	0.8143
	6	82	20/29	68.97	4.312	1.231	0.9455
LOW TIDE	1	167	22/29	75.86	4.103	0.8892	0.7507
	2	174	25/29	86.21	4.652	1.019	0.8229
	3	174	24/29	82.76	4.458	0.9703	0.7921
	4	174	24/29	82.76	4.458	0.9141	0.7508
	5	182	14/29	48.28	2.498	0.6632	0.6824

**Table 43 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY  
IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT  
KANDLA CREEK AND ,NEAR BY CREEKS DURING NEAP TIDE IN APRIL  
2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	240	27/30	90.00	4.744	0.9912	0.8236
	2	198	22/30	73.33	3.971	0.891	0.8105
	3	197	22/30	73.33	3.975	0.966	0.8304
	4	170	23/30	76.67	4.284	0.9299	0.8248
	5	173	17/30	56.67	3.105	0.8937	0.8297
	6	59	15/30	50.00	3.433	1.01	0.8738
LOW TIDE	1	114	22/30	73.33	4.434	1.027	0.8601
	2	170	19/30	63.33	3.505	0.8775	0.7967
	3	199	16/30	53.33	2.834	0.835	0.7672
	4	151	17/30	56.67	3.189	0.9182	0.8358
	5	179	16/30	53.33	2.892	0.755	0.753

**Table 44 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND , NEAR BY CREEKS DURING SPRING TIDE IN APRIL 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	79-214	24/29	82.76
			BLUE GREEN	2-6	2/29	6.90
			DINOFLAGELLATES	0-12	3/29	10.34
			TOTAL PHYTO PLANKTON	82-225	29	-
LOW TIDE	Sub surface	5	DIATOMS	157-181	24/29	82.76
			BLUE GREEN	1-6	2/29	6.90
			DINOFLAGELLATES	0-8	3/29	10.34
			TOTAL PHYTO PLANKTON	167-182	29	-

**Table 45 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND , NEAR BY CREEKS DURING NEAP TIDE IN APRIL 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	49-217	23/30	76.67
			BLUE GREEN	7-15	3/30	10.00
			DINOFLAGELLATES	1-8	4/30	13.33
			TOTAL PHYTO PLANKTON	59-240	30	-
LOW TIDE	Sub surface	5	DIATOMS	102-187	23/30	76.67
			BLUE GREEN	4-11	3/30	10.00
			DINOFLAGELLATES	2-7	4/30	13.33
			TOTAL PHYTO PLANKTON	114-199	30	-



**Table 46 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN APRIL 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	JETTY	434	35/37	94.59	5.599	1.062	0.8433
	SPM	414	31/37	83.78	4.979	1.08	0.8743
LOW TIDE	JETTY	437	29/37	78.38	4.605	0.8933	0.7963
	SPM	410	29/37	78.38	4.654	1.022	0.8526

**Table 47 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN APRIL 2022**

Tide	Samplin g Station	Abundanc e In units/L	No of Species observe d /total species	% of diversity	Margalef' s diversity index (Species Richness S)	Shanno n Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson' s Index) 1-D
HIGH TIDE	JETTY	197	26/32	81.25	4.732	0.9898	0.8318
	SPM	139	21/32	65.63	4.053	0.995	0.8507
LOW TIDE	JETTY	130	14/32	43.75	2.671	0.7682	0.7515
	SPM	157	25/32	78.13	4.747	1.064	0.8672

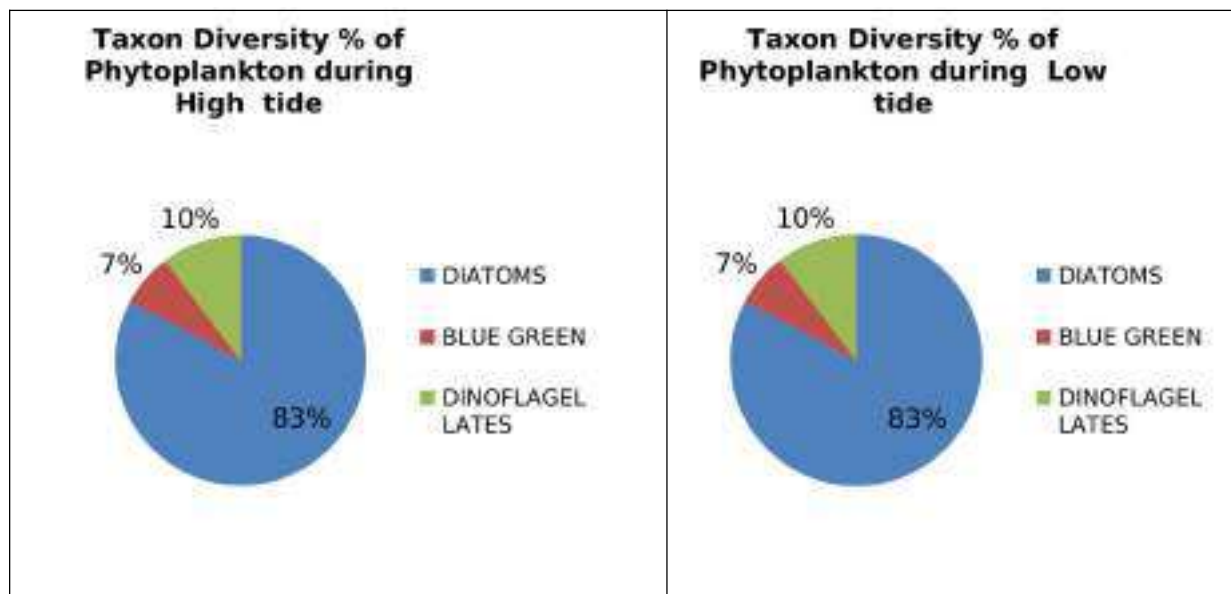
**Table 48 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPADPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN APRIL 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN	18-22	5/37	13.51
			DIATOMS	384-401	27/37	72.98
			DINOFLAGELLATES	11-12	5/37	13.51
			TOTAL PHYTO PLANKTON	414-434	37	
LOW TIDE	Sub surface	2	BLUE GREEN	12-15	5/37	13.51
			DIATOMS	385-419	27/37	72.98
			DINOFLAGELLATES	3-13	5/37	13.51
			TOTAL PHYTO PLANKTON	410-437	37	

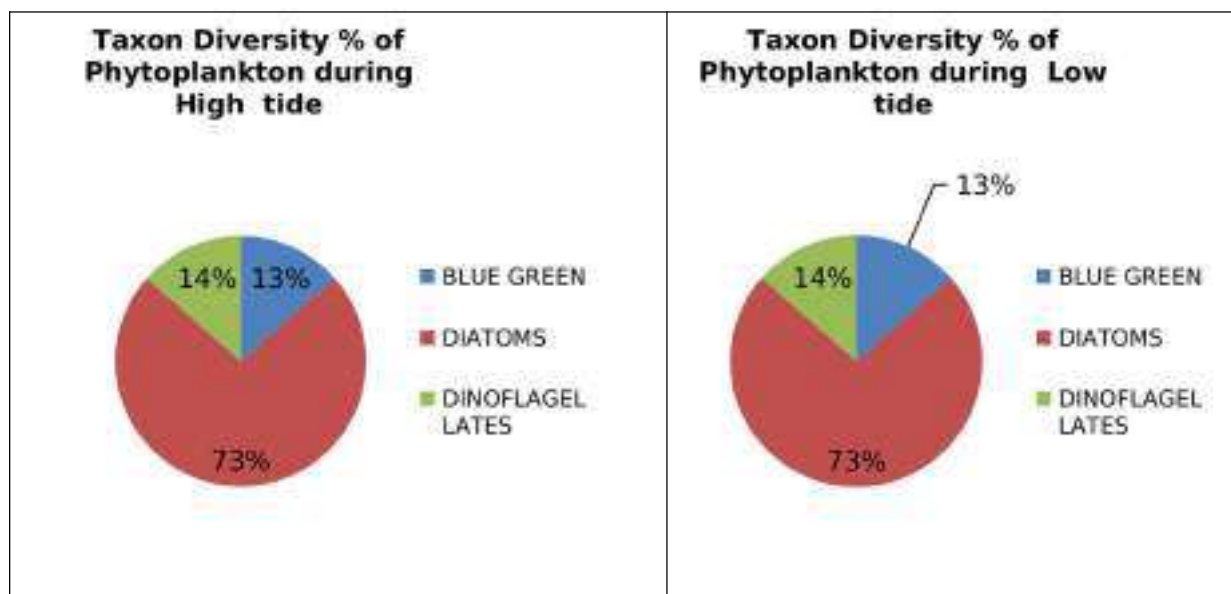
**Table 49 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPADPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN APRIL 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN	9-10	6/32	18.75
			DIATOMS	119-182	21/32	65.62
			DINOFLAGELLATES	5-11	5/32	15.63
			TOTAL PHYTO PLANKTON	139-197	32	-
LOW TIDE	Sub surface	2	BLUE GREEN	5-8	6/32	18.75
			DIATOMS	120-137	21/32	65.62
			DINOFLAGELLATES	5-12	5/32	15.63
			TOTAL PHYTO PLANKTON	130-157	32	-

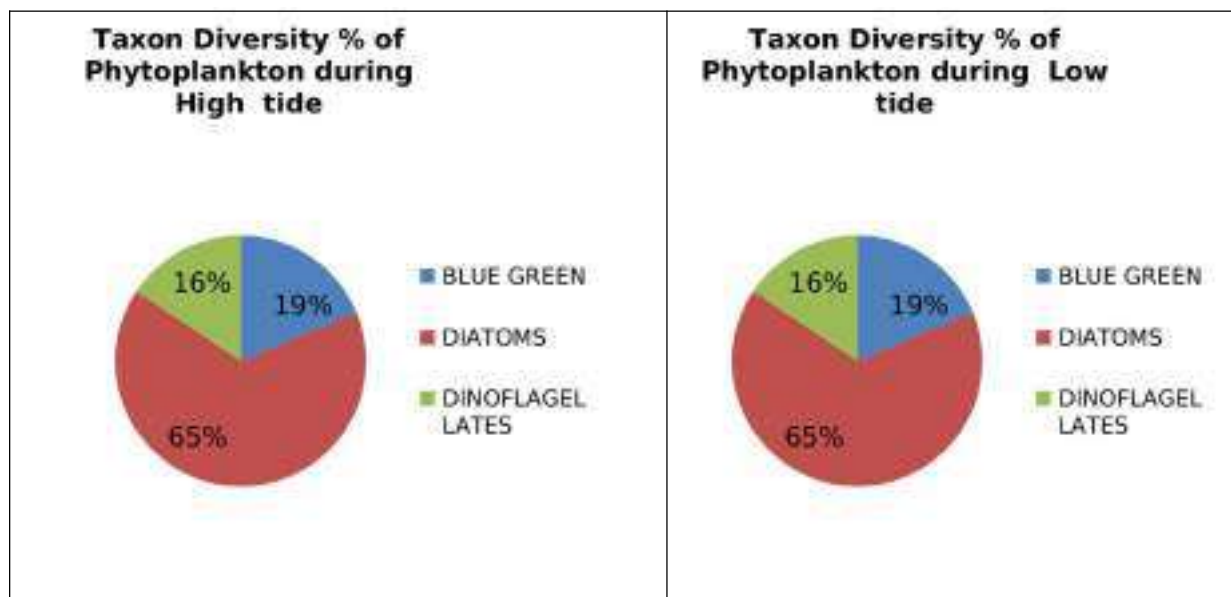
**TAXON DIVERSITY % OF PHYTOPLANKTON DURING HIGH TIDE AND LOW TIDE PERIOD DURING SPRING TIDE IN KANDALA CREEK AND NEARBY CREEKS**



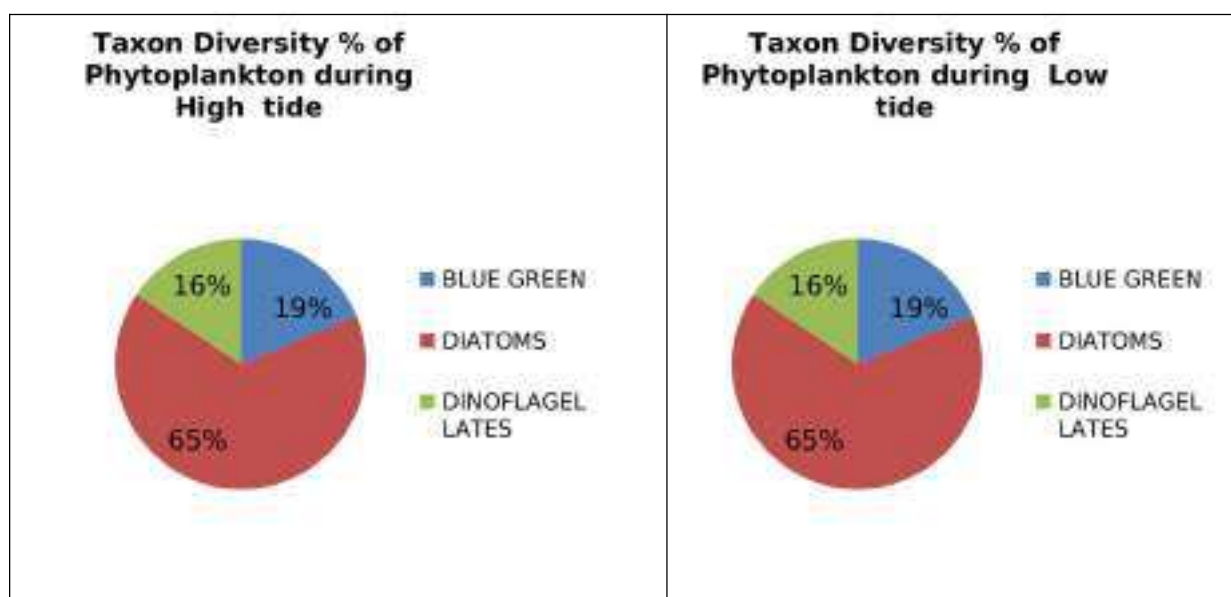
**TAXON DIVERSITY % OF PHYTOPLANKTON DURING HIGH TIDE AND LOW TIDE PERIOD DURING NEAP TIDE IN KANDALA CREEK AND NEARBY CREEKS**



**TAXON DIVERSITY % OF PHYTOPLANKTON DURING HIGH TIDE AND LOW TIDE PERIOD DURING SPRING TIDE IN PATH FINDER CREEK, VADINAR**



**TAXON DIVERSITY % OF PHYTOPLANKTON DURING HIGH TIDE AND LOW TIDE PERIOD DURING NEAP TIDE IN PATH FINDER CREEK, VADINAR**



### **ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPA harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khorī creek) during high tide period and low tide period of spring tide and Neap tide in April, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly 8 groups, and 8 larval forms; Tintinids, Copepods, Arrow worms, Medusa, Mysids Urochordata, Foraminiferans , and 8 larval forms; The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly 9 groups, Tintinids, Copepods, Arrow worms ,Mysids, Urochordata, Ciliates, Medusa and , Foraminiferans and 9 larval forms

Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $70-198 \times 10^3$  N/  $m^3$  during high tide and  $119-167 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $53-184 \times 10^3$  N/  $m^3$  during high tide and  $80-106 \times 10^3$  N/  $m^3$  during low tide of Neap Tide period.

For the evaluation of the Zoo plankton population in DPA OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM) During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly Tintinids , Copepods, Medusa, Urochordata , Foraminiferans and 9 larval forms. The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly Eight groups, Tintinids , Copepods, Arrow worms, Urochordata, Ciliates, Medusa , Foraminiferans and 8 larval forms, Zooplankton of the sampling stations at sub surface layer in the DPA OOT Jetty area of path finder creek was  $158 \times 10^3$  N/  $m^3$  during high tide and  $84 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA SPM area of path finder creek was  $113 \times 10^3$  N/  $m^3$  during high tide and  $107 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT jetty area in path finder creek was recorded  $110 \times 10^3$  N/  $m^3$  during high tide and  $74 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap. Zooplankton of the sampling stations at sub surface layer in the DPA SPM area in path finder creek was recorded  $83 \times 10^3$  N/  $m^3$  during high tide and  $95 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap Tide .

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the stations Kandla creek region and nearby creeks was varying from 4.991- 6.051 with an average of 5.578 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities varying from 3.935- 5.471 with an average of 4.881 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations was varying from 3.105- 4.744 with an average of 3.919 during the sampling conducted in high tide and varying from 2.834- 4.434 with an average of 3.371 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 6.321 and 5.642 respectively. Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 5.5 and 4.066 respectively.

Margalef's diversity index (Species Richness) S of Zooplankton communities near Jetty at Path finder creek was varying from 4.68- 3.253 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) S of Zooplankton

communities near SPM at Path finder creek was varying from 3.168-4.831 respectively during the consecutive High tide and low tide period.

**Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.995 - 1.203 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.133 ( $H'(\log_{10})$ ) during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.962 -1.214( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.129( $H'(\log_{10})$ ) during consecutive low tide period .

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 1.09 - 1.214( $H'(\log_{10})$ ) between selected sampling stations with an average value of 1.160( $H'(\log_{10})$ ) during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 0.916- 1.194of ( $H'(\log_{10})$ ) between selected sampling stations with an average value of1.087( $H'(\log_{10})$ ) during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.121-1.171 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling *station near SPM* at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.12-0.959 respectively

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.954-0.870 during the sampling conducted consecutive High tide period and Low tide period of Neap tide. -While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 0.758- 0.979 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks



stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

**Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.780-0.892 between selected sampling stations with an average of 0.853 during high tide period and was varying from 0.817- 0.910 with an average value of 0.879 between selected sampling stations during low tide

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of neap tide except few, which was varying from 0.872-0.930 between selected sampling stations with an average of 0.898 during high tide period and was varying from 0.832-0.923 with an average value of 0.887 between selected sampling stations during consecutive low tide. This species diversity suggests a relatively few successful species in this habitat during April 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.8221 and 0.8818 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.8733 and 0.8337 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.7728-0.806 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.7032 and 0.8275 respectively.



**Table 50 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN APRIL 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group p	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	198	33/34	97.06	6.051	1.175	0.865
	2	140	29/34	85.29	5.666	1.182	0.8756
	3	181	31/34	91.18	5.771	1.203	0.8921
	4	147	28/34	82.35	5.41	1.111	0.8534
	5	183	27/34	79.41	4.991	0.9953	0.7799
	6	70	20/34	58.82	4.472	1.174	0.9217
LOW TIDE	1	119	23/34	67.65	4.603	1.13	0.8802
	2	167	29/34	85.29	5.471	1.189	0.8965
	3	125	26/34	76.47	5.178	1.214	0.9095
	4	146	27/34	79.41	5.217	1.15	0.8891
	5	125	20/34	58.82	3.935	0.9621	0.8174

**Table 51 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN APRIL 2022**

Tide	Sampling Station	Abundance In No $\times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	184	32/37	86.47	5.944	1.193	0.8923
	2	144	28/37	75.68	5.433	1.214	0.9087
	3	134	28/37	75.68	5.513	1.147	0.8807
	4	179	30/37	81.08	5.59	1.202	0.9028
	5	136	24/37	64.86	4.682	1.09	0.8722
	6	53	15/37	40.54	3.526	1.111	0.9303
LOW TIDE	1	105	25/37	67.57	5.157	1.194	0.9231
	2	96	20/37	54.05	4.163	1.135	0.9178
	3	103	24/37	64.86	4.963	1.182	0.9098
	4	106	21/37	56.76	4.289	1.008	0.8528
	5	80	16/37	43.24	3.423	0.9156	0.8326

**Table 52 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN APRIL 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	13-21	6/34	17.65
			Copepods	23-79	13/34	38.24
			Arrow worms	0-2	1/34	2.94
			Medusa	0-4	1/34	2.94
			Mysids	0-5	1/34	2.94
			Urochordata	0-6	2/34	5.88
			Foraminiferans	2-6	2/34	5.88
			Larval forms	22-98	8/34	23.53
			TOTAL ZOOPLANKTON N/ M <sup>3</sup>	70-198	34	
LOW TIDE	Sub surface	5	Tintinids	8-22	6/34	17.65
			Copepods	36-63	13/34	38.24
			Arrow worms	0-2	1/34	2.94
			Medusa	0-4	1/34	2.94
			Mysids	0-2	1/34	2.94
			Urochordata	0-8	2/34	5.88
			Foraminiferans	0-6	2/34	5.88
			Larval forms	57-72	8/34	23.53
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	119-167	34	

**Table 53 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK AND , NEAR BY CREEKS DURING NEAP TIDE IN APRIL 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	4-20	4/37	10.81
			Copepods	28-79	14/37	37.84
			Arrow worms	0-1	1/37	2.70
			Mysids	1-19	3/37	8.11
			Urochordata	0-5	2/37	5.41
			Ciliates	0-4	1/37	2.70
			Medusa	0-2	1/37	2.70
			Foraminiferans	0-2	2/37	5.41
			Larval forms	14-69	9/37	24.32
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	53-184	37	
LOW TIDE	Sub surface	5	Tintinids	6-13	4/37	10.81
			Copepods	27-50	14/37	37.84
			Arrow worms	0-2	1/37	2.70
			Mysids	6-23	3/37	8.11
			Urochordata	0-1	2/37	5.41
			Ciliates	0-2	1/37	2.70
			Medusa	0-1	1/37	2.70
			Foraminiferans	0-2	2/37	5.41
			Larval forms	20-40	9/37	24.32
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	80-106	37	

**Table 54 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN APRIL 2022**

Tide	Sampling Station	Abundance In $\times 10^3 \text{N} / \text{m}^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	158	33/33	100	6.321	1.121	0.8221
	SPM	113	27/33	81.82	5.5	1.12	0.8733
LOW TIDE	Jetty	84	26/33	78.79	5.642	1.171	0.8818
	SPM	107	20/33	60.61	4.066	0.9593	0.8337

**Table 55 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN APRIL 2022**

Tide	Sampling Station	Abundance In $\text{N} \times 10^3 / \text{m}^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	110	23/30	76.67	4.68	0.9538	0.7728
	SPM	83	15/30	50.00	3.168	0.7575	0.7032
LOW TIDE	Jetty	74	15/30	50.00	3.253	0.8695	0.806
	SPM	95	23/30	76.67	4.831	0.9787	0.8275

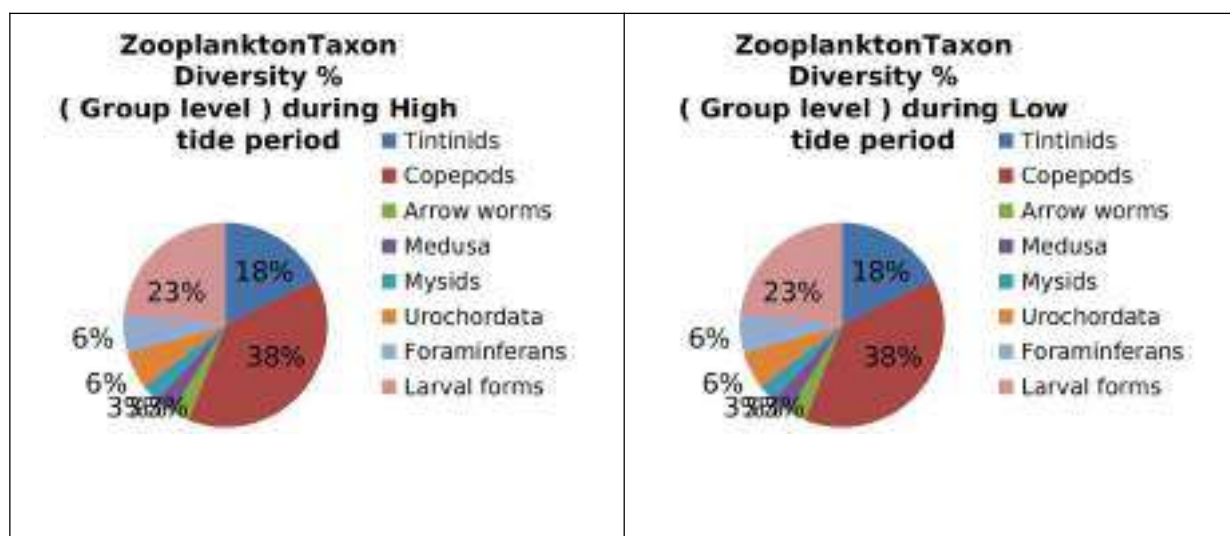
**Table 56 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN APRIL 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	14-19	6/33	18.18
			Copepods	36-43	13/33	39.39
			Urochordata	4-5	2/33	6.06
			Medusa	0-1	1/33	3.03
			Foraminiferans	6	2/33	6.06
			Larval forms	48-89	9/33	27.28
			TOTAL ZOOPLANKTON NO/L	113-158	33	
LOW TIDE	Sub surface	2	Tintinids	7-26	6/33	18.18
			Copepods	28-34	13/33	39.39
			Urochordata	1-4	2/33	6.06
			Medusa	0-1	1/33	3.03
			Foraminiferans	1-3	2/33	6.06
			Larval forms	42-44	9/33	27.28
			TOTAL ZOOPLANKTON NO/M3	84-107	33	

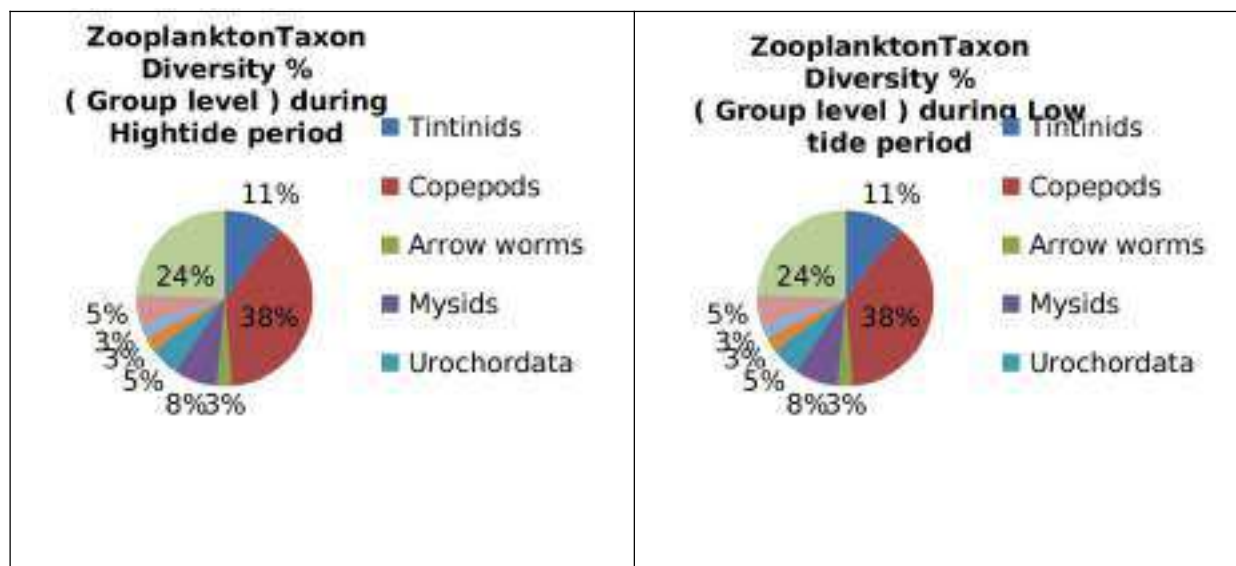
**Table 57 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN APRIL 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	17-23	5/30	16.67
			Copepods	18-20	11/30	36.67
			Arrow worms	0-2	1/30	3.33
			Urochordata	1-3	2/30	6.67
			Ciliates	0-1	1/30	3.33
			Medusa	0-1	1/30	3.33
			Foraminiferans	0-1	1/30	3.33
			Larval forms	45-61	8/30	26.67
			TOTAL ZOOPLANKTON	83-110	30	
LOW TIDE	Sub surface	2	Tintinids	9-20	5/30	16.67
			Copepods	29-30	11/30	36.67
			Arrow worms	1-4	1/30	3.33
			Urochordata	2-4	2/30	6.67
			Ciliates	0	1/30	3.33
			Medusa	0	1/30	3.33
			Foraminiferans	1	1/30	3.33
			Larval forms	27-41	8/30	26.67
			TOTAL ZOOPLANKTON	74-95	30	

**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Kandla Creek and nearby Creeks**

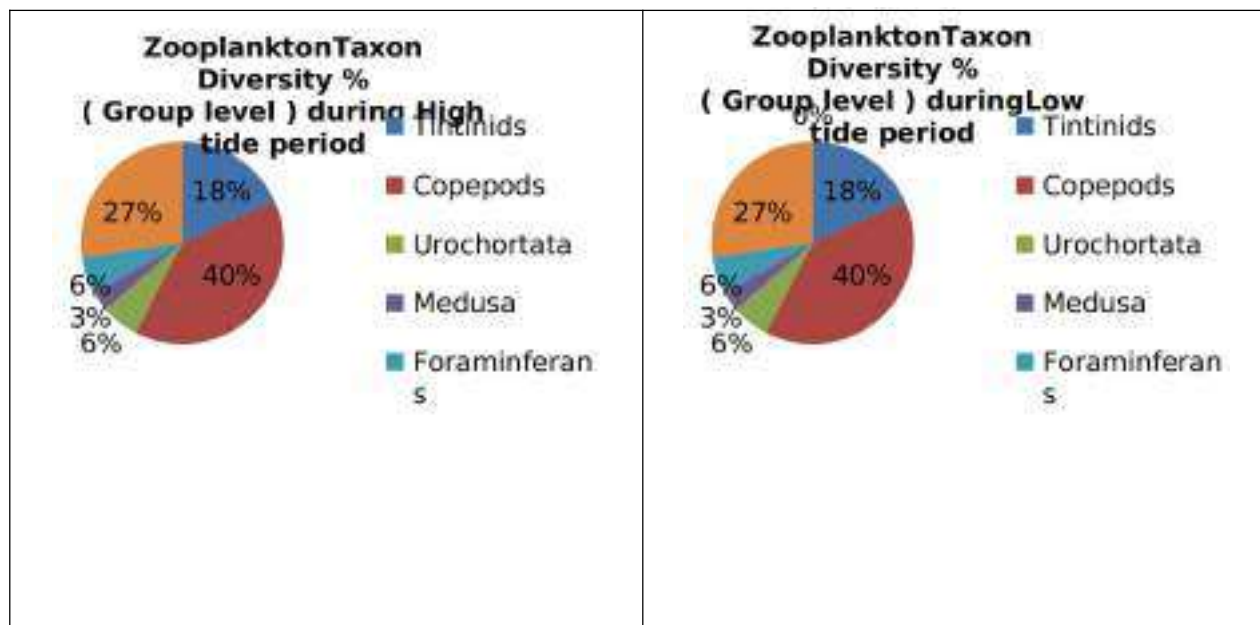


**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Kandla Creek and nearby Creeks**

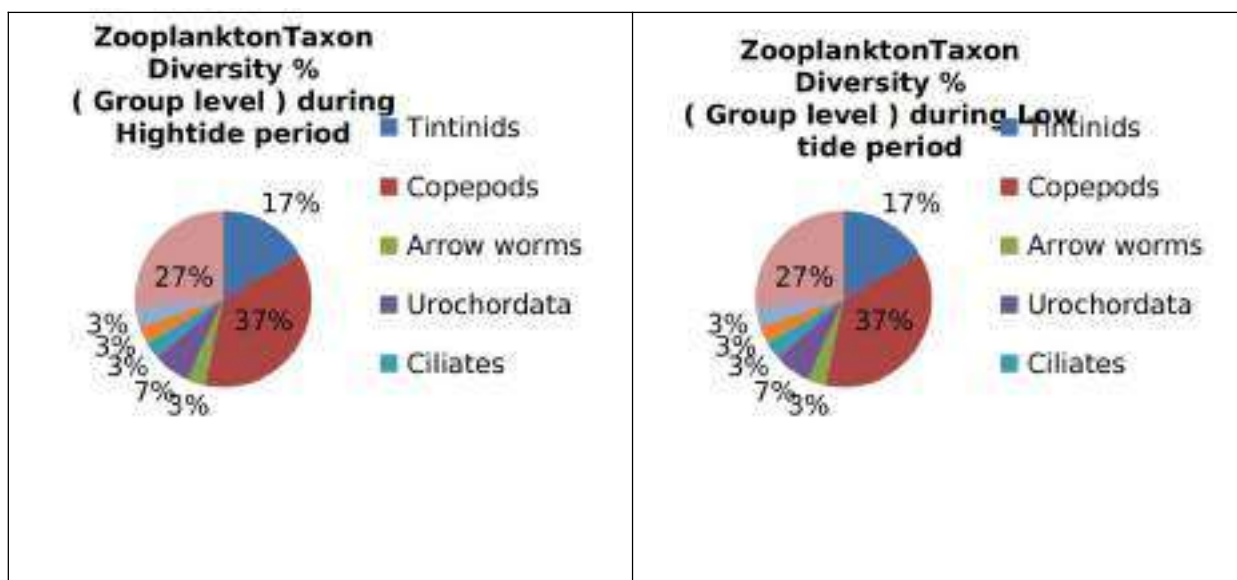




**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM**



**TABLE 58 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B2	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Dominant
			Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D2	Abundant
			Hemiaulales	Bellerocheaceae	<i>Bellerochea sp</i>	D3	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D4	Very sparse
					<i>Eucampia sp</i>	D5	Very sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp</i>	D6	Very sparse

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			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D7	Sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D8	Sparse
			Thalassiosirales	Thalassiosiraceae	<i>Planktoniellasp</i>	D9	Very sparse
					<i>Thalassiosira sp</i>	D10	Very sparse
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D11	Sparse
					<i>Triceratium sp.</i>	D12	Very sparse
		Bacillariophyceae	Naviculales	Naviculaceae	<i>Navicula sp</i>	D13	Very sparse
				Pleurosigmataceae	<i>Pleurosigma sp</i>	D14	Sparse
				Pinnulariaceae	<i>Pinnularia sp</i>	D15	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D16	Sparse
					<i>Nitzschia sp</i>	D17	Very sparse

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					<i>Pseudo-nitzschia</i> sp	D18	Sparse
			Surirellales	Surirellaceae	<i>Surirella</i> sp	D19	Very sparse
		Fragilariophyceae	Thalassionematales	Thalassionemataceae	<i>Thalassiothrix</i> sp.	D20	Scattered
					<i>Thalassionema</i> sp.	D21	Very sparse
			Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp	D22	Very sparse
					<i>Fragilaria</i> sp	D23	Very sparse
					<i>Synedrass</i>	D24	Sparse
DINO FLAGELLATES	Dinoflagellata / Dinzoa	Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF1	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF2	Very sparse

**TABLE 59 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING AND NEAP TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
					<i>Oscillatoria sp.</i>	B2	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B3	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Dominant
			Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D2	Abundant
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp</i>	D3	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D4	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D5	Sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetocerossp.</i>	D6	Sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D7	Scattered
			Thalassiosirales	Thalassiosiraceae	<i>Planktoniellasp</i>	D8	Very sparse
					<i>Thalassiosira sp</i>	D9	Very sparse
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D10	Very sparse
					<i>Triceratium sp.</i>	D11	Very sparse
		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D12	Very sparse

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					<i>Nitzschia</i> sp	D13	Very sparse
					<i>Pseudo-nitzschia</i> sp.	D14	Very sparse
			Surirellales	Surirellaceae	<i>Surirella</i> sp	D15	Very sparse
			Naviculales	Naviculaceae	<i>Navicula</i> sp	D16	Very sparse
				<u>Pleurosigmataceae</u>	<i>Pleurosigma</i> sp.	D17	Sparse
		Fragilariophyceae	Thalassionematales	Thalassionemataceae	<i>Thalassiothrix</i> sp.	D18	Abundant
					<i>Thalassionema</i> sp.	D19	Very sparse
			Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp	D20	Very sparse
					<i>Fragilaria</i> sp	D21	Very sparse
					<i>Synedrassp</i>	D22	Sparse
			Tabellariales	Tabellariaceae	<i>Tabellaria</i> sp	D23	Very sparse
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Noctiluca / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca</i> sp.	DF1	Very sparse
		Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF2	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
					<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE 60 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Chlorococcales	Chroococcaceae	<i>Merismopedia sp.</i>	B1	Very sparse
			Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B2	Sparse
					<i>Oscillatoria sp.</i>	B3	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B4	Very sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B5	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Dominant
					<i>Palmeria sp.</i>	D2	Very sparse
			Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp	D3	Scattered
			Hemiaulales	Belleracheaceae	<i>Bellerachea</i> sp	D4	Sparse
				Streptothecaceae	<i>Helicotheca sp</i>	D5	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Very sparse
					<i>Eucampia sp</i>	D7	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D8	Dominant
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp	D9	Dominant
			Melosirales	Melosiraceae	<i>Melosira sp</i>	D10	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D11	Scattered
			Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp	D12	Very sparse

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					<i>Thalassiosira sp</i>	D13	Sparse
				Lauderiaceae	<i>Lauderia</i> sp	D14	Very sparse
			Triceratiales	Triceratiaceae	<i>Odontella</i> sp.	D15	Abundant
					<i>Triceratium</i> sp.	D16	Very sparse
		Bacillariophyceae	Naviculales	Pleurosigmataceae	<i>Pleurosigma</i> sp	D17	Sparse
				Pinnulariaceae	<i>Pinnularia</i> sp	D18	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D19	Sparse
					<i>Nitzschia</i> sp	D20	Sparse
					<i>Pseudo-nitzschia</i> sp	D21	Sparse
			Surirellales	Surirellaceae	<i>Campylodiscus</i> sp	D22	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Synedra</i> sp.	D23	Sparse
			Striatellales	Striatellaceae	<i>Striatella</i> sp	D24	Very sparse
			Licmophorales	Licmophoraceae	<i>Licmophora</i> sp.	D25	Very sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix</i> sp.	D26	Very sparse
					<i>Thalassionema</i> sp.	D27	Very sparse
DINOFLAGELLATES	Dinoflagellata / Dinozoa	Noctiluca / Noctiluiphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca</i> sp.	DF1	Sparse
		Dinophyceae	Peridiniales	Proto-peridiniaceae	<i>Proto-peridinium</i> sp.	DF2	Sparse



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			Dinophysales	Dinophysaceae	<i>Dinophysis sp.</i>	DF3	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF4	Very sparse
					<i>Ceratium tripos</i>	DF5	Sparse

**TABLE 61 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND NEAP TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Chlorococcales	Chroococcaceae	<i>Merismopedia sp.</i>	B1	Very sparse
			Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B2	Very sparse
					<i>Lyngbya sp.</i>	B3	Very sparse
					<i>Oscillatoria sp.</i>	B4	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B5	Very sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B6	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Abundant
			Biddulphiales	Biddulphiaceae	<i>Biddulphi</i> sp	D2	Scattered
			Hemiaulales	Bellerucheaceae	<i>Belleruche</i> sp	D3	Sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D4	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D5	Dominant
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp	D6	Scattered
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D7	Sparse
			Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp	D8	Very sparse
					<i>Thalassiosira sp</i>	D9	Very sparse
			Triceratiales	Triceratiaceae	<i>Odontella sp</i>	D10	Sparse
					<i>Triceratium</i> sp	D11	Very sparse
		Bacillariophyceae	Naviculales	Naviculaceae	<i>Navicula</i> sp	D12	Very sparse

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				Pinnulariaceae	<i>Pinnularia</i> sp	D13	Very sparse
				Pleurosigmataceae	<i>Pleurosigma</i> sp	D14	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D15	Sparse
					<i>Nitzschia</i> sp	D16	Scattered
					<i>Pseudo-nitzschia</i> sp	D17	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Synedra</i> sp.	D18	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassiothrix</i> sp.	D19	Very sparse
			Climacospheniales	Climacospheniaceae	<i>Climacosphenia</i> sp.	D20	Very sparse
			Licmophorales	Licmophoraceae	<i>Licmophora</i> sp.	D21	Very sparse
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Noctiluca / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca</i> sp.	DF1	Sparse
		Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF2	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
					<i>Ceratium fusus</i>	DF4	Very sparse
					<i>Ceratium tripos</i>	DF5	Very sparse

**TABLE 62 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA HARBOUR AREA  
AT KANDLA CREEK AND NEARBY CREEK SDURING SPRING TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Sparse
					<i>Tintinnopsis gracilis</i>	T3	Very sparse
					<i>Tintinnopsis mortensenii</i>	T4	Very sparse
					<i>Tintinnopsis radix</i>	T5	Very sparse
				Tintinnidae	<i>Amphorides sp.</i>	T6	Very sparse
COPEPODS	ATHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Bestiolina sp.</i>	C2	Very sparse
					<i>Parvocalanus sp.</i>	C3	Sparse
				Eucalanidae	<i>Subeucalanus sp.</i>	C4	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C5	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C6	Very sparse
				Acartiidae	<i>Acartia sp.</i>	C7	Very sparse
				Temoridae	<i>Temora sp.</i>	C8	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C9	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C10	Scattered
				Euterpinidae	<i>Euterpina sp.</i>	C11	Sparse
				Canthocamptidae	<i>Canthocamptus sp.</i>	C12	Very sparse
			Poecilostomatatoida	Oncaeidae	<i>Oncaea sp.</i>	C13	Very sparse

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ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
MYSIDS	ATHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Solenoceridae	<i>Solenocera sp.</i>	M1	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse
				Fritillariidae	<i>Fritillaria sp.</i>	U2	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L2	Sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophioplutes larvae/ Echinoplutes larvae	L5	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L6	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L7	Very sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L8	Sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very sparse
				Rotaliidae	<i>Rotalia sp.</i>	F2	Very sparse

**TABLE 63 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Very sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Sparse
					<i>Tintinnopsis gracilis</i>	T3	Very sparse
					<i>Tintinnopsis radix</i>	T4	Sparse
COPEPODS	ATHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Eucalanidae	<i>Pareucalanus sp.</i>	C3	Very sparse
					<i>Subeucalanus sp.</i>	C4	Very sparse
				Acartiidae	<i>Acartia sp.</i>	C5	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C6	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C7	Very sparse
				Euchaetidae	<i>Euchaeta sp.</i>	C8	Very sparse
				Temoridae	<i>Temora sp.</i>	C9	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C10	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C11	Abundant
				Euterpinidae	<i>Euterpina sp.</i>	C12	Very sparse
			Poecilostomatatoida	Oncaeidae	<i>Oncaea sp.</i>	C13	Very sparse
				Corycaeidae	<i>Corycaeus sp.</i>	C14	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
MYSIDS	ATHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Scattered
					<i>Penaeus sp.</i>	M2	Sparse
				Solenoceridae	<i>Solenocera sp.</i>	M3	Sparse

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UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse
				Fritillariidae	<i>Fritillaria sp.</i>	U2	Very sparse
CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
FISH LARVAE	CHORDATA SUBPHYLUM: VERTEBRATA	Superclass: Pisces			Fish larvae	L5	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L6	Sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophioplutes larvae/ Echinoplutes larvae	L7	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Very sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L9	Very sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very sparse
				Rotaliidae	<i>Rotalia sp.</i>	F2	Very sparse

**TABLE 64 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Abundant
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Very sparse
					<i>Tintinnopsis mortensenii</i>	T4	Very sparse
					<i>Tintinnopsis radix</i>	T5	Sparse
				Xystonellidae	<i>Favella sp.</i>	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Eucalanidae	<i>Subeucalanus sp.</i>	C3	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C4	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C5	Very sparse
				Temoridae	<i>Temora sp.</i>	C6	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C7	Scattered
			Harpacticoida	Canthocamptidae	<i>Canthocamptus sp</i>	C8	Very sparse
				Clytemnestridae	<i>Clytemnestra sp.</i>	C9	Very sparse
				Euterpinae	<i>Euterpina sp.</i>	C10	Very sparse
				Ectinosomatidae	<i>Microsetella sp.</i>	C11	Very sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C12	Very sparse
				Corycaeidae	<i>Corycaeus sp.</i>	C13	Very sparse
UROCHORDATA	CHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Sparse



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	SUB PHYLUM UROCHORDATA			Fritillariidae	<i>Fritillaria sp.</i>	U2	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
ASCIDIAN LARVAE	CHORDATA SUBPHYLUM: TUNICATA	Ascidacea			Ascidian tadpole larvae	L2	Sparse
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca	Decapoda		Brachyuran zoea larvae	L3	Sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L4	Very sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L5	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae/ Echinopluteus larvae	L6	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L7	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Very sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L9	Very sparse
FORAMINIFERA	FORAMINIFERA	Globobulimina	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very sparse
				Rotaliidae	<i>Rotalia sp.</i>	F2	Very sparse

**TABLE 65 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF APRIL 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus sp.</i>	T1	Scattered
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis mortensenii</i>	T3	Very sparse
					<i>Tintinnopsis radix</i>	T4	Sparse
				Xystonellidae	<i>Favella sp.</i>	T5	Sparse
COPEPODS	ATHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Eucalanidae	<i>Pareucalanus sp.</i>	C3	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C4	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C5	Abundant
			Harpacticoida	Canthocamptidae	<i>Canthocamptus sp</i>	C6	Very sparse
				Clytemnestridae	<i>Clytemnestra sp.</i>	C7	Very sparse
				Euterpinae	<i>Euterpina sp.</i>	C8	Very sparse
				Ectinosomatidae	<i>Microsetella sp.</i>	C9	Very sparse
			Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C10	Very sparse
				Corycaeidae	<i>Corycaeus sp.</i>	C11	Very sparse

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ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Sparse
				Fritillariidae	<i>Fritillaria sp.</i>	U2	Very sparse
CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
ASCIDIAN LARVAE	CHORDATA SUBPHYLUM: TUNICATA	Ascidacea			Ascidian tadpole larvae	L2	Very sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophioplutes larvae/ Echinoplutes larvae	L5	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L6	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L7	Very sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L8	Very sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Rotaliidae	<i>Rotalia sp.</i>	F1	Very sparse

**BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPA harbour region and nearby creek. The meiobenthic organisms during spring tide were represented by Polychaetes *Dasybranchus* sp., *Prinispo* sp. *Notomastus* sp., and , During Neap tide Polychates *Nereis* sp . *Prinispo*, *Dasybranchus* sp and few Amphipods were detected.

**Table 66 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING SPRING TIDE IN APRIL 2022**

Benthic fauna	ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS REPRESENTATION BY GROUP						
	DPA HARBOUR			CREEKS			
POLYCHAETES	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6	
Family : Capitellidae <i>Dasybranchus</i> sp.	40	60	30	40	20	0	
Family Spionidae <i>Prinispo</i> sp.	20	40	20	10	40		
Family : Capitellidae <i>Notomastus</i> sp	0	10	20	20	20	0	
Total Polychates N/M <sup>2</sup>	60	110	70	70	80		
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	60	110	70	70	80		

NS : No sample

**Table 67 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING NEAP TIDE IN APRIL 2022**

Benthic fauna	ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS REPRESENTATION BY GROUP						
	DPA HARBOUR			CREEKS			
POLYCHAETES	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6	
Family : Neridae <i>Nereis</i> sp.	10	20	10	20	10	0	
Family Spionidae <i>Prinispo</i> sp.	20	40	10	40	20	0	
Family : Capitellidae <i>Dasybranchus</i> sp	50	60	40	20	20	0	
<b>Total Polychaetes</b>							
<b>Un identified Amphipods</b>	10	-	-	20	20	0	
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	90	120	60	100	70	0	

# Meteorological Observation

## **11.1 Meteorological Data**

### **Temperature**

Temperature records indicate that the area experiences tropical coastal climate. The moderating effects of the nearby sea and the fairly high amount of relative humidity in the atmosphere have restricted the variability. The seasonal variations of temperature follow closely the course of the sun.

Automatic Weather station ( **ID KAZPHOEN424**) have been installed in Seva Sadan - 3 at the Deendayal Port which records the data on Temperature (°C), Relative Humidity (%), Wind speed (kmph), Wind Direction (°), Solar radiation (w/m<sup>2</sup>) and Rainfall mm.

### **Temperature**

The mean day time temperature for Deendayal Port was 26.0 °C. The day-time maximum temperature was 41.6°C. The minimum mean night time temperature recorded was 23.5 °C.

### **Solar Radiation**

The mean Solar Radiation in April was 101.53 w/m<sup>2</sup>. The maximum solar radiation recorded in the month of April was 331.7 w/m<sup>2</sup>.

### **Rainfall**

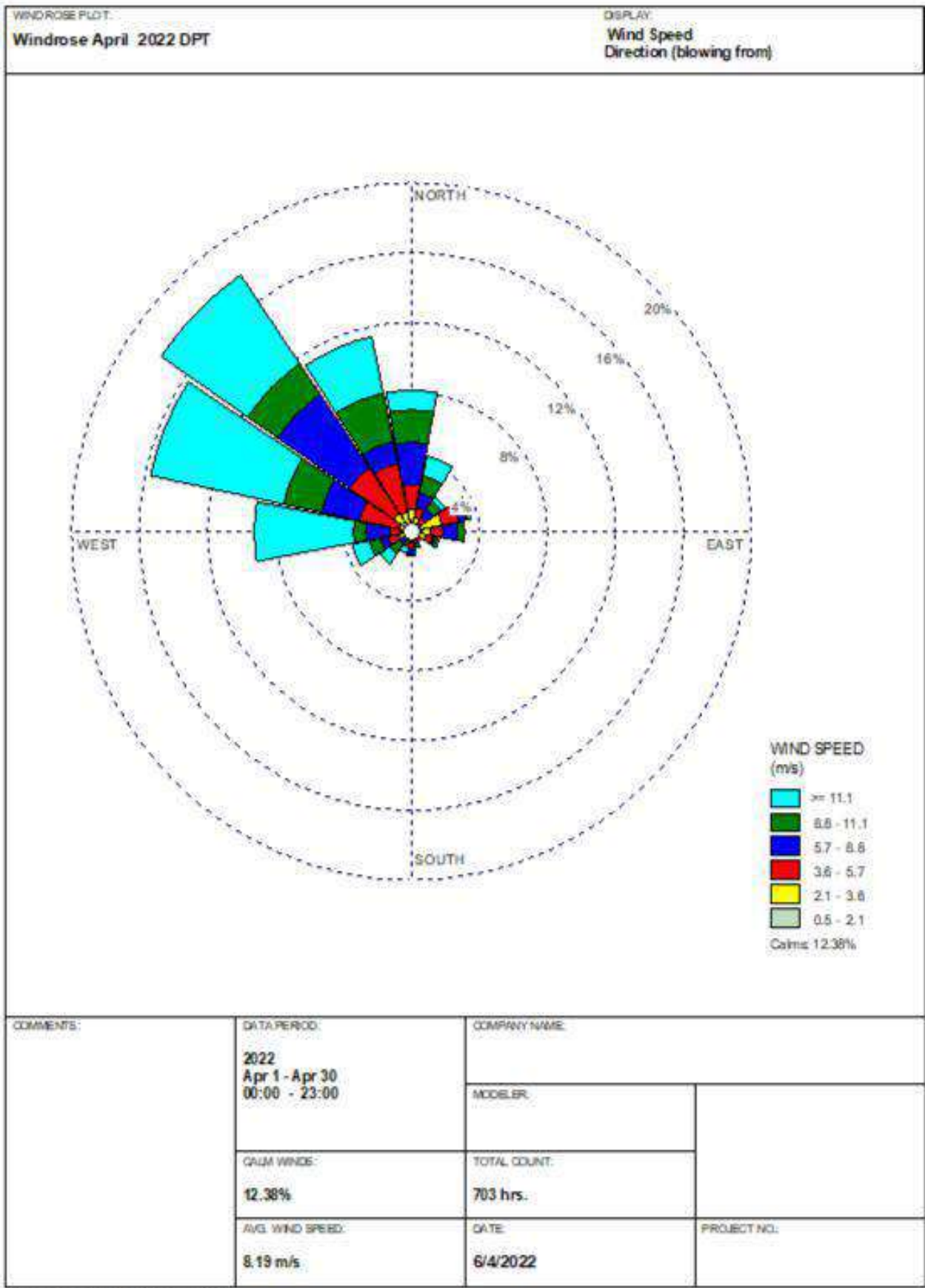
There is no any Rainfall in the month of April.

### **Relative Humidity**

The mean day-time Relative humidity was 16.0 % for the month of April and mean night time Relative humidity was 31.0 %. Maximum Relative humidity recorded during day-time was 95.0 % and maximum Relative humidity recorded during night-time was 67.0%.

### **Wind Velocity and Wind Direction**

The mean wind velocity for the entire month of April was 0.7 m/s. Maximum wind velocity recorded was 34.2 m/s . The wind direction was mostly North West.



## **12.0 Conclusive Summary and Remedial measures Suggested**

The AAQ monitoring at six locations of Deendayal Port Kandla indicates that the mean PM<sub>10</sub> values at all locations viz. Coal storage area, Marine Bhavan, Gopalpuri Hospital, Tuna Port, Kandla Colony and Oil Jetty area were found above the permissible standards (100 µg/m<sup>3</sup>) and the PM<sub>2.5</sub> values are found for five locations ( Marine Bhavan building, Oil jetty, Gopalpuri , Tuna Port & Estate building) within permissible limit Except Coal Storage area. (Limit 60 µg/m<sup>3</sup>).

The AAQ monitoring Vadinar at Admin building found within permissible standards for both PM<sub>10</sub> (Limit 100 µg/m<sup>3</sup>) & PM<sub>2.5</sub> (Limit 60 µg/m<sup>3</sup>)

Drinking water at all the twenty locations was found potable and was within permissible limits of BIS standards (IS 10500).

Noise quality was also within the set permissible standards of an Industrial Area. The noise level observed during day time was >75 dB (A) and at night time was >70 dB (A) during the entire monitoring period.

The sewage treated water of Deendayal Port Colony (Gopalpuri) was in line with the standards set by the Gujarat Pollution Control Board.

### **Reasons for higher Values of PM<sub>10</sub>**

Large amount of coal is handled at Berth No. 6, 7, 8 and 9. The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.

Also, the coal laden trucks are not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.



## **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of April, 2022 were beyond the permissible limit at all locations mentioned above Except Tuna Port, Vadinar Signal building and Admin building for PM<sub>10</sub> . Given below are the remedial measures suggest to minimize the Air pollution at Deendayal Port.

During April, 2022 overall ambient air quality of the DPA is within GPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, and Marine Bhavan. To improve air quality the port is using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and unpaved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

Installed Mist Cannons system to suppresses dust generated in crushing and demolition sites, in material storage, cross-docking of Coal.

## **Solution towards the Green port:**

Practice should be initiated for using mask as preventative measure, to avoid inhalation of dust particle- Mask advised in sensitive areas.

Use of renewable energy like solar energy should be optimal and ensure to work continuously.

Display of Environmental Initiative Boards and create awareness towards public. Stay sanitized of public transport and all basic items at public interaction places as much as possible.

Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.

Limit the Activity and time of Exposure in Sensitive Area Prior planning.

Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.

New scanning technology and new high power Tugs are reducing operation timing and CO2 Emission are good creativity.

Initiate Natural Gas (CNG) as fuel by all buses and trucks.

Guidelines for Coal Handling by GPCB should be strictly followed.  
(<http://gpcb.gov.in/pdf/coal-handling-guidelines.pdf>)

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## ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY



**REPORT** : **DCPL/DPA/21-22/27**

**Months** : **July**

**Page** : **01**

**Prepared by** : **DETOXCORPORATIONPVT.LTD.,SURAT**

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# ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT

## ENVIRONMENTAL MONITORING REPORT- July 2022

### 1. EXECUTIVE SUMMARY

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF& CC to identify non conformity in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### A) Ambient Air

The monitoring of Ambient Air quality at 6 locations at Deendayal Port Authority Kandla and 2 at Vadinar Port on 24 hourly basis for TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> in twice a Week at Gopalpuri, Tuna Port, Marine Bhavan building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and Vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The TSPM values in month of July 2022 were found 687 µg/m<sup>3</sup> maximum at Coal Storage area on 29.07.2022 and minimum 118 µg/m<sup>3</sup> at Tuna Port on 01.07. 2022. The PM<sub>10</sub> values were found from 550 µg/m<sup>3</sup> maximum at Coal Storage area on 01.07.2022 and minimum 73 µg/m<sup>3</sup> at Tuna Port on 15.07. 2022. The PM<sub>2.5</sub> values were found from 177 µg/m<sup>3</sup> maximum at Coal Storage area on 29.07. 2022 and minimum 33 µg/m<sup>3</sup> at Tuna Port on 01.07 2022. The PM<sub>10</sub> and PM<sub>2.5</sub> values were found for four locations (Marine Bhavan building, Coal storage area, Estate building, Oil jetty) to above the permissible limit. The PM<sub>10</sub> & PM<sub>2.5</sub> values were found for four locations (Gopalpuri Hospital , Vadinar Signal building & Admin building) mostly within permissible limit.

The overall values of July for SO<sub>2</sub> were found maximum of 6.64 µg/m<sup>3</sup> and minimum of 1.09 µg/m<sup>3</sup>. NO<sub>2</sub> were found maximum 23.07 µg/m<sup>3</sup> and minimum 9.47 µg/m<sup>3</sup>, NH<sub>3</sub> were found maximum 11.23 µg/m<sup>3</sup> and minimum 4.59 µg/m<sup>3</sup>, C<sub>6</sub>H<sub>6</sub> were found maximum 1.22 µg/m<sup>3</sup> and minimum 1.00 µg/m<sup>3</sup>, CO were found maximum 2.23 mg/m<sup>3</sup> and minimum of 1.08 mg/m<sup>3</sup>, CO<sub>2</sub> were found maximum 2758 ppm and minimum of 285 ppm and NMHC were found BQL (Below Quantification Limit).

#### B) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:

The results obtained from the study for the month of July 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) was not adversely affected by Port activities.



**C) Drinking Water Quality**

Drinking water is water intended for human consumption for drinking and cooking purposes from designated source. The drinking water being supplied to Deendayal Port was safe for drinking purpose. At all drinking water monitoring stations around port area were found to be as per the drinking water specifications given in IS 10500:2012 as per tested parameters only.

The average results for 20 locations were as: pH were found Min 7.38 and maximum 8.60, TDS were found min 660 mg/l and Max found 920 mg/l, Chloride were found Min 75.17 mg/l and Max 205.46 mg/l, Total Hardness were found Min 150 mg/l and Max 350 mg/l and Calcium were found Min 19.93 mg/l and Max 56.11 mg/l, colour found colourless and odour were odourless. In all water samples BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count (E-coli & Coliform) is absent in all drinking water samples.

**D) Monitoring Performance of Sewage Treatment Plant**

It was seen that the performance of STP at Deendayal Township, DPA STP Plant and Vadinar STP plant was satisfactory by overall. The treatment plant was well maintained during [July 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. The average results for 3 locations as per below. Two locations (Gopalpuri & DPA STP) and one location at Vadinar. The pH were found 7.21 to Max 7.44, Total Suspended Solids were found 35 to 69 mg/l, Residual Chlorine were below Detection Limit (Less Than 0.5), COD were found 20.5 to 70.7 mg/l and 3day BOD @ 27 °C were found 4 to 18 mg/l.

**E) Weather**

The mean day time temperature for Deendayal Port was 25.6 °C. The day-time maximum temperature was 34.3°C. The mean night time temperature recorded was 28.4 °C. The mean Solar Radiation in July month was 115.72 w/m<sup>2</sup>. The maximum solar radiation was recorded 623.2 w/m<sup>2</sup> in 18<sup>th</sup> July and the minimum solar radiation was recorded 0.23 w/m<sup>2</sup> in 27<sup>th</sup> July. The mean Relative humidity was 88.15 % for the month of July. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 47 %. The average wind velocity for the entire month of July was 1.56 m/s. Maximum wind velocity was recorded 13.8 m/s. The wind direction was mostly North West.

**F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 13 locations at Deendayal Port ranged from 49.6 dB(A) to 70.9 dB(A) and it was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from 46.6 dB to 66.2 dB(A) and it was within the permissible limits of 70 dB(A) for the industrial area for the night time.

## **2.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 kms. From the mouth of Gulf of Kachchh. Latitude: 23° 01" N Longitude: 70° 13"E. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rose to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15 consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. The west coast port handled 72,225 million tonnes of cargo in 2008-09, over 11% more than 64,920 million tonnes handled in 2007-08. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. Although Deendayal Port Authority officials declined to elaborate given the ongoing election code of conduct, it is reliably learnt that the port will soon initiate the process of selecting developers for four clean cargo berths that together aim to handle 8 million tonnes of cargo. The four berths will be supported by a 14 m draft capable of handling 75,000 dwt vessels.

The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural up-gradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32MMTPA Essar Oil Refinery in Jamnagar District. Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the prescribed standards by GPCB/CPCB/MoEF& CC. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port. The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd

# Ambient Air Quality Monitoring

### 3. Introduction

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution

Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

#### 3.1 Ambient Air Quality Monitoring

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

##### ● Air Quality Monitoring Methodology

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, NMHC& Benzene, and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours for gaseous parameters. The reagents for SO<sub>2</sub>- Mercuric Chloride, Potassium Chloride and EDTA used. For NO<sub>2</sub>- Sodium Hydroxide and Sodium Arsenite. For NH<sub>3</sub> need Conc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO<sub>2</sub>, NO<sub>2</sub>. The GFA filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub>& PM<sub>2.5</sub>. The AAQ samples are collected two consecutive days a week as per CPCB guidelines, from all the eight locations as mentioned in the EMP.

#### 3.2 Results

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of July 2022 are given in Tables 1 to 6. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building &Nr. Signal Building) are given in Tables 7 to 8.

**Note: AL1 To AL8 are Air Monitoring Location 1 to 8. Where AL1 Marine Bhavan, AL2 Oil Jetty, AL3 Estate Office, AL4 Gopalpuri Hospital, AL5 Coal Storage, AL6 Tuna Port, AL7 Signal Building (Vadinar) and AL8 Admin Building (Vadinar).**

**Location 1: Marine Bhavan (AL1)**

**Table 1 : Results of Air Pollutant Concentration at Marine Bhavan**

Table 1 : Results of Air Pollutant Concentration at Marine Bhavan										
Parameter	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL1 – 1	01.07.2022	167	97	57	0.73	1.57	20.08	14.31	9.53	9.44
					2.18		12.47		8.70	
					1.81		10.39		10.08	
AL1 – 2	05.07.2022	185	127	52	2.90	2.90	11.77	11.77	11.74	10.31
					3.26		13.16		10.08	
					2.54		10.39		9.12	
AL1 – 3	11.07.2022	223	148	68	4.35	4.11	18.01	17.31	8.98	9.62
					2.54		20.08		10.36	
					5.44		13.85		9.53	
AL1 – 4	15.07.2022	193	126	59	3.63	2.66	10.39	12.00	11.46	9.25
					2.54		11.08		8.56	
					1.81		14.54		7.74	
AL1 – 5	18.07.2022	262	174	76	2.90	2.90	19.39	17.55	5.25	8.84
					2.54		18.01		10.22	
					3.26		15.24		11.05	
AL1 - 6	22.07.2022	304	212	86	5.08	4.71	21.47	20.78	9.81	7.83
					4.71		22.16		7.04	
					4.35		18.70		6.63	
AL1 - 7	25.07.2022	261	177	78	6.16	5.56	20.78	18.01	8.01	8.15
					5.44		17.31		9.53	
					5.08		15.93		6.91	
AL1 – 8	29.07.2022	301	202	90	3.63	4.23	16.62	14.08	10.91	10.27
					4.35		14.54		8.84	
					4.71		11.08		11.05	
Monthly Average		237	158	71		3.58		15.73		9.21
Standard Deviation		53	40	14		1.29		3.18		0.90

**Table 1 : Results of Air Pollutant Concentration at Marine Bhavan**

Parameter	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL1 – 1	01.07.2022	1.15	BQL	1.63	615
AL1 – 2	05.07.2022	1.12	BQL	1.5	1123
AL1 – 3	11.07.2022	1.04	BQL	1.89	1792
AL1 – 4	15.07.2022	1.15	BQL	2.11	1075
AL1 – 5	18.07.2022	1.12	BQL	1.08	2563
AL1 - 6	22.07.2022	1.18	BQL	1.78	632
AL1 - 7	25.07.2022	1.04	BQL	2.23	1023
AL1 - 8	29.07.2022	1.18	BQL	2.19	1429
<b>Monthly Average</b>		<b>1.12</b>	<b>-</b>	<b>1.80</b>	<b>1282</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.39</b>	<b>646</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 237 µg/m<sup>3</sup>, The mean PM<sub>10</sub> value was 158 µg/m<sup>3</sup>, PM<sub>2.5</sub> value was 71 µg/m<sup>3</sup> which is above the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.58 µg/ m<sup>3</sup>, 15.73 µg/ m<sup>3</sup> & 9.21 µg/ m<sup>3</sup> respectively. These were within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.80 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 2: Oil Jetty (AL2)**

Table 2 : Results of Air Pollutant Concentration at Oil Jetty										
	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL2 -1	01.07.2022	156	91	54	3.26	3.75	10.39	9.93	7.04	7.00
					5.08		8.31		5.39	
					2.90		11.08		8.56	
AL2 -2	05.07.2022	227	147	69	1.45	3.51	11.77	11.08	6.63	8.33
					3.63		9.00		9.53	
					5.44		12.47		8.84	
AL2 -3	11.07.2022	253	172	74	6.89	6.65	24.24	19.39	7.46	9.53
					8.34		19.39		10.08	
					4.71		14.54		11.05	
AL2 -4	15.07.2022	236	160	65	3.26	2.54	13.16	15.01	10.22	11.23
					1.45		15.24		11.46	
					2.90		16.62		12.02	
AL2 – 5	18.07.2022	315	208	92	4.30	3.73	22.16	18.70	7.46	7.32
					3.63		17.31		6.63	
					3.26		16.62		7.87	
AL2 – 6	22.07.2022	232	171	58	5.80	4.83	13.85	15.70	4.97	6.95
					4.71		17.31		6.91	
					3.99		15.93		8.98	
AL2 – 7	25.07.2022	182	111	59	2.54	1.81	20.78	16.62	10.64	8.98
					1.81		15.24		8.43	
					1.09		13.85		7.87	
AL2 -8	29.07.2022	181	122	54	2.90	4.35	11.77	13.16	5.53	8.52
					5.44		13.16		9.81	
					4.71		14.54		10.22	
Monthly Average		223	148	66		3.90		14.95		8.48
Standard Deviation		50	38	13		1.47		3.39		1.46

**Table 2 : Results of Air Pollutant Concentration at Oil Jetty**

		C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL2 -1	01.07.2022	1.12	BQL	1.62	869
AL2 -2	05.07.2022	1.15	BQL	1.69	1181
AL2 -3	11.07.2022	1.02	BQL	1.69	1259
AL2 -4	15.07.2022	1.17	BQL	1.94	1882
AL2 -5	18.07.2022	1.22	BQL	1.77	1790
AL2 -6	22.07.2022	1.21	BQL	2.11	633
AL2 -7	25.07.2022	1.12	BQL	1.75	780
AL2 -8	29.07.2022	1.02	BQL	2.06	1842
<b>Monthly Average</b>		<b>1.13</b>	<b>-</b>	<b>1.83</b>	<b>1280</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.18</b>	<b>505</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

Oil Jetty Area, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> was mainly by motor vehicle emission produced from various types of vehicles at Oil Jetty Area. The mean TSPM values at Oil Jetty was 223 µg/m<sup>3</sup>. The mean PM<sub>10</sub> value was 148 µg/m<sup>3</sup>, PM<sub>2.5</sub> value was 66 µg/m<sup>3</sup> which is above the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit, The mean concentration of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.90 µg/m<sup>3</sup>, 14.95 µg/m<sup>3</sup> and 8.48 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.13 µg/m<sup>3</sup> which was well below the permissible limit of 5.0 µg/m<sup>3</sup>, NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.83 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



**Location 3: Kandla Colony – Estate Office (AL-3)**

**Table 3 : Results of Air Pollutant Concentration at Estate Office**

Table 3 : Results of Air Pollutant Concentration at Estate Office										
Parameter	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL3 – 1	01.07.2022	175	108	65	1.81	1.69	22.42	23.07	6.12	5.26
					2.54		25.34		5.45	
					0.73		21.45		4.21	
AL3 – 2	05.07.2022	261	170	83	2.54	3.63	17.87	14.49	6.14	6.53
					3.99		12.13		8.75	
					4.35		13.47		4.69	
AL3 – 3	11.07.2022	315	207	93	5.80	4.59	14.21	14.87	9.78	8.40
					3.63		18.54		8.31	
					4.35		11.87		7.12	
AL3 – 4	15.07.2022	272	184	81	2.18	3.38	17.25	15.19	8.64	9.21
					3.26		11.54		9.87	
					4.71		16.78		9.13	
AL3 – 5	18.07.2022	336	220	98	6.53	5.32	17.52	16.80	5.63	6.82
					5.44		20.78		6.12	
					3.99		12.11		8.72	
AL3 – 6	22.07.2022	311	234	68	4.71	3.62	15.24	15.62	5.11	5.97
					2.90		13.36		6.48	
					3.26		18.26		6.32	
AL3 – 7	25.07.2022	228	141	78	1.45	2.78	15.87	17.21	9.21	8.75
					3.99		16.42		8.32	
					2.90		19.35		8.73	
AL3 – 8	29.07.2022	284	184	96	4.71	4.71	12.45	12.47	5.36	7.72
					5.08		13.10		7.56	
					4.35		11.85		10.23	
Monthly Average		273	181	83		3.72		16.22		7.33
Standard Deviation		52	42	12		1.16		3.13		1.41

<b>Table 3 : Results of Air Pollutant Concentration at Estate Office</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL3 -1</b>	01.07.2022	1.03	BQL	1.61	531
<b>AL3 -2</b>	05.07.2022	1.04	BQL	1.47	915
<b>AL3 -3</b>	11.07.2022	1.15	BQL	1.74	1119
<b>AL3 -4</b>	15.07.2022	1.14	BQL	2.06	1278
<b>AL3 – 5</b>	18.07.2022	1.16	BQL	2.05	1669
<b>AL3 – 6</b>	22.07.2022	1.03	BQL	2.18	688
<b>AL3 – 7</b>	25.07.2022	1.06	BQL	2.06	686
<b>AL3 – 8</b>	29.07.2022	1.08	BQL	2.23	1791
<b>Monthly Average</b>		<b>1.09</b>	<b>-</b>	<b>1.93</b>	<b>1085</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.28</b>	<b>468</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Kandla Port Colony was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Kandla port Colony were 273 µg/m<sup>3</sup>, The mean PM<sub>10</sub> value was 181 µg/m<sup>3</sup>, PM<sub>2.5</sub> value was 83 µg/m<sup>3</sup> which is above the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.72 µg/m<sup>3</sup>, 16.22 µg/m<sup>3</sup> and 7.33 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.09 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.93 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 4: Gopalpuri Hospital (AL-4)**

**Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital**

Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
Parameter	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL4 -1	01.07.2022	133	86	42	1.54	2.62	14.12	13.95	6.65	7.43
					4.21		9.89		9.89	
					2.11		17.85		5.75	
AL4 -2	05.07.2022	158	99	53	1.35	2.17	10.21	11.56	4.36	5.50
					2.01		12.32		6.35	
					3.14		12.14		5.78	
AL4 -3	11.07.2022	170	104	57	2.65	3.10	15.65	16.55	4.12	4.59
					3.45		15.24		5.65	
					3.21		18.75		4.01	
AL4 -4	15.07.2022	133	87	42	4.12	3.13	21.32	17.26	5.69	5.45
					2.17		14.56		6.35	
					3.11		15.89		4.32	
AL4 – 5	18.07.2022	166	103	58	4.13	3.66	17.23	14.27	4.87	6.53
					3.21		11.25		5.96	
					3.64		14.32		8.75	
AL4 – 6	22.07.2022	181	116	60	5.78	4.77	21.12	20.38	6.32	6.43
					4.32		22.45		4.35	
					4.21		17.56		8.63	
AL4 – 7	25.07.2022	215	130	74	2.21	3.15	15.18	18.91	8.32	7.09
					3.12		21.56		8.75	
					4.11		19.98		4.21	
AL4 – 8	29.07.2022	220	135	82	4.32	4.43	14.56	12.81	5.36	6.01
					3.21		13.32		8.45	
					5.75		10.56		4.21	
Monthly Average		172	107	58		3.38		15.71		6.13
Standard Deviation		33	18	14		0.87		3.07		0.93

<b>Table 4 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL4 -1</b>	01.07.2022	1.13	BQL	1.48	500
<b>AL4 -2</b>	05.07.2022	1.17	BQL	1.42	1544
<b>AL4 -3</b>	11.07.2022	1.15	BQL	1.74	1119
<b>AL4 -4</b>	15.07.2022	1.12	BQL	1.79	1576
<b>AL4 -5</b>	18.07.2022	1.07	BQL	1.73	1578
<b>AL4 -6</b>	22.07.2022	1.14	BQL	2.21	870
<b>AL4 -7</b>	25.07.2022	1.02	BQL	2.19	1277
<b>AL4 -8</b>	29.07.2022	1.05	BQL	2.19	1682
<b>Monthly Average</b>		<b>1.11</b>	<b>-</b>	<b>1.84</b>	<b>1268</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.32</b>	<b>416</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 172 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 107 µg/m<sup>3</sup> which is slightly above the permissible limit, PM<sub>2.5</sub> value was 58 µg/m<sup>3</sup> which is within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.32 µg/m<sup>3</sup>, 17.98 µg/m<sup>3</sup> and 7.47 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.10 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.74 mg/m<sup>3</sup> which is well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 5: Coal Storage Area (AL-5)**

Table 5 : Results of Air Pollutant Concentration at Coal Storage Area										
Parameter	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL5 – 1	01.07.2022	684	550	130	4.35	4.11	21.45	19.36	5.14	6.06
					4.71		15.35		4.32	
					3.26		21.28		8.72	
AL5 – 2	05.07.2022	359	243	109	6.24	4.93	14.35	19.38	10.56	10.29
					5.89		21.65		11.32	
					2.65		22.14		8.98	
AL5 – 3	11.07.2022	453	321	124	7.58	6.01	15.27	17.62	6.56	6.24
					6.32		18.34		4.26	
					4.12		19.25		7.89	
AL5 – 4	15.07.2022	490	350	131	5.23	6.25	22.14	19.98	8.69	8.26
					7.21		24.11		6.98	
					6.32		13.68		9.12	
AL5 – 5	18.07.2022	596	426	154	4.58	3.31	17.25	18.29	8.36	6.01
					2.36		21.65		4.56	
					2.98		15.96		5.12	
AL5 – 6	22.07.2022	521	391	127	2.64	2.31	23.61	19.47	9.25	8.32
					1.98		20.58		6.38	
					2.31		14.23		9.32	
AL5 – 7	25.07.2022	630	462	156	4.65	4.73	11.68	13.12	7.12	7.06
					5.32		12.35		8.36	
					4.23		15.32		5.69	
AL5 – 8	29.07.2022	687	503	177	2.31	2.93	17.29	16.66	9.34	7.52
					2.12		14.36		5.89	
					4.35		18.32		7.32	
Monthly Average		553	406	139		4.32		17.98		7.47
Standard Deviation		117	101	22		1.42		2.26		1.47

<b>Table 5 : Results of Air Pollutant Concentration at Coal Storage Area</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL5 – 1</b>	01.07.2022	1.08	BQL	1.54	510
<b>AL5 – 2</b>	05.07.2022	1	BQL	1.32	755
<b>AL5 – 3</b>	11.07.2022	1.06	BQL	1.51	2758
<b>AL5 – 4</b>	15.07.2022	1.12	BQL	1.69	2648
<b>AL5 – 5</b>	18.07.2022	1.05	BQL	1.97	1761
<b>AL5 – 6</b>	22.07.2022	1.2	BQL	1.59	723
<b>AL5 – 7</b>	25.07.2022	1.16	BQL	2.19	802
<b>AL5 – 8</b>	29.07.2022	1.11	BQL	2.08	2366
<b>Monthly Average</b>		<b>1.10</b>	<b>-</b>	<b>1.74</b>	<b>1540</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.31</b>	<b>951</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 553 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 406 µg/m<sup>3</sup>, The PM<sub>2.5</sub> values were 139 µg/m<sup>3</sup> which is well above the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.32 µg/m<sup>3</sup>, 17.98 µg/m<sup>3</sup> and 7.47 µg/m<sup>3</sup> respectively and were all within the permissible limit. The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.10 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.74 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 6: Tuna Port (AL-6)**

**Table 6 : Results of Air Pollutant Concentration at Tuna Port**

Table 6 : Results of Air Pollutant Concentration at Tuna Port										
Parameters	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL6 -1	01.07.2022	118	78	33	3.63	2.78	21.36	16.52	9.63	9.50
					2.90		12.58		8.75	
					1.81		15.63		10.11	
AL6 – 2	05.07.2022	128	84	40	2.18	3.70	12.47	14.31	6.65	8.23
					3.26		15.93		9.39	
					5.66		14.54		8.66	
AL6 – 3	11.07.2022	144	91	45	4.35	4.59	22.58	18.40	5.31	5.06
					3.99		18.25		4.56	
					5.44		14.36		5.32	
AL6 – 4	15.07.2022	119	73	38	2.69	3.00	8.85	10.92	6.75	6.52
					3.32		11.36		8.12	
					2.98		12.55		4.69	
AL6 – 5	18.07.2022	143	89	44	4.71	4.71	20.98	17.86	9.35	9.75
					3.63		18.25		10.36	
					5.80		14.36		9.53	
AL6 – 6	22.07.2022	149	95	49	5.08	5.08	24.35	21.95	8.25	6.40
					3.99		22.14		5.98	
					6.16		19.36		4.98	
AL6 – 7	25.07.2022	144	87	46	5.44	4.59	21.17	19.57	7.74	7.37
					2.90		18.25		8.29	
					5.44		19.30		6.08	
AL6 – 8	29.07.2022	148	94	50	4.35	4.95	17.26	13.98	10.23	8.60
					4.71		12.35		7.35	
					5.80		12.34		8.23	
Monthly Average		137	86	43		4.18		16.69		7.68
Standard Deviation		13	8	6		0.90		3.52		1.63

<b>Table 6 : Results of Air Pollutant Concentration at Tuna Port</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL6 -1</b>	01.07.2022	1.02	BQL	1.68	460
<b>AL6 – 2</b>	05.07.2022	1.19	BQL	1.56	495
<b>AL6 – 3</b>	11.07.2022	1.02	BQL	2.1	1133
<b>AL6 – 4</b>	15.07.2022	1.09	BQL	2.06	1818
<b>AL6 – 5</b>	18.07.2022	1.01	BQL	1.36	1240
<b>AL6 – 6</b>	22.07.2022	1.15	BQL	2.14	549
<b>AL6 – 7</b>	25.07.2022	1	BQL	2.17	921
<b>AL6 – 8</b>	29.07.2022	1.15	BQL	1.88	1268
<b>Monthly Average</b>		<b>1.08</b>	<b>-</b>	<b>1.87</b>	<b>986</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.30</b>	<b>474</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port was 137 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 86 µg/m<sup>3</sup>, the mean PM<sub>2.5</sub> value was 43 µg/m<sup>3</sup> which is within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.18 µg/m<sup>3</sup>, 16.69 µg/m<sup>3</sup> and 7.68 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.08 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.87 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



**Location 7: Signal Building (Vadinar) (AL-7)**

**Table 7 : Results of Air Pollutant Concentration at Signal building Vadinar**

Table 7 : Results of Air Pollutant Concentration at Signal building Vadinar										
Parameters	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL7 -1	02.07.2022	150	99	45	4.71	3.14	13.85	14.08	5.66	6.45
					3.63		16.62		7.60	
					1.09		11.77		6.08	
AL7 -2	05.07.2022	137	89	41	5.80	5.56	12.47	15.24	9.53	8.10
					4.71		15.24		6.77	
					6.16		18.01		8.01	
AL7 -3	08.07.2022	146	91	52	1.81	2.66	13.16	12.93	5.39	6.77
					3.63		14.54		7.04	
					2.54		11.08		7.87	
AL7 -4	12.07.2022	185	110	68	5.08	3.99	18.01	18.01	8.98	9.39
					2.18		18.70		9.12	
					4.71		17.31		10.08	
AL7 -5	15.07.2022	179	100	60	1.81	1.57	14.54	13.62	7.74	6.26
					0.73		15.93		5.80	
					2.18		10.39		5.25	
AL7 -6	19.07.2022	175	122	75	2.54	3.75	19.39	19.39	8.15	8.38
					3.99		18.70		9.81	
					4.71		20.08		7.18	
AL7 -7	22.07.2022	151	98	49	6.16	4.59	14.54	15.23	6.49	6.08
					3.26		13.85		5.94	
					4.35		17.31		5.80	
AL7-8	26.07.2022	189	117	66	1.45	3.39	13.16	12.47	4.80	5.38
					3.63		12.47		5.39	
					5.08		11.77		5.94	
AL7-9	29.07.2022	164	103	55	6.16	4.35	14.54	12.23	6.35	6.21
					4.35		11.77		5.66	
					2.54		10.39		6.63	
Monthly Average		164	103	57		4		15		7
Standard Deviation		19	11	11		1		2		1

Table 7 : Results of Air Pollutant Concentration at Signal building Vadinar					
Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	
<b>NAAQMS limit</b>					
AL7 -1	02.07.2022	1.16	BQL	1.57	446
AL7 -2	05.07.2022	1.1	BQL	1.43	425
AL7 -3	08.07.2022	1.21	BQL	1.27	597
AL7 -4	12.07.2022	1.08	BQL	1.31	502
AL7 -5	15.07.2022	1.12	BQL	1.81	550
AL7 -6	19.07.2022	1.08	BQL	2.05	315
AL7 -7	22.07.2022	1.06	BQL	2.16	537
AL7 -8	26.07.2022	1	BQL	1.97	285
AL7 -9	29.07.2022	1.02		1.87	380
<b>Monthly Average</b>		<b>1.1</b>	<b>-</b>	<b>1.7</b>	<b>457</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.35</b>	<b>112</b>

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Signal building Vadinar 164 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 103µg/m<sup>3</sup> which is slightly above the permissible limit, the mean PM<sub>2.5</sub> value was 57 µg/m<sup>3</sup> which is within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4 µg/m<sup>3</sup>, 15 µg/m<sup>3</sup> and 7 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.10 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. HC's were below the detectable limit and Carbon Monoxide concentration was 1.70 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 8: Admin Building (Vadinar) (AL-8)**

Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar										
Parameters	Date	TSPM [µg/m3]	PM <sub>10</sub> [µg/m3]	PM <sub>2.5</sub> [µg/m3]	SO <sub>2</sub> [µg/m3]		NO <sub>2</sub> [µg/m3]		NH <sub>3</sub> [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL8 -1	02.07.2022	157	104	49	3.26	2.66	11.77	11.08	7.04	6.49
					1.81		11.08		6.49	
					2.90		10.39		5.94	
AL8 -2	05.07.2022	161	105	50	5.08	3.75	15.93	15.93	8.15	7.09
					3.63		17.31		5.25	
					2.54		14.54		7.87	
AL8 -3	08.07.2022	134	88	41	2.18	3.51	9.70	12.01	6.77	8.70
					4.35		12.47		10.22	
					3.99		13.85		9.12	
AL8 -4	12.07.2022	196	118	70	5.44	4.71	17.31	14.08	7.60	6.17
					3.99		13.16		5.25	
					4.71		11.77		5.66	
AL8 -5	15.07.2022	184	116	55	1.45	2.18	10.39	9.47	7.87	7.32
					2.18		8.31		8.01	
					2.90		9.70		6.08	
AL8 -6	19.07.2022	138	93	43	3.99	3.26	15.24	16.85	5.53	5.67
					3.26		17.31		6.22	
					2.54		18.01		5.25	
AL8 -7	22.07.2022	164	102	58	0.73	1.09	8.31	9.69	8.70	7.60
					1.09		9.00		6.77	
					1.45		11.77		7.32	
AL8-8	26.07.2022	163	104	52	2.18	2.06	10.39	12.93	6.49	8.61
					1.81		15.93		9.12	
					2.18		12.47		10.22	
AL8-9	29.07.2022	170	98	59	3.26	3.38	13.16	13.62	5.66	6.26
					4.35		11.77		6.22	
					2.54		15.93		6.91	
Monthly Average		163	103	53		3		13		7
Standard Deviation		20	10	9		1		3		1

<b>Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL8 -1</b>	02.07.2022	1.08	BQL	1.54	451
<b>AL8 -2</b>	05.07.2022	1.11	BQL	1.3	474
<b>AL8 -3</b>	08.07.2022	1.13	BQL	1.61	514
<b>AL8 -4</b>	12.07.2022	1.04	BQL	1.58	498
<b>AL8 -5</b>	15.07.2022	1.05	BQL	2.01	501
<b>AL8 -6</b>	19.07.2022	1.18	BQL	1.99	337
<b>AL8 -7</b>	22.07.2022	1.17	BQL	1.7	491
<b>AL8 -8</b>	26.07.2022	1.17	BQL	2.08	437
<b>AL8 -9</b>	29.07.2022	1.1	BQL	1.52	456
<b>Monthly Average</b>		<b>1.12</b>	<b>-</b>	<b>1.73</b>	<b>463</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.27</b>	<b>57</b>

\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM value at Admin Building Vadinar was 163 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 103 µg/m<sup>3</sup> which is slightly above the permissible limit, PM<sub>2.5</sub> value was 53 µg/m<sup>3</sup> which is within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.0 µg/m<sup>3</sup>, 13.0 µg/m<sup>3</sup> and 7.0 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Admin Building, Vadinar Port. The mean Benzene concentration was 1.162 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.73 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

### **3.3 Observations and Conclusion**

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Total Suspended Particulate matter as TSPM, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan, Estate Office and Oil Jetty. The concentration of PM<sub>10</sub> was slightly higher at Gopalpuri Hospital, Admin building Vadinar & Signal building Vadinar while the concentration of PM<sub>2.5</sub> was found within permissible limit. Only at Tuna port, all parameters of ambient air quality were found within the limit.

# Meteorological Observation

#### **4.1 Meteorological Data**

Automatic Weather station (ID KAZPHOEN424) have been installed in Seva Sadan - 3 at the Deendayal Port which records the data on Temperature (°C), Relative Humidity (%), Wind speed (kmph), Wind Direction (°), Solar radiation (w/m<sup>2</sup>) and Rainfall mm.

##### **Temperature**

The mean day time temperature for Deendayal Port was 25.6 °C. The day-time maximum temperature was 34.3°C. The mean night time temperature recorded was 28.4 °C.

##### **Solar Radiation**

The mean Solar Radiation in July month was 115.72 w/m<sup>2</sup>. The maximum solar radiation was recorded 623.2 w/m<sup>2</sup> in 18<sup>th</sup> July and the minimum solar radiation was recorded 0.23 w/m<sup>2</sup> in 27<sup>th</sup> July

##### **Rainfall**

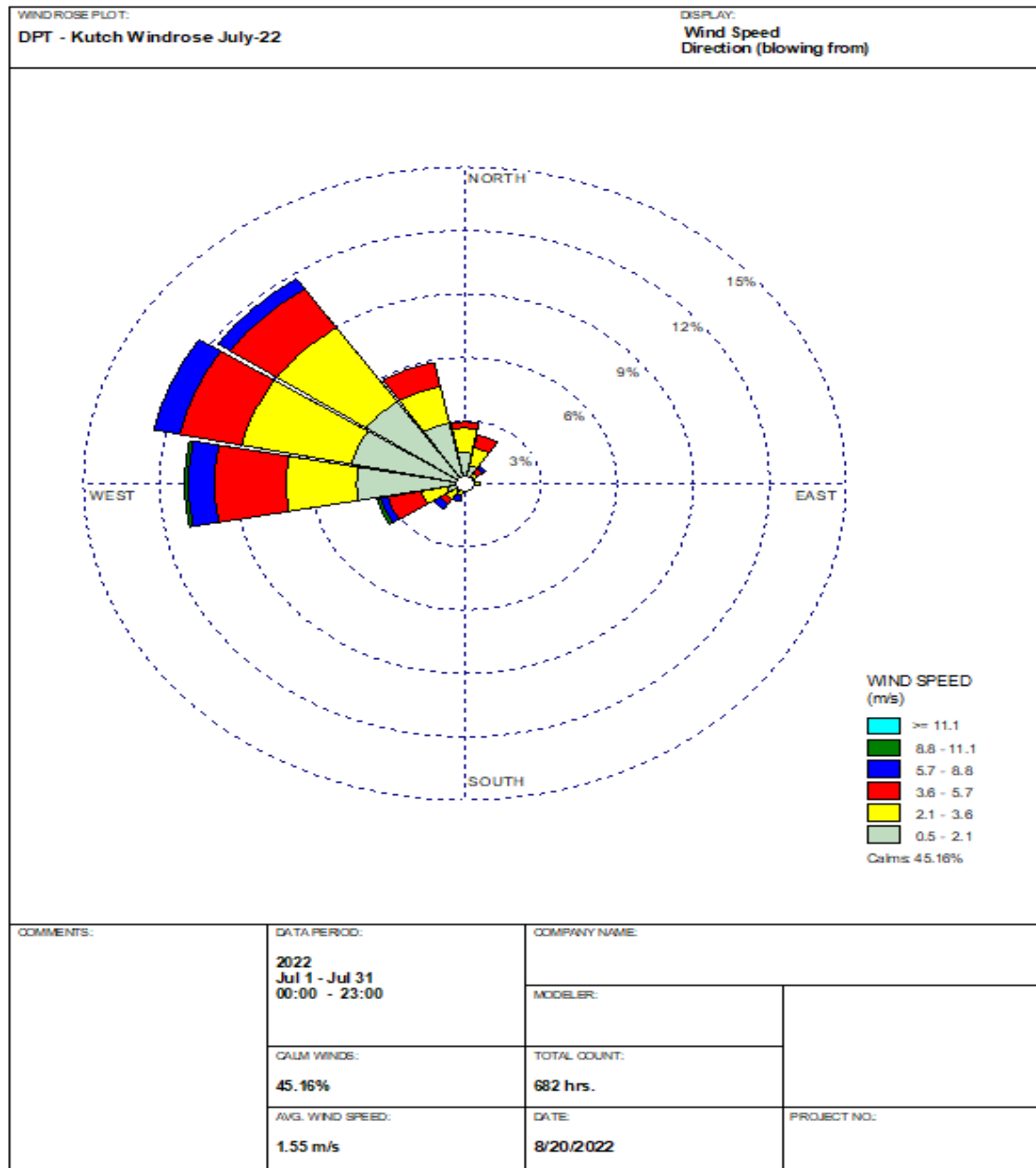
The total Rainfall in the month of July was recorded 6.5 mm.

##### **Relative Humidity**

The mean Relative humidity was 88.15 % for the month of July. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 47 %.

##### **Wind Velocity and Wind Direction**

The average wind velocity for the entire month of July was 1.56 m/s. Maximum wind velocity was recorded 13.8 m/s. The wind direction was mostly North West.





# Drinking Water Monitoring

## **5.0 Drinking Water Quality Monitoring**

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

### **5.1 Drinking Water Monitoring Methodology**

Drinking water samples were collected from 20 locations as prescribed in the tender document. Samples for physico-chemical analysis were collected in 2 Carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS 3025 Part-1, analysis was done as per IS3025/APHA standard methods and, the analysis results compare with IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate , Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (cfu) .

### **5.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 9 to Table No. 15

**Table 9: Drinking Water Quality Monitoring Parameters for Nirman Building 1 (23° 0' 27"E, 70° 13' 21"N) P & C building (23° 0' 33"E 70° 13' 20"N) & Main Gate (North) at Kandla (23° 0' 26.97"E, 70° 13' 21.87"N)**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C building	Main Gate North	Acceptable Limits as per IS 10500 :2012 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 :
1	pH	-	8.48	8.18	8.6	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	634	610	560	500	2000
3	Turbidity	NTU	1	0.2	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1313	1210	1110	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	160.36	145.32	120.27	250	1000
9	Total Hardness	mg/l	340	240	200	200	600
10	Calcium	mg/l	40.08	48.10	52.10	75	200
11	Salinity	‰	0.29	0.26	0.22	NS*	NS*
12	Mg as Mg	mg/l	58.32	29.16	17.01	30	100
13	Fluorides as F	mg/l	0.22	0.31	0.13	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	27.72	24.26	21.49	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	0.40	0.28	0.81	45	No Relaxation
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
18	Sodium as Na	mg/l	98.57	91.74	88.00	NS*	NS*
19	Potassium as K	mg/l	3.59	5.94	3.04	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Table 10: Drinking Water Quality Monitoring Parameters for Canteen, (23° 2' 17.2674"E, 70° 13' 18.2814"N) West Gate – I(23° 59' 40.48"E, 70° 12' 50.96"N) & Wharf Area (22° 59' 52.2"E, 70° 13' 22.95"N) at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per IS 10500 :	Permissible Limits in the absence of Alternate Source as per IS 10500 :
1	pH	-	7.63	7.6	7.57	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	650	620	600	500	2000
3	Turbidity	NTU	1	0.6	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1260	1240	1760	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	145.32	130.29	120.27	250	1000
9	Total Hardness	mg/l	210	210	230	75	600
10	Calcium	mg/l	56.11	52.10	48.10	30	200
11	Salinity	‰	0.26	0.26	0.24	NS*	NS*
12	Mg as Mg	mg/l	17.01	19.44	26.73	0.3	100
13	Fluorides as F	mg/l	0.29	0.18	0.16	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	31.65	28.18	21.25	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	8.26	2.62	0.60	45	No Relaxation
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
18	Sodium as Na	mg/l	96.98	97.46	93.40	NS*	NS*
19	Potassium as K	mg/l	4.61	3.19	3.75	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd- 0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 11:Drinking Water Quality Monitoring Parameters for Sewa sadan – 3,( 23° 0' 22.55"E, 70° 13' 15.34"N) Workshop I (23° 0' 33.74"E, 70° 13' 20.05"N)&Custom Building (23° 1' 8.70"E, 70° 12' 52.0"N) at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.66	7.75	7.95	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	540	460	659	500	2000
3	Turbidity	NTU	1	0.7	0.5	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1182	940	1333	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	100.22	145.32	125.28	250	1000
9	Total Hardness	mg/l	200	170	240	200	600
10	Calcium	mg/l	44.09	40.08	48.10	75	200
11	Salinity	‰	0.22	0.18	0.26	NS*	NS*
12	Mg as Mg	mg/l	21.87	17.01	29.16	30	100
13	Fluorides as F	mg/l	0.15	1.16	0.26	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	24.03	21.02	37.43	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	2.21	0.20	0.94	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	86.43	76.83	98.64	NS*	NS*
19	Potassium as K	mg/l	2.94	2.73	3.39	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd- 0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 12:Drinking Water Quality Monitoring Parameters for Port Colony Kandla(23° 11' 14.9"E, 70° 12' 48.4"N) Hospital Kandla 23° 1' 5.02"E, 70° 12' 44.38"N)& A.O. Building (23° 3' 42.89"E, 70° 8' 41.5"N) atGandhidham**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.92	7.65	7.71	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	595	697	920	500	2000
3	Turbidity	NTU	1	1	1	1	5
4	Odour	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1149	1399	1220	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	145.32	205.46	115.26	250	1000
9	Total Hardness	mg/l	170	190	310	200	600
10	Calcium	mg/l	44.09	40.08	48.10	75	200
11	Salinity	‰	0.23	0.26	0.37	NS*	NS*
12	Mg as Mg	mg/l	14.58	21.87	46.17	30	100
13	Fluorides as F	mg/l	0.07	0.40	0.45	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	25.41	40.43	62.84	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	0.40	0.54	7.38	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	88.56	102.22	187.70	NS*	NS*
19	Potassium as K	mg/l	2.94	3.08	3.79	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l, Fe-0.009 mg/l,Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd- 0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 13: Drinking Water Quality Monitoring Parameters for School Gopalpuri,( 23° 5' 1.03"E, 70° 7' 55.42"N) Guest House (23° 4' 43.14"E, 70° 7' 51.92"N) & E - Type Quarter(23° 4' 59.90"E, 70° 7' 56.72"N) at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.72	7.61	7.56	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	603	497	495	500	2000
3	Turbidity	NTU	0.8	0.4	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1221	969	952	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	90.20	100.22	95.21	250	1000
9	Total Hardness	mg/l	240	210	180	200	600
10	Calcium	mg/l	40.08	40.08	40.08	75	200
11	Salinity	‰	0.21	0.16	0.18	NS*	NS*
12	Mg as Mg	mg/l	34.02	26.73	19.44	30	100
13	Fluorides as F	mg/l	0.23	0.26	0.35	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	30.03	25.18	20.10	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	0.74	0.87	0.60	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	88.51	71.94	70.96	NS*	NS*
19	Potassium as K	mg/l	4.36	2.59	2.72	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd- 0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 14:Drinking Water Quality Monitoring Parameters for F - Type Quarter, (23° 4' 38.45"E, 70° 8' 8.63"N) Hospital Gopalpuri (23° 4' 54.09"E, 70° 8' 7.5"N) & Tuna Port (23° 58' 23.06"E, 70° 5' 35.6"N)**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.6	8.38	7.88	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	492	518	1970	500	2000
3	Turbidity	NTU	1	0.6	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1020	1020	3250	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	100.22	75.17	74.97	250	1000
9	Total Hardness	mg/l	190	220	350	200	600
10	Calcium	mg/l	44.09	48.10	40.08	75	200
11	Salinity	‰	0.17	0.18	0.14	NS*	NS*
12	Mg as Mg	mg/l	19.44	24.3	60.75	30	100
13	Fluorides as F	mg/l	0.33	0.23	1.39	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	21.95	25.64	123.60	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.41	2.48	4.03	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	73.97	77.65	460.00	NS*	NS*
19	Potassium as K	mg/l	2.68	3.54	6.80	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



**Table 15: Drinking Water Quality Monitoring Parameters for Vadinar Jetty (22° 25' 51.73"E, 69° 41' 36.62"N) & Port Colony (22° 30' 26.25"E, 69° 39' 45.03"N) at Vadinar**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.46	7.38	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	480	468	500	2000
3	Turbidity	NTU	1.00	0.30	1	5
4	Odor	-	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	5	15
6	Conductivity	µs/cm	940	945	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	104.97	89.97	250	1000
9	Total Hardness	mg/l	150	160	200	600
10	Calcium	mg/l	19.93	20.41	75	200
11	Salinity	‰	0.16	0.10	NS*	NS*
12	Mg as Mg	mg/l	85.05	72.90	30	100
13	Fluorides as F	mg/l	0.31	0.27	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	53.82	50.24	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.95	0.67	45	100
17	Iron as Fe	mg/l	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	94.9	74.2	NS*	NS*
19	Potassium as K	mg/l	BQL(1.88)	BQL(1.85)	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd- 0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **5.3 Results & Discussion**

The colour of all drinking water samples was found Colourless and odour of the samples also agreeable. All parameters were found within the specified limit as per the Drinking water Standard.

#### **pH**

The pH values for drinking water samples were ranges from 7.38-8.60 and mean value was 7.81. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Total Dissolved Solids (TDS)**

TDS values in the studied area varied between 460-920 mg/l. None of the sampling points showed higher TDS values than the prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of July ranged from 940-1760 $\mu$ s/cm and mean value was 1167  $\mu$ s/cm.

#### **BOD**

BOD value in the studied area was found Below Quantification Limit (2.0 mg/l). IS 10500:2012 does not show any standard values for BOD in drinking water.

#### **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. Chloride value in the studied area varied between 75.17 – 205.46 mg/l and mean value was 120.24 mg/l. The Chloride was found within the Permissible limit of the Drinking Water Standard.

#### **Calcium**

Calcium value in the studied area varied between 19.93 – 56.11 mg/l and mean was 42.70 mg/l. The Calcium values were found to be within the Permissible limit of the Drinking Water Standard. If calcium is present beyond the maximum acceptable limit, it causes incrustation of pipes.

#### **Magnesium**

Magnesium value in the studied area varied between 14.58 - 85.05 mg/l and mean value was 33.05 mg/l. All the locations had Magnesium within the prescribed limits of 30-100 mg/L.

#### **Total Hardness**

Hardness value in the studied area varied between 150- 350 mg/l and mean was 220 mg/l. The values of total hardness were found within the Permissible limit of the Drinking Water Standard (200-600 mg/L).

### **Iron**

Iron value in the studied area was found Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards is 0.3 mg/L. The excess amount of iron causes slight toxicity; gives stringent taste to water.

### **Fluoride**

Fluoride value in the studied area varied between 0.07 – 1.39 mg/l and mean was 0.37 mg/l. The Fluoride values were in line the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphates**

Sulphate value in the studied area varied between 20.10 – 62.84 mg/l and mean was 31.19 mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

Nitrite values in all the water samples were found Below Quantification Limit (0.1 mg/l). There were no specified standard values for Nitrites in Drinking water. The minimum Nitrate value in drinking water of DPA was ranges from 0.20-8.26 mg/l which is well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected ranged from 0.10 to 0.37 ‰. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected ranged from 70.96- 460.0 mg/l and Potassium salts ranged from 2.59 to 6.80 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter (E-coli and total coliform) at all location shows that Bacteria were not detectable. This shows that drinking water samples were safe for human consumption as per tested parameters.

## **5.4 Conclusions**

These results were compared with acceptable limits as prescribed in IS 10500:2012–Drinking Water Specification. It was seen from the analysis data that during the study period the water was safe for human consumption as per analyzed parameters only at all drinking water monitoring stations.

# Noise Quality Monitoring

## 6.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 6.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 6.2 Results

**Table 16: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	6:00 am to 10:00 PM	10:00PM to 6:00 AM
1	Marine Bhavan	58.4	56.1
2	Nirman Building 1	62.9	59.2
3	Tuna Port	56.8	55.2
4	Main Gate North	69.2	64.4
5	West Gate I	69.3	63.2
6	Canteen Area	63.0	55.6
7	Main Road	72.2	66.2
8	ATM Building	70.4	65.2
9	Wharf Area /Jetty Area	70.9	63.8
10	Port & Custom Office	49.6	46.6
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	56.6	55.1
12	Nr. Port Colony, Vadinar	63.9	54.1
13	Nr. Vadinar Jetty	56.0	56.3

### 6.3 Conclusions

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 13 locations at Deendayal Port ranged from 49.6 dB(A) to 70.9 dB(A) and it was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all 13 locations of Deendayal Port ranged from 46.6 dB to 66.2 dB(A) and it was within the permissible limits of 70 dB(A) for the industrial area for the night time.

# Soil

# Quality Monitoring

## **7.0 Soil Monitoring**

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

### **7.1 Methodology**

The soil samples were collected in the month of July 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.



## 7.2 Results

**Table-17: Chemical Characteristics of Soil in the Study Area for Tuna port,(22° 58' 10.18"E, 70° 6' 3.7"N) IFFCO plant (23° 26' 8.37"E, 70° 13' 4.4"N), Khori creek, (22° 58' 10.18"E, 70° 6' 3.7"N) Nakti Creek,( 23° 2' 1.10"E, 70° 9' 33.6"N) DPA admin site,( 22° 26' 30.9"E, 69° 40' 37.03"N) DPA colony(22° 23' 57.09"E, 69° 42' 49.42"N)**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main	Sand from creek after tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	7.58	7.94	7.64	8.01	8.03	8.57
3	Electrical Conductivity	µs/cm	34,800.00	11,000.00	22,980.00	24,990.0	490.0	786.0
4	Moisture	%	16.40	7.76	5.74	30.79	8.76	4.88
5	Total Organic Carbon	%	0.39	0.24	0.16	0.71	1.94	0.64
6	Alkalinity	mg/kg	80.08	70.07	40.04	50.05	20.02	24.02
7	Total Nitrogen	%	0.03	0.02	0.01	0.06	0.17	0.06
8	Chloride	mg/kg	3,772.0	1,241.0	2,184.0	2,531.0	79.4	179.0
9	Sulphate	mg/kg	1,407.00	738.00	2,270.00	673.04	22.08	17.05
10	Phosphorus	mg/kg	2.80	3.06	6.20	2.20	BQL	BQL
11	Potassium	mg/kg	110.41	85.96	54.22	171.18	17.11	39.36
12	Sodium	mg/kg	2,425.00	1,168.00	1,374.00	1,761.00	63.55	109.55
13	Calcium	mg/kg	200.40	172.34	216.43	156.31	396.79	260.90
14	Copper as Cu	mg/kg	16.60	61.60	18.00	24.40	74.50	56.30
15	Lead as Pb	mg/kg	BQL	BQL	6.90	6.20	BQL	BQL
16	Nickel as Ni	mg/kg	14.60	31.20	11.50	35.80	18.10	26.80
17	Zinc as Zn	mg/kg	24.00	92.70	17.70	52.60	74.00	37.20
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg).

### **7.3 Discussion**

- The data shows that value of pH ranges from 7.58 at Tuna Port (Near Main Gate of Port) to 8.01 at (Nakti Creek) and mean was 7.79 at Deendayal Port. At Vadinar Port the pH ranges from 8.03 DPA Admin Site to 8.57 at DPA colony and mean was 8.30 indicating that all soil samples were neutral to slight basic. Tuna Port sample showed maximum conductivity of 34800  $\mu\text{S}/\text{cm}$  and minimum was 1100  $\mu\text{S}/\text{cm}$ , while Vadinar location showed maximum conductivity of 490  $\mu\text{S}/\text{cm}$  and minimum was 786  $\mu\text{S}/\text{cm}$  at DPA Colony mean was 638  $\mu\text{S}/\text{cm}$ .
- Total organic Carbon ranged from 0.16 % to 0.71 % at Deendayal Port and mean was 0.38. At Vadinar Port, organic Carbon range from 0.64% to 1.94 % and mean was 1.29 %.
- The concentration of Phosphorus and Potassium in the soil samples varies from 2.20 mg/kg at Nakti Creek to 6.20 mg/kg at Khor Creek and 54.22 mg/kg at Khor Creek to 171.18 mg/kg at Nakti Creek at Deendayal Port and mean was 105.44 mg/kg at Deendayal Port. The concentration of Phosphorus was found BQL at Vadinar and mean concentration of Potassium at Vadinar site was 28.24 mg/kg.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khor Creek & Nakti Creek) were of saline nature as they were coastal soil; whereas other locations are inland locations and have different chemical properties.

### **Heavy Metals in the Soil**

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### **7.4 Conclusion**

The soils of Deendayal Port and Vadinar Port appear to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

# Sewage Treatment Quality Monitoring

## 8.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guidelines of State Pollution Control Board and other statutory bodies.

### 8.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

### 8.2 Results

**Table 18: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	06.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.44	7.26	6.5 - 8.5
2	Total Suspended Solids	mg/l	143	49	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	88	30	100
5	BOD @ 27 °C	mg/l	28.0	13.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	16.0		
7	MLVSS	%	90.0		

**Table 19: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

Date of Sampling	15.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.56	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	87	57	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	70	30	100
5	BOD @ 27 °C	mg/l	22.0	10.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	22.0		
7	MLVSS	%	87.0		

**Table 20: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

Date of Sampling	19.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.56	7.29	6.5 - 8.5
2	Total Suspended Solids	mg/l	98	69	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	70	60	100
5	BOD @ 27 °C	mg/l	21.0	17.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	14.0		
7	MLVSS	%	90.0		

**Table 21: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	26.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.44	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	101	64	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	80	40	100
5	BOD @ 27 °C	mg/l	21.0	12.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	12.0		
7	MLVSS	%	92.0		

**Table 22: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	06.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.56	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	55	40	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	70	50	100
5	BOD @ 27 °C	mg/l	28.0	19.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	32.0		
7	MLVSS	%	88.0		

**Table 23: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

Date of Sampling		15.07.2022			
Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.65	7.41	6.5 - 8.5
2	Total Suspended Solids	mg/l	78	62.0	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	72.0	50.0	100
5	BOD @ 27 °C	mg/l	24.0	15.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l		38.0	
7	MLVSS	%		89.0	

**Table 24: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

Date of Sampling		19.07.2022			
Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.45	7.23	6.5 - 8.5
2	Total Suspended Solids	mg/l	72	35	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	50	20	100
5	BOD @ 27 °C	mg/l	14.0	4.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l		36.0	
7	MLVSS	%		87.0	

**Table 25: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	26.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.56	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	72	40	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	60	20	100
5	BOD @ 27 °C	mg/l	18.0	4.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	32.0		
7	MLVSS	%	89.0		

**Table 26: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	06.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.61	7.44	6.5 - 8.5
2	Total Suspended Solids	mg/l	100	59.6	100
3	Residual Chlorine	mg/		<0.5	-
4	COD	mg/l	101.0	51	100
5	BOD @ 27 °C	mg/l	34.0	18.0	30



**Table 27: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	15.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.45	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	89	40	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	80	48	100
5	BOD @ 27 °C	mg/l	28.0	16.0	30

**Table 28: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	19.07.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.51	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	107.5	36.1	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	131.3	50.5	100
5	BOD @ 27 °C	mg/l	-	-	30

**Table 29: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	21.06.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.33	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	99.8	44.9	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	121.2	70.7	100
5	BOD @ 27 °C	mg/l	-	-	30

### 8.3 Conclusions:

The GPCB specification for pH, TSS, Residual Chlorine, COD and BOD for STP outlet were 6.5 to 8.5, 100 mg/l, 0.5 mg/l, 100 mg/l and 30 mg/l respectively. The outlet values for pH were ranges from 7.23-7.4, 7.26-7.32, and 7.21-7.44 at Gopalpuri, KPT and Vadinar respectively. The Total Suspended Solids values were 35-62 mg/l, 49-69 mg/l, 36.1-59.6 mg/l at Gopalpuri, KPT and Vadinar respectively. The COD values were ranges from 20.5-50 mg/l, 30-60 mg/l, and 48-70.7 at Gopalpuri, KPT and Vadinar respectively. The BOD values were ranges from 4-19 mg/l, 10-17 mg/l, and 16-18 mg/l at Gopalpuri, KPT and Vadinar respectively. At all sampling location Residual Chlorine were found below detectable limit. All parameters for STP outlet are within limit.

# Marine Water Quality Monitoring

## **9.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of ‘green thinking’. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the “fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”.

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at “integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources.” The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 07<sup>th</sup> & 08<sup>th</sup> July-2022 in harbor regions of DPA & Vadinar during Neap tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 15<sup>th</sup> & 16<sup>th</sup> July 2022 in harbor regions of DPA & Vadinar during Spring tide period first quarter of Lunar Cycle.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbour area and two stations in Nakti creek and one station in Khorī creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

**Sampling Locations**

<b>Offshore monitoring requirement</b>	<b>Number of locations</b>
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khorī creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

**9.1 Marine Water Quality and Results**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khorī & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 30 to 37.

**Table 30: Marine Water Quality Monitoring Parameters for location near DPA colony**

Sr. No.	Parameters	Unit	Kandla Creek Near DPA colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.45	7.35	7.59	7.55
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	32.1	33.0	31.2	32.1
5	Turbidity	NTU	42	45	46	47
6	Total Dissolved Solids	mg/l	41443	40010	39820.0	41830.0
7	Total Suspended Solids	mg/l	778	662	612.5	738.8
8	Total Solids	mg/l	42300	40708	40608.0	42620.0
9	DO	mg/l	5.2	5.1	5.4	5.3
10	COD	mg/l	96.0	86.0	90.0	88.0
11	BOD	mg/l	BQL	BQL	0.46	0.36
12	Silica	mg/l	0.52	0.40	0.37	0.04
13	Phosphate	mg/l	0.49	0.19	2183	1594
14	Sulphate	mg/l	1593.9	1524.6	2.15	1.81
15	Nitrate	mg/l	2.48	4.70	0.15	0.15
16	Nitrite	mg/l	0.19	0.16	721.44	761.52
17	Calcium	mg/l	601.20	641.28	1628.1	1652.4
18	Magnesium	mg/l	1215	1409.4	11445.0	10540.0
19	Sodium	mg/l	11830.0	10956.0	312.0	402.0
20	Potassium	mg/l	372.0	358.0	0.44	1.16
21	Iron	mg/l	2.08	0.59	0.46	0.36
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 31: Marine Water Quality Monitoring Parameters for location near passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.26	7.31	7.46	7.43
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	33.9	32.6	30.2	30.8
5	Turbidity	NTU	38	37	43	42
6	Total Dissolved Solids	mg/l	41332	40820	39530.0	38950.0
7	Total Suspended Solids	mg/l	748	649	492.8	486.1
8	Total Solids	mg/l	42120	41489	40090.0	40014.0
9	DO	mg/l	4.9	4.8	5.4	4.9
10	COD	mg/l	68.0	64.0	72.0	70.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.46	0.38	0.64	0.24
13	Phosphate	mg/l	0.23	0.25	0.30	0.42
14	Sulphate	mg/l	1201.2	2148.3	1917	1594
15	Nitrate	mg/l	4.83	1.88	4.56	2.82
16	Nitrite	mg/l	0.11	0.12	0.11	0.06
17	Calcium	mg/l	561.12	521.04	681.36	641.28
18	Magnesium	mg/l	1287.9	1458	1701	1676.7
19	Sodium	mg/l	9307.0	9674.0	10330.0	10169.0
20	Potassium	mg/l	348.0	359.0	412.0	409.0
21	Iron	mg/l	0.56	1.42	1.12	0.63
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Nitrite: 0.05mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 32: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.51	7.48	7.51	7.6
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	31.2	30.3	33.5	32.6
5	Turbidity	NTU	46	41	39	40
6	Total Dissolved Solids	mg/l	38446	41706	41150.0	41485.0
7	Total Suspended Solids	mg/l	553	844	638.8	897.9
8	Total Solids	mg/l	40048	42674	42019.0	42420.0
9	DO	mg/l	4.7	4.6	4.8	5.1
10	COD	mg/l	68.0	62.0	78.0	74.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.72	0.60	0.84	0.48
13	Phosphate	mg/l	0.29	0.36	0.31	0.38
14	Sulphate	mg/l	1663.2	1085	1675	2056
15	Nitrate	mg/l	2.62	2.95	2.28	1.95
16	Nitrite	mg/l	0.07	BQL	BQL	BQL
17	Calcium	mg/l	681.36	721.44	681.36	721.44
18	Magnesium	mg/l	1287.9	996.3	1749.6	1701
19	Sodium	mg/l	9033.0	9741.0	11250.0	10718.0
20	Potassium	mg/l	365.0	261.0	461.0	514.0
21	Iron	mg/l	1.25	BQL	1.69	4.86
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).



**Table 33: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	DPA 4			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.35	7.23	7.45	7.38
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	31.7	32.6	30.8	30.3
5	Turbidity	NTU	39	40	42	41
6	Total Dissolved Solids	mg/l	42949	41470	38743.0	38808.0
7	Total Suspended Solids	mg/l	819	844	598.8	694.7
8	Total Solids	mg/l	43780	42514	40019.0	40078.0
9	DO	mg/l	4.5	5	5.2	4.7
10	COD	mg/l	52.0	50.0	62.0	57.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.48	0.40	0.66	0.80
13	Phosphate	mg/l	0.20	0.24	0.27	0.31
14	Sulphate	mg/l	9286.2	1640.1	1917	1698
15	Nitrate	mg/l	2.55	6.38	3.22	4.77
16	Nitrite	mg/l	0.08	0.09	0.07	0.10
17	Calcium	mg/l	601.20	561.12	641.28	721.44
18	Magnesium	mg/l	1555.2	1628.1	1701	1628.1
19	Sodium	mg/l	11668.0	11259.0	10829.0	10623.0
20	Potassium	mg/l	358.0	341.0	483.0	498.0
21	Iron	mg/l	0.12	0.46	0.72	0.10
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 34: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.45	7.41	7.49	7.55
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	33.0	32.1	30.1	32.1
5	Turbidity	NTU	42	43	45	40
6	Total Dissolved Solids	mg/l	39660	40260	35000.0	36084.0
7	Total Suspended Solids	mg/l	850	736	482.2	741.8
8	Total Solids	mg/l	40520	41086	39682.0	41978.0
9	DO	mg/l	5.3	5.1	4.6	5
10	COD	mg/l	95.0	86.0	90.0	87.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.59	0.56	0.56	0.52
13	Phosphate	mg/l	0.52	0.64	0.34	0.23
14	Sulphate	mg/l	2333.1	6675.9	1698	2056
15	Nitrate	mg/l	0.81	3.69	4.50	2.95
16	Nitrite	mg/l	0.07	0.11	0.06	0.10
17	Calcium	mg/l	681.36	641.28	761.52	641.28
18	Magnesium	mg/l	1506.6	1628.1	1652.4	1701
19	Sodium	mg/l	10156.0	8153.0	10356.0	9985.0
20	Potassium	mg/l	361.0	373.0	427.0	302.0
21	Iron	mg/l	1.51	4.27	0.72	0.73
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 35: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.49	Sampling not possible during Low Tide	7.52	Sampling not possible during Low Tide
2	Color	-	Colorless		Colorless	
3	Odor	-	Odorless		Odorless	
4	Salinity	‰	31.7		32.8	
5	Turbidity	NTU	47		39	
6	Total Dissolved Solids	mg/l	41800		42238.0	
7	Total Suspended Solids	mg/l	389		366.6	
8	Total Solids	mg/l	42198		43114.0	
9	DO	mg/l	4.6		4.7	
10	COD	mg/l	110.0		106.0	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	0.72		0.68	
13	Phosphate	mg/l	0.26		0.38	
14	Sulphate	mg/l	8662.5		2795	
15	Nitrate	mg/l	1.07		3.42	
16	Nitrite	mg/l	0.14		0.11	
17	Calcium	mg/l	721.44		601.2	
18	Magnesium	mg/l	1020.6		1773.9	
19	Sodium	mg/l	10900.0		11557.0	
20	Potassium	mg/l	364.0		533.0	
21	Iron	mg/l	0.55		BQL	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		BQL	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1 mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 36: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.32	7.26	7.45	7.48
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	31.2	32.6	31.8	31.2
5	Turbidity	NTU	46	41	38	41
6	Total Dissolved Solids	mg/l	40970	41360	39140.0	38310.0
7	Total Suspended Solids	mg/l	350	368	401.3	310.2
8	Total Solids	mg/l	42032	41736	40102.0	40462.0
9	DO	mg/l	4.5	4.3	4.8	5.0
10	COD	mg/l	70.0	74.0	74.0	72.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.80	0.52	0.84	0.66
13	Phosphate	mg/l	0.31	1.16	0.40	0.42
14	Sulphate	mg/l	3026.1	1201.2	3095	2564
15	Nitrate	mg/l	0.80	2.01	4.16	5.30
16	Nitrite	mg/l	0.06	0.07	0.10	0.09
17	Calcium	mg/l	601.20	521.04	561.12	601.2
18	Magnesium	mg/l	1166.4	1142.1	1749.6	1773.9
19	Sodium	mg/l	9530.0	9609.0	11043.0	10980.0
20	Potassium	mg/l	331.0	360.0	536.0	400.0
21	Iron	mg/l	0.38	0.28	0.27	0.96
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 37: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr.Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.40	7.20	7.44	7.37
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	33.0	33.9	31.7	31.8
5	Turbidity	NTU	43.0	40.0	38.0	36.0
6	Total Dissolved Solids	mg/l	41810.0	41200.0	42920.0	43060.0
7	Total Suspended Solids	mg/l	313.0	358.0	337.9	462.2
8	Total Solids	721.44	42140.0	41584.0	44400.0	44460.0
9	DO	mg/l	4.6	4.4	3.9	3.8
10	COD	mg/l	89.0	90.0	92.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.68	0.71	0.78	0.80
13	Phosphate	mg/l	0.11	0.38	0.49	0.54
14	Sulphate	mg/l	831.6	1940.4	2287	2888
15	Nitrate	mg/l	0.19	0.27	2.28	3.02
16	Nitrite	mg/l	BQL	BQL	0.07	0.05
17	Calcium	mg/l	641.28	561.12	721.44	681.36
18	Magnesium	mg/l	972	996.3	1628.1	1628.1
19	Sodium	mg/l	9756.0	9892.0	10620.0	10180.0
20	Potassium	mg/l	372.0	361.0	378.0	344.0
21	Iron	mg/l	BQL	0.1	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

## **9.2 Results & Discussion for Marine water samples**

Marine water quality of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

### **pH**

The limit of pH value for drinking water was 7.28 to 7.65. During spring tide the pH values was ranges from 7.23-7.51 at KPT and 7.20-7.40 at Vadinar while during Neap Tide pH values was ranges from 7.38-7.60 at KPT and 7.30-7.48 at Vadinar.

### **Color and Odour**

All marine samples was found odourless and Colourless at all locations.

### **Total Dissolved Solids (TDS)**

TDS values in the studied area during Spring Tide varied between 38446 to 42949 mg/l at KPT and 40970 to 41810 mg/l at Near Vadinar while during Neap Tide TDS values was varied 12238 to 42238 mg/l at KPT and 38310 to 43060 mg/l at Near Vadinar.

### **Calcium**

Calcium value in the studied area during Spring Tide varied between 521.04 to 721.44 mg/l at KPT and 521.64 to 641.28 mg/l at Near Vadinar while during Neap Tide calcium values between 561.12 to 761.52 mg/l at KPT and 601.20 to 721.49 at Vadinar.

### **Magnesium**

Magnesium value in the studied area during Spring Tide varied between 996.30 to 1628.10 mg/l at KPT and 972.00 to 1666.40 mg/l at Near Vadinar while during Neap Tide calcium values between 1628.10 to 1773.90 mg/l at KPT and 1628.10 to 1773.90 at Vadinar.

### **Iron**

Iron values in the studied area during Spring Tide was found 0.12 to 4.27 mg/l at KPT and 0.38 to 0.10 mg/l at Vadinar while during Neap Tide the iron values was varied 0.10 to 4.86 mg/l at KPT and 0.27 to 0.96 at Vadinar.

### **Sulphates**

Sulphate values in the studied area during Spring Tide was found 1085 to 9286 mg/l at KPT and 831.60 to 03026.10 mg/l at Vadinar while during Neap Tide the Sulphate values was varied 1593.90 to 3095.40 mg/l at KPT and 2286.90 to 2888.00 at Vadinar.

## **Salinity**

Salinity values in the studied area during Spring Tide was found 30.33 to 33.95 ‰ at KPT and 31.23 to 33.95 ‰ at Vadinar while during Neap Tide the Salinity values was varied 30.10 to 33.50 ‰ at KPT and 30.78 to 31.80 at Vadinar.

## **Sodium and Potassium Salts**

During Spring Tide the Sodium values ranged from 8153-11830 mg/l at KPT & 9530-9892 mg/l at Vadinar and Potassium salts ranged from 261-373 mg/l at KPT & 331-372 mg/l at Vadinar while during Neap Tide the sodium values was ranges from 9985-11557 mg/l at KPT & 10180-11043 mg/l at Vadinar and Potassium salts ranged from 553 -344 mg/l at KPT & 344-536 mg/l at Vadinar.

## **DO**

From the studied samples, DO in marine water during Spring Tide was found in ranges from 4.5 - 5.3 mg/l at KPT and 4.3-4.6 mg/l at Vadinar while during Neap Tide 3.80-5.40 mg/l at KPT and 3.80-5.30 mg/l at Vadinar.

## **BOD**

BOD in marine water in the studied samples was found Below Quantification limit. Which is under than 5.0 mg/l

## **Heavy Metals in Marine Water**

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

## **9.3 Conclusion**

In the present study period marine water samples were analyzed and found inline as per Primary Water Quality criteria for class SW-IV WATERS (For Harbour Waters).

# Marine Sediment Quality Monitoring



## **10.0 Marine Sediments**

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

### **10.1 Results**

The Sediment Quality results are given in below from table no. 38& 39.

**Table 38: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	2.72	3.87	2.94	2.51	2.14	5.84	4.10
3	Organic Carbon	mg/kg	1.58	2.24	1.71	1.46	1.24	3.39	2.38
4	Inorganic Phosphate	mg/kg	109.00	119.00	121.00	128.00	142.00	166.00	154.00
5	Moisture	%	12.20	26.26	12.16	8.88	19.20	32.26	34.44
6	Aluminium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
7	Silica	mg/kg	23.80	12.60	24.66	26.20	32.12	42.66	48.62
8	Phosphate	mg/kg	2.98	1.10	1.36	1.30	2.32	BQL	1.80
9	Sulphate	mg/kg	352.00	457.27	717.15	475.52	506.93	964.14	570.00
10	Nitrite	mg/kg	0.12	0.11	0.11	0.11	0.12	0.11	0.13
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	11.20	12.82
12	Calcium	mg/kg	109.02	144.29	56.91	112.22	106.61	134.66	160.32
13	Magnesium	mg/kg	101.57	150.66	140.45	94.77	122.47	222.10	184.68
14	Sodium	mg/kg	166.90	599.10	205.00	152.00	227.00	492.00	360.00
15	Potassium	mg/kg	19.00	54.60	10.88	18.25	28.72	48.06	30.75
16	Chromium	mg/kg	5.50	89.70	9.40	10.20	45.90	103.20	72.20
17	Nickel	mg/kg	BQL	29.80	BQL	BQL	12.40	30.40	24.10
18	Copper	mg/kg	BQL	12.00	BQL	BQL	BQL	22.40	12.60
19	Zinc	mg/kg	BQL	55.50	BQL	BQL	18.40	46.90	34.60
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

**Table 39 : Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	2.90	3.91	3.36	1.66	1.69	3.78	4.24
3	Organic Carbon	mg/kg	1.68	2.27	1.95	0.96	0.98	2.19	2.46
4	Inorganic Phosphate	mg/kg	112.00	106.00	126.00	124.00	118.00	130.00	136.00
5	Moisture	%	9.57	19.76	8.92	7.78	5.97	34.60	22.70
6	Aluminium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
7	Silica	mg/kg	22.20	14.20	16.00	18.00	24.20	39.60	40.00
8	Phosphate	mg/kg	2.60	BQL	1.31	2.82	3.02	1.46	2.09
9	Sulphate	mg/kg	375.86	571.44	793.00	520.97	563.60	884.41	526.54
10	Nitrite	mg/kg	0.12	0.11	0.11	0.10	0.12	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	11.00	11.24
12	Calcium	mg/kg	144.30	206.20	222.42	178.02	116.00	124.25	96.16
13	Magnesium	mg/kg	60.03	66.42	36.16	41.32	48.60	255.15	208.98
14	Sodium	mg/kg	431.48	569.60	427.94	2501.22	367.58	1175.67	922.29
15	Potassium	mg/kg	30.98	77.27	32.22	252.03	32.28	152.86	145.70
16	Chromium	mg/kg	18.20	87.70	22.40	17.20	25.40	111.90	79.50
17	Nickel	mg/kg	BQL	30.20	BQL	BQL	5.10	51.20	30.90
18	Copper	mg/kg	BQL	16.10	BQL	BQL	BQL	32.90	16.70
19	Zinc	mg/kg	16.30	57.60	5.40	BQL	12.00	99.60	40.60
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg,Cd: 1.0mg/kg,Hg: 1.0mg/kg, As: 1.0mg/kg)

## **10.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

## **10.3 Conclusion**

The soil types are majority Sandy loamy. Also all heavy metals found below Quantification limit wise Al,Pb, Cd, Hg , AS and Nitrate for some locations.

# **ECOLOGICAL MONITORING OF MARINE ENVIRONMENT**

## **11.1 INTRODUCTION:**

### **Sampling Stations:**

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 7<sup>th</sup> July 2022 in harbour region of DPT at Kandla Creek, and on 8<sup>th</sup> July 2022 in creeks near by the port during Neap tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 16<sup>th</sup> July ,2022 in harbour region of DPT at Kandla Creek and on 17<sup>nd</sup> July, 2022 in creeks near by the port during spring tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period. The same sampling schedule was repeated during consecutive spring and neap tide in same month.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during Neap tide on 07/07/2022 and Spring tide period on 14/07/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplankton density and their population).

**TABLE #40 SAMPLING LOCATIONS**

<b>monitoring requirement</b>	<b>Number of locations</b>
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near I <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

**Sampling methodology adopted:**

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample were taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with nilyobolt cloth of 20µm mesh size.

**Samples Processing for chlorophyll estimation:**

Samples for the chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 1998).

**PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is general term for organisms have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplankton is free floating organisms that are capable of photosynthesis and zooplankton is the various free-floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, *plankton* and *nekton* (Lalli and Parsons, 1997). *Plankton* consists of all organisms drifting in the water and is unable to swim against water currents, whereas *Nekton* includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

#### **Phytoplankton in the marine environment:**

Phytoplankton is free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio purifier and bio indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; diatoms and dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of



deterioration of water quality, and many algal indicators have been used to assess environmental status.

### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the watercolumn at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

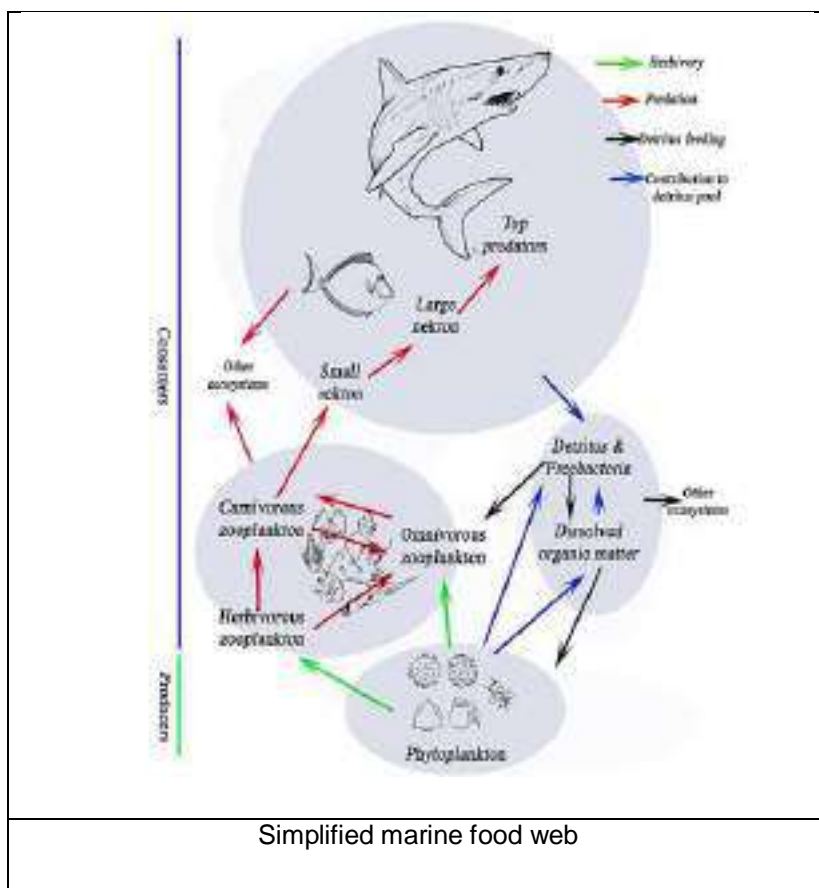
Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals

that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplankton is efficient grazers of the phytoplankton and is referred to as living machines transforming plant material into animal tissue. Hence, they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajbhiye, 2002).



### Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilo meters in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that cause this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly, the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton July also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

**Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight. After the tow of about 15-30minutes, plankton net was pulled up and washed down to the tail and collected the plankton adhered to plankton net in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward. For quantitative evaluation 50 L water samples were collected from subsurface layer and filtered through 20µm mesh size net by using bucket and filtration assembly.

**Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

**Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

**Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest axon possible. A thorough literature search was conducted for the identification of the different groups of zooplankton that were encountered

***Cell counts by drop count method:***

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22x 60mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the

concentrated plankton, total number of plankton in the original volume of sample filtered was calculated as units/L.

### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment–water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42 $\mu$  in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes

### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

#### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

#### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

## **DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurran, A. E. (1988)

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H. R. *etal.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. The diversity measures that incorporate the two concepts JULY be termed heterogeneity measures (Magurran, 2004).

Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate specie richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness (*S*) and evenness (*J*)

### **Simpson's diversity index**

Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran ,2004).

The formula for calculating D is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where  $n_i$  = the total number of organisms of each individual species

$N$  = the total number of organisms of all species

The value of  $D$  ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When  $D$  increases diversity decreases. Simpson's index is therefore usually expressed as  $1-D$  or  $1/D$ . (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment
- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

### **Species richness indices**

The species richness( $S$ ) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness JULY be concomitant with severe or chronic human-induced perturbation (Fair Fair weather 1990,) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness( $S$ ) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index ( $d$ ), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.



The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximised when all types are equally abundant (Rosenzweig, M. L. (1995).

#### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index (**H**), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index (**H**) reproduces community parameters to a single number by using an equation.

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

$$H' = - \sum_{j=1}^i \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

#### **RESULTS:**

##### **CHLOROPHYLL-a:**

Water Samples for the chlorophyll estimation were collected from sub surface layer during high tide and low tide period of the tidal cycle for each sampling locations and analysed for Chlorophyll -a and after acidification for Pheophytin -a. Chlorophyll- a value was used as algal biomass indicator (APHA, 1998) Algal biomass was estimated by converting Chlorophyll value.

In the sub surface water chlorophyll-a was varying from 0.204-0.746 mg/m<sup>3</sup> with an average value 0.380mg/m<sup>3</sup> of in harbour region of DPT in Kandla Creek during sampling done in spring tide period of July 2022. In the nearby creeks chlorophyll-a was varying from 0.205- 0.497 mg/m<sup>3</sup> with an average value 0.351mg/m<sup>3</sup> Pheophytin -a level was below detectable limit- the all the sampling stations during spring tide.

In the sub surface water chlorophyll-a was varying from 0.205- 0.613mg/m<sup>3</sup> with an average value 0.400 mg/m<sup>3</sup> in harbour region of DPT in Kandla Creek during sampling done in Neap tide period of July 2022. In the nearby creeks chlorophyll-a was varying from 0.204- 0.512 mg/m<sup>3</sup> with an average value 0.343mg/m<sup>3</sup> Pheophytin -a level was below detectable limit- the all the sampling stations.

In the sub surface water chlorophyll-a was varying from 0.307- 0.614mg/m<sup>3</sup> in harbour region of DPT OOT in path finder Creek during sampling done in spring tide period of July 2022. In the sub surface



water chlorophyll-a was varying from 0.204-0.323 mg/m<sup>3</sup>.in harbour region of DPT OOT in path finder Creek during sampling done in Neap Tide periodof July 2022

**TABLE #41 VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINARDURING SPRING TIDE IN JULY 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.410	BDL	27.47
		Low tide	0.746	BDL	49.98
2	KPT 2	High tide	0.204	BDL	13.67
		Low tide	0.410	BDL	27.47
3	KPT 3	High tide	0.204	BDL	13.67
		Low tide	0.306	BDL	20.50
CREEKS					
4	KPT-4 Khori-I	High tide	0.205	BDL	13.74
		Low tide	0.322	BDL	21.57
5	KPT-5 Nakti-I	High tide	0.424	BDL	28.41
		Low tide	0.305	BDL	20.44
6	KPT-6 Nakti-II	High tide	0.497	BDL	33.30
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.307	BDL	20.57
8		Low tide	0.614	BDL	41.14
9	SPM	High tide	0.353	BDL	23.65
10	SPM	Low tide	0.526	BDL	35.24

BDL: Below Detectable Limit.

**TABLE #42 VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA ,NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN JULY 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPT HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.528	BDL	35.38
		Low tide	0.613	BDL	41.07
2	KPT 2	High tide	0.322	BDL	21.57
		Low tide	0.291	BDL	19.50
3	KPT 3	High tide	0.441	BDL	29.55
		Low tide	0.205	BDL	13.74
CREEKS					
4	KPT-4 Khor-I	High tide	0.338	BDL	22.65
		Low tide	0.512	BDL	34.30
5	KPT-5 Nakti-I	High tide	0.204	BDL	13.67
		Low tide	0.420	BDL	28.14
6	KPT-6 Nakti-II	High tide	0.240	BDL	16.08
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.204	BDL	13.67
8		Low tide	0.302	BDL	20.23
9	SPM	High tide	0.306	BDL	20.50
10	SPM	Low tide	0.323	BDL	21.64

BDL: Below Detectable Limit.

**PHYTOPLANKTON POPULATION:**

For the evaluation of the Phytoplankton population in DPT harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms, blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 19 genera. Blue green was represented by 5 genera and Dinoflagellates were represented by 4 genera during the sampling conducted in spring tide in JULY, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 50-210 units/ L during high tide period and 78-113 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 26 genera, Blue green algae were represented 5 genera and Dinoflagellates with 3 genera during the sampling conducted in Neap tide in July, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 43-224 units/ L during high tide period and 121-185 units/ L during low tide of Neap Tide.

For the evaluation of the Phytoplankton population in DPT OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; jetty area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 24 genera, Blue Green algae by 2 genera and Dinoflagellates 4 genera each during the sampling conducted in spring tide in July, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area was 227 units/ L during high tide period and 216 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the *SPM area* was varying from 179 units/ L during high tide period and 168 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 28 genera and Blue green algae 4 genera and Dinoflagellates by 2 genera during the sampling conducted in Neap tide in JULY, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 251 units/ L during high tide period and 230 units/ L

during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 195 units/ L during high tide period and 219 units/ L during low tide of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 2.812- 3. 586 with an average of 3.231 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.054- 2.750 with an average of 2.429 during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 1.900- 3.761 with an average of 2.918 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 1.750- 4.047 with an average of 3.018 during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 3.687 at OOT jetty area and 2.506 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 3.163 and 3.513 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 4.525 at OOT jetty area and 3.224 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 4.046 and SPM area was 3.897 during the consecutive low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.736- 0.843 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of

0.796 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.7008 - 0.802 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.754 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.698 - 0.912 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.827 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.695 - 0.869 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.787 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.911 at OOT jetty area and 0.838 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.755 and 0.840 at SPM during the consecutive low tide period.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.924 at OOT jetty area and 0.758 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.923 and at SPM area was 0.903 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.729 - 0.813 between selected sampling stations with an average of 0.763 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from

0.738- 0.794 between selected sampling stations with an average of 0.761 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during neap tide also, which was varying from 0.735- 0.847 with an average value of 0.800 between selected sampling stations during high tide period and 0.747- 0.797 varying from with an average value of 0.770 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.804 at OOT jetty area and 0.823 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.689 and 0.788 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.797 at OOT jetty area and 0.674 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.802 and at SPM area was 0.803 during the consecutive low tide period.

High species diversity suggests a greater number of successful species and a more stable ecosystem more ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole.

**Table # 43 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% Of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	200	20/28	71.43	3.586	0.7726	0.7294
	2	145	18/28	64.29	3.416	0.8434	0.7697
	3	181	17/28	60.71	3.078	0.8151	0.7752
	4	210	20/28	71.43	3.553	0.7891	0.7478
	5	165	16/28	57.14	2.938	0.7362	0.7435
	6	50	12/28	42.86	2.812	0.8227	0.8131
LOW TIDE	1	113	14/28	50.00	2.75	0.802	0.7876
	2	98	13/28	46.43	2.617	0.7394	0.7391
	3	80	10/28	35.71	2.054	0.7008	0.7383
	4	94	11/28	39.29	2.201	0.7401	0.7442
	5	78	12/28	42.86	2.525	0.7921	0.7942

**Table # 44 HYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING NEAP TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	204	21/34	61.76	3.761	0.8479	0.7931
	2	180	15/34	44.12	2.696	0.8108	0.7914
	3	224	21/34	61.76	3.696	0.8556	0.8047
	4	165	18/34	52.94	3.329	0.912	0.8316
	5	193	11/34	32.35	1.9	0.6987	0.7353
	6	43	9/34	26.47	2.127	0.8373	0.8472
LOW TIDE	1	121	15/34	44.12	2.919	0.7709	0.7696
	2	140	21/34	61.76	4.047	0.8694	0.7977
	3	122	16/34	47.06	3.122	0.8033	0.7853
	4	171	10/34	29.41	1.75	0.6957	0.7505
	5	185	18/34	52.94	3.256	0.7999	0.7471

**Table # 45 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN JULY2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	38-197	19/28	67.86
			BLUE GREEN	3-12	5/28	17.86
			DINOFLAGELLATES	0-5	4/28	14.28
			TOTAL PHYTO PLANKTON	<b>50-210</b>	<b>28</b>	
LOW TIDE	Sub surface	5	DIATOMS	71-101	19/28	67.86
			BLUE GREEN	2-177	5/28	17.86
			DINOFLAGELLATES	0-1	4/28	14.28
			TOTAL PHYTO PLANKTON	<b>78-113</b>	<b>28</b>	

**TABLE # 46 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN JULY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	31-214	26/34	76.47
			BLUE GREEN	1-12	5/34	14.71
			DINOFLAGELLATES	1-3	3/34	8.82
			TOTAL PHYTO PLANKTON	<b>43-224</b>	<b>34</b>	
LOW TIDE	Sub surface	5	DIATOMS	118-182	26/34	76.47
			BLUE GREEN	0-3	5/34	14.71
			DINOFLAGELLATES	0-2	3/34	8.82
			TOTAL PHYTO PLANKTON	<b>121-185</b>	<b>34</b>	



**TABLE # 47 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H(\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	jetty	227	21/30	70.00	3.687	0.911	0.8049
	SPM	179	14/30	46.67	2.506	0.8379	0.8234
LOW TIDE	jetty	216	18/30	60.00	3.163	0.755	0.6889
	SPM	168	19/30	63.33	3.513	0.8405	0.7882

**TABLE # 48 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H(\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	251	26/34	76.47	4.525	0.9246	0.7971
	SPM	195	18/34	52.94	3.224	0.7584	0.674
LOW TIDE	Jetty	230	23/34	67.65	4.046	0.9232	0.8016
	SPM	219	22/34	64.71	3.897	0.9029	0.8031

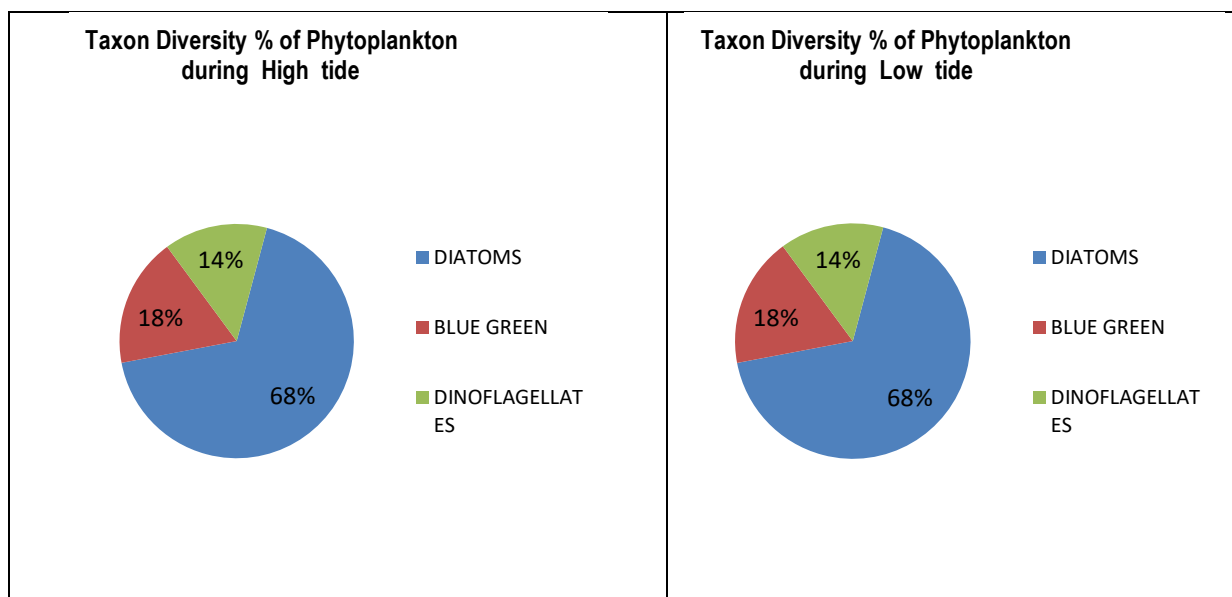
**TABLE # 49 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPTOOT AT PATH FINDER CREEK,VADINAR & NEAR BY SPM, DURING SPRING TIDE IN JULY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN	0-2	2/30	6.67
			DIATOMS	178-222	24/30	80.00
			DINOFLAGELLATES	1-3	4/30	13.33
			TOTAL PHYTO PLANKTON	<b>179-227</b>		
LOW TIDE	Sub surface	2	BLUE GREEN	1-5	2/30	6.67
			DIATOMS	166-210	24/30	80.00
			DINOFLAGELLATES	1	4/30	13.33
			TOTAL PHYTO PLANKTON	<b>168-216</b>		

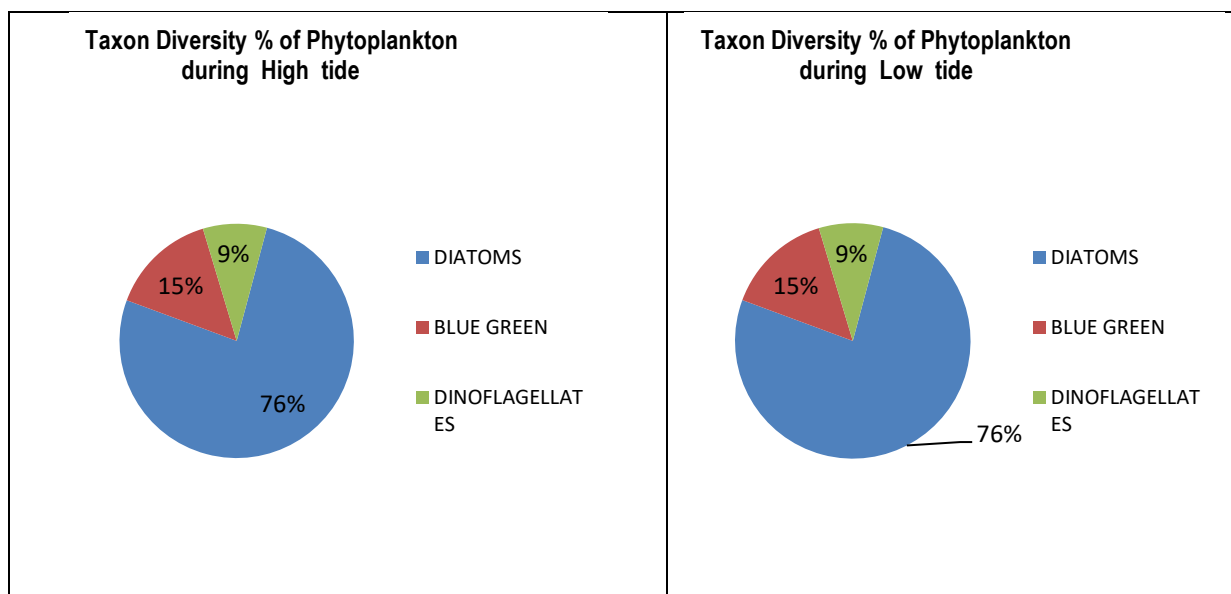
**Table # 50 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPTOOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN JULY 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN	3-6	4/34	11.76
			DIATOMS	191-243	28/34	82.36
			DINOFLAGELLATES	1-2	2/34	5.88
			TOTAL PHYTO PLANKTON	<b>195-251</b>	34	
LOW TIDE	Sub surface	2	BLUE GREEN	2	28/34	11.76
			DIATOMS	217-227	2/34	82.36
			DINOFLAGELLATES	0-1	2/34	5.88
			TOTAL PHYTO PLANKTON	<b>219-230</b>	34	

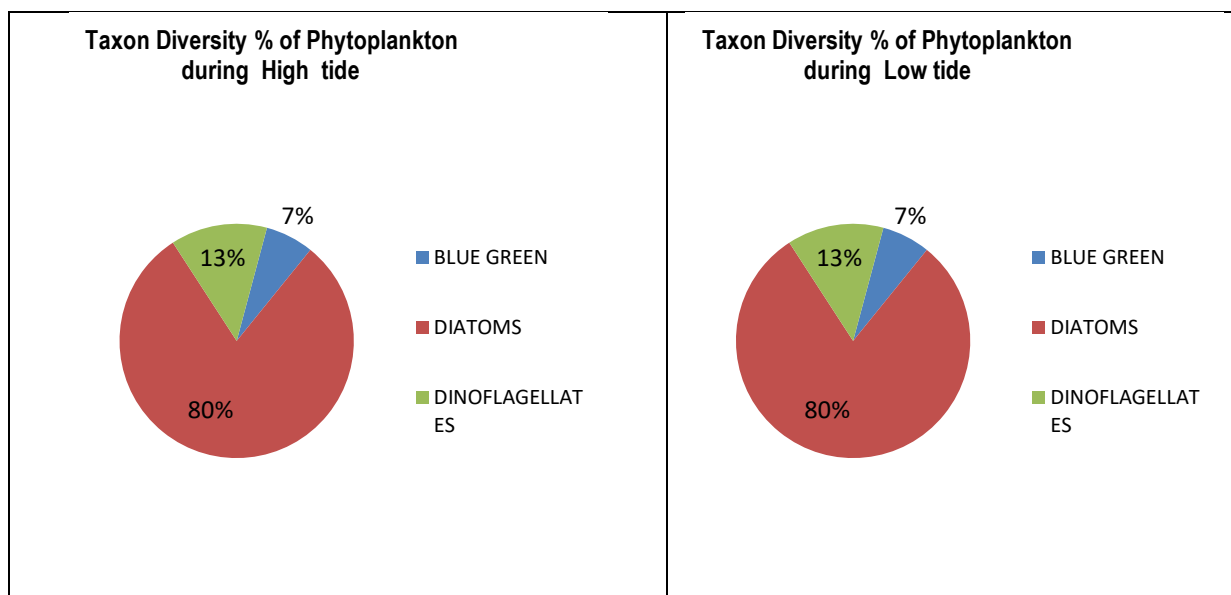
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Kandala creek and nearby creeks**



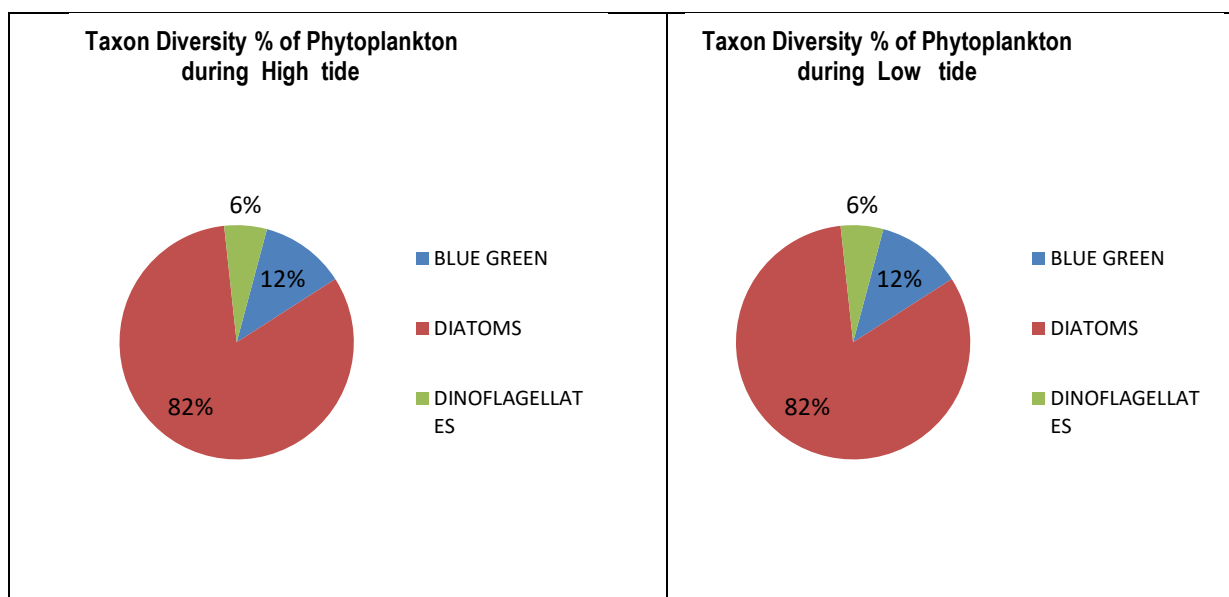
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Kandala creek and nearby creeks**



**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



### Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar



For the evaluation of the Zooplankton population in DPT harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khorī creek) during high tide period and low tide period of spring tide and Neap tide in JULY, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly eight groups; Tintinnids, Copepods, Arrow worms, MEDUSA, Urochordata, Ciliates, Foraminiferans, Nematodes and 8 larval forms. The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly six groups; Tintinnids, Copepods, Rotifers, Arrow worms, Ciliates, Nematode and 8 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from  $33-146 \times 10^3$  N/ m<sup>3</sup> during high tide and  $65-107 \times 10^3$  N/ m<sup>3</sup> during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from  $31-128 \times 10^3$  N/ m<sup>3</sup> during high tide and  $56-82 \times 10^3$  N/ m<sup>3</sup> during low tide of Neap Tide period.

For the evaluation of the Zooplankton population in DPT OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM).

During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly Six groups Tintinnids, Copepods, Arrow worms, Urochordata, Mysids, Foraminiferans and 7 larval forms. The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly Five groups, Titinids, Copepods, Urochordata, Foraminifera, Nematode and 9 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPT OOT Jetty area of path finder creek was  $120 \times 10^3$  N/  $m^3$  during high tide and  $87 \times 10^3$  N/  $m^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area of path finder creek was  $70 \times 10^3$  N/  $m^3$  during high tide and  $94 \times 10^3$  N/  $m^3$  during low tide of spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT OOT jetty area in path finder creek was recorded  $89 \times 10^3$  N/  $m^3$  during high tide and  $120 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap tide. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area in path finder creek was recorded  $75 \times 10^3$  N/  $m^3$  during high tide and  $118 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the stations Kandla creek region and nearby creeks was varying from 2.288- 3.852 with an average of 3.006 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities varying from 2.276- 4.085 with an average of 2.875 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations was varying from 2.621- 4.912 with an average of 3.840 during the sampling conducted in high tide and varying from 2.496 - 3.726 with an average of 3.208 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 4.178 and 4.254 respectively.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling

station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 4.237 and 4.611 respectively.

Margalef's diversity index (Species Richness) S of Zooplankton communities near Jetty at Path finder creek was varying from 4.01- 3.76 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) S of Zooplankton communities near SPM at Path finder creek was varying from 3.243 -2.725 respectively during the consecutive High tide and low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.789 -0.992 ( $H'(\log 10)$ ) between selected sampling stations with an average value of 0.877 ( $H'(\log 10)$ ) during high tide period of spring tide.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.839-0.984( $H'(\log 10)$ ) between selected sampling stations with an average value of 0.891 ( $H'(\log 10)$ ) during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.881-1.119( $H'(\log 10)$ ) between selected sampling stations with an average value of 0.981( $H'(\log 10)$ ) during high tide period of Neap tide.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 0.786- 0.948 of ( $H'(\log 10)$ ) between selected sampling stations with an average value of 0.903( $H'(\log 10)$ ) during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.055-1.056 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.950-0.969 respectively

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.920-1.065 during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 1.006-0.997 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour

region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

**Simpson's diversity index:**

Simpson's index (D) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.792 - 0.872 between selected sampling stations with an average of 0.827 during high tide period and was varying from 0.837 - 0.861 with an average value of 0.845 between selected sampling stations during low tide

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of Neap tide except few, which was varying from 0.794 - 0.895 between selected sampling stations with an average of 0.849 during high tide period and was varying from 0.757 - 0.865 with an average value of 0.831 between selected sampling stations during consecutive low tide. This species diversity suggests a relatively few successful species in this habitat during July 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.880 and 0.882 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.822 and 0.809 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.829 - 0.901 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.887 and 0.890 respectively.

**TABLE # 51 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/ groups observed /total species/g roup	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	107	19/28	67.86	3.852	0.9921	0.8718
	2	82	13/28	46.43	2.723	0.8614	0.807
	3	109	17/28	60.71	3.411	0.9008	0.8206
	4	146	13/28	46.43	2.408	0.8234	0.7922
	5	118	17/28	60.71	3.354	0.8944	0.8399
	6	33	9/28	32.14	2.288	0.7888	0.8277
LOW TIDE	1	82	19/28	67.86	4.085	0.9837	0.8612
	2	107	14/28	50.00	2.782	0.8873	0.8401
	3	69	12/28	42.86	2.598	0.8701	0.841
	4	65	12/28	42.86	2.635	0.8733	0.8447
	5	81	11/28	39.29	2.276	0.8389	0.8373

**TABLE # 52 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In $No \times 10^3 / m^3$	No of Species/ groups observed /total species/g roup	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	108	24/31	77.42	4.912	1.119	0.8946
	2	117	23/31	74.19	4.62	1.057	0.8638
	3	128	20/31	64.52	3.916	0.9808	0.8333
	4	93	17/31	54.84	3.53	0.9641	0.842
	5	105	17/31	54.84	3.438	0.8858	0.7936
	6	31	10/31	32.26	2.621	0.8806	0.8667
LOW TIDE	1	56	16/31	51.61	3.726	0.9456	0.8422
	2	62	16/31	51.61	3.634	0.9481	0.854
	3	72	15/31	48.39	3.274	0.9061	0.8365
	4	82	12/31	38.71	2.496	0.7861	0.7573
	5	62	13/31	41.94	2.908	0.9301	0.8646



**Table # 53 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN JULY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	1-7	5/28	17.86
			Copepods	23-60	9/28	32.15
			Arrow worms	0	1/28	3.57
			Urochordata	0-1	1/28	3.57
			Ciliates	0-5	1/28	3.57
			Medusa	0-1	1/28	3.57
			Larval forms	8-80	8/28	28.57
			Foraminiferans	0	1/28	3.57
			Nematode	0	1/28	3.57
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>33-146</b>	<b>28</b>	
LOW TIDE	Sub surface	5	Tintinids	0-6	5/28	17.86
			Copepods	33-51	9/28	32.15
			Arrow worms	0-1	1/28	3.57
			Urochordata	0	1/28	3.57
			Ciliates	1-3	1/28	3.57
			Medusa	0	1/28	3.57
			Larval forms	22-49	8/28	28.57
			Foraminiferans	0-1	1/28	3.57
			Nematode	0-1	1/28	3.57
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>65-107</b>	<b>28</b>	

**TABLE # 54 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN JULY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	1-11	7/31	22.57
			Copepods	11-56	12/31	38.71
			Rotifers	0-10	1/31	3.23
			Arrow worms	0-2	1/31	3.23
			Ciliates	0-2	1/31	3.23
			Larval forms	18-64	8/31	25.80
			Nematode	0-1	1/31	3.23
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>31-128</b>	<b>31</b>	
LOW TIDE	Sub surface	5	Tintinids	2-3	7/31	22.57
			Copepods	20-40	12/31	38.71
			Rotifers	0-2	1/31	3.23
			Arrow worms	0	1/31	3.23
			Ciliates	0-2	1/31	3.23
			Larval forms	23-48	8/31	25.80
			Nematode	0-1	1/31	3.23
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>56-82</b>	<b>31</b>	

**Table # 55 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In $\times 10^3 \text{N} / \text{m}^3$	No of Species/ groups observed /total species/ group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	120	21/33	63.64	4.178	1.055	0.8804
	SPM	70	19/33	57.58	4.237	0.9497	0.8215
LOW TIDE	Jetty	87	20/33	60.61	4.254	1.056	0.8818
	SPM	95	22/33	66.67	4.611	0.9685	0.8087

**TABLE # 56 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN JULY 2022**

Tide	Sampling Station	Abundance In $\text{N} \times 10^3 / \text{m}^3$	No of Species/ groups observed /total species/ group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	89	19/29	65.52	4.01	0.9196	0.8294
	SPM	75	15/29	51.72	3.243	1.006	0.8868
LOW TIDE	Jetty	120	19/29	65.52	3.76	1.065	0.901
	SPM	118	14/29	48.28	2.725	0.9966	0.8898

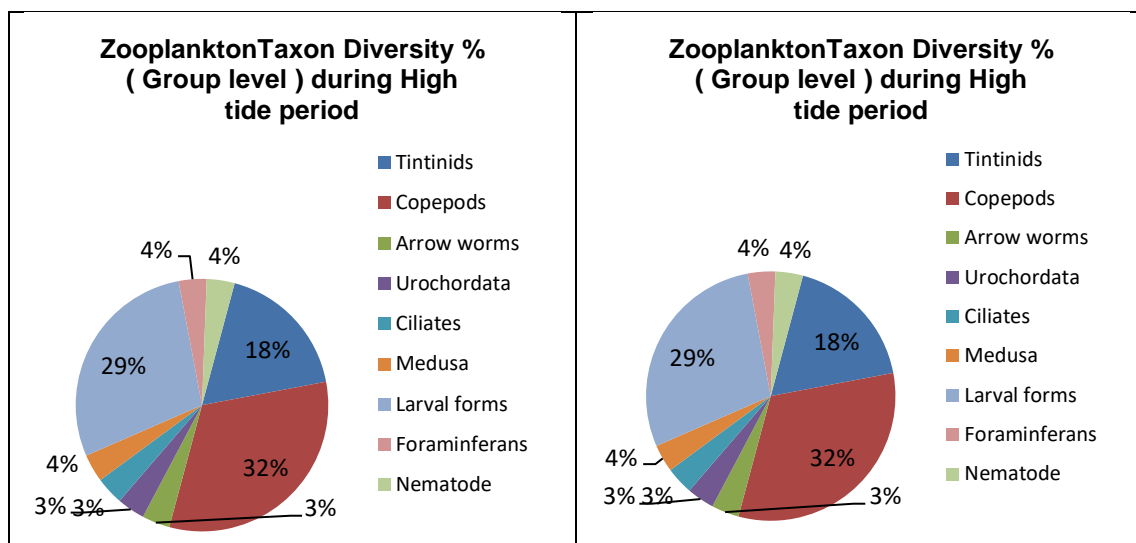
**Table # 57 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN JULY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	14-29	6/33	18.19
			Copepods	23-47	14/33	42.42
			Arrow worms	0	1/33	3.03
			Mysids	1-2	2/33	6.06
			Urochordata	1	2/33	6.06
			Larval forms	30-42	7/33	21.21
			Foraminiferans	0	1/33	3.03
			TOTAL ZOOPLANKTON NO/L	<b>70-120</b>	<b>33</b>	
LOW TIDE	Sub surface	2	Tintinids	17-21	6/33	18.19
			Copepods	27-42	14/33	42.42
			Arrow worms	0-1	1/33	3.03
			Mysids	0-2	2/33	6.06
			Urochordata	0-1	2/33	6.06
			Larval forms	27-43	7/33	21.21
			Foraminiferans	0-1	1/33	3.03
			TOTAL ZOOPLANKTON NO/L	<b>87-94</b>	<b>33</b>	

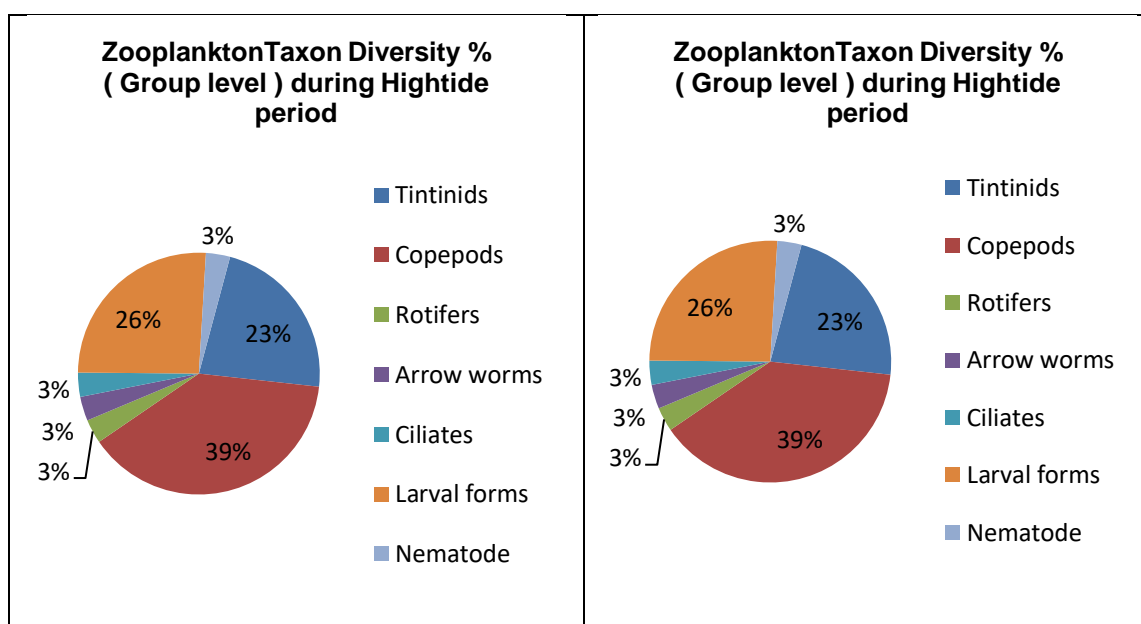
**TABLE # 58 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN JULY 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	21-32	6/29	20.69
			Copepods	19-25	10/29	34.48
			Urochordata	1-2	2/29	6.90
			Larval forms	27-35	9/29	31.03
			Foraminifera	0-1	1/29	3.45
			Nematode	0-1	1/29	3.45
			TOTAL ZOOPLANKTON	<b>75-89</b>	<b>29</b>	
LOW TIDE	Sub surface	2	Tintinids	29-33	6/29	20.69
			Copepods	27-33	10/29	34.48
			Urochordata	0	2/29	6.90
			Larval forms	54-61	9/29	31.03
			Foraminifera	0	1/29	3.45
			Nematode	0-1	1/29	3.45
			TOTAL ZOOPLANKTON	<b>118-120</b>	<b>29</b>	

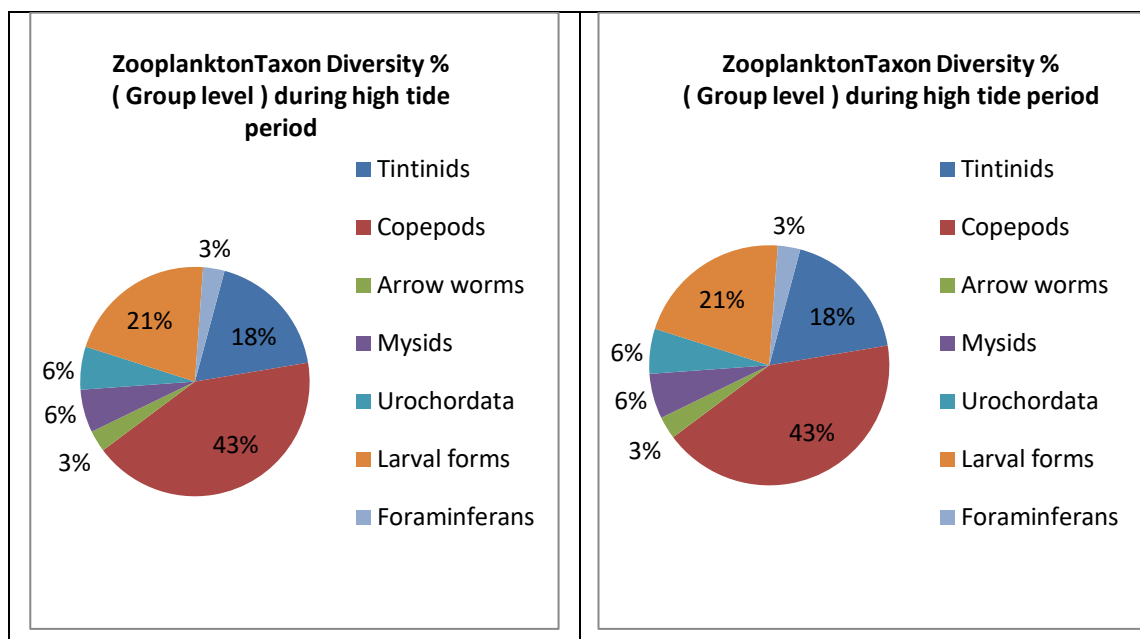
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Kandla Creek and nearby Creeks**



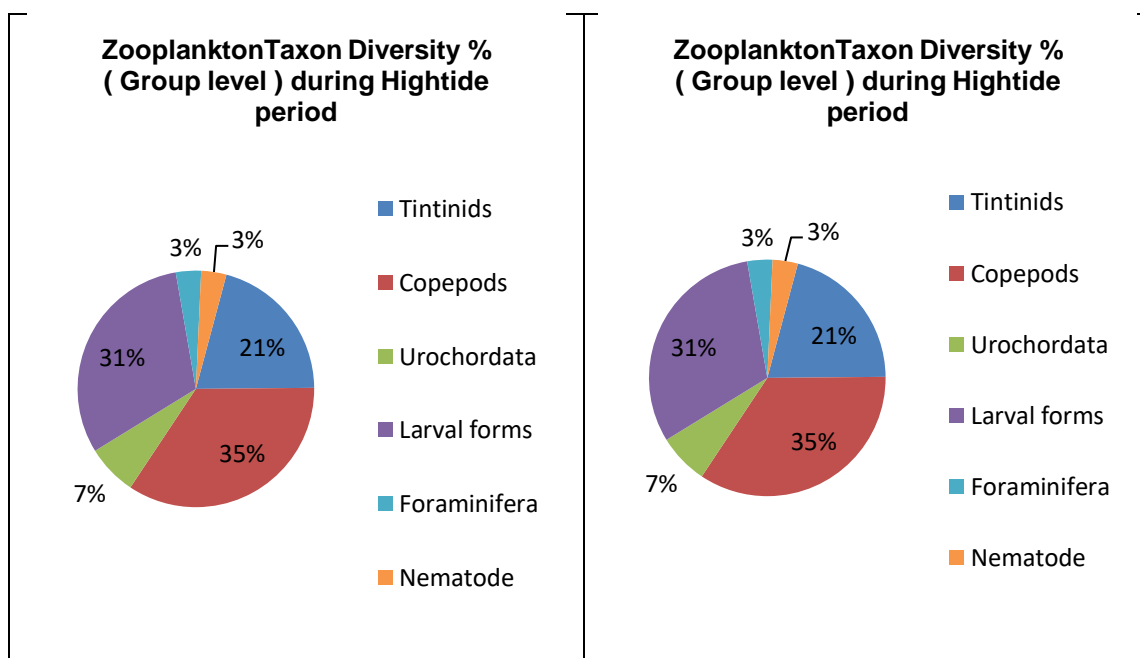
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Kandla Creek and nearby Creeks**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM**



**TABLE # 59 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF JULY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Sparse
					<i>Lyngbya sp.</i>	B2	Very sparse
					<i>Oscillatoria sp.</i>	B3	Sparse
					<i>Trichodesmium sp.</i>	B4	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B5	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Scattered
			Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D2	Dominant
			Hemiaulales	Belleracheaceae	<i>Belleracheasp</i>	D3	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D4	Very sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetocerossp</i>	D5	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylumsp</i>	D6	Abundant
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D7	Very sparse
			Thalassiosirales	Thalassiosiraceae	<i>Thalassiosirasp</i>	D8	Very sparse

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			Triceratales	Triceratiaceae	Odontella sp.	D9	Sparse
					<i>Triceratium</i> sp.	D10	Very sparse
		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D11	Very sparse
					Nitzschiasp	D12	Very sparse
			Naviculales	Pleurosigmaaceae	<i>Pleurosigma</i> sp	D13	Very sparse
				Pinnulariaceae	<i>Pinnularia</i> sp	D14	Very sparse
			Surirellales	Surirellaceae	<i>Surirella</i> sp	D15	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	Fragilariasp	D16	Very sparse
					Synedrasp	D17	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassionema</i> sp.	D18	Sparse
					<i>Thalassiothrix</i> sp.	D19	Scattered
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF1	Very sparse
			Dinophysales	Dinophysaceae	<i>Dinophysis</i> sp.	DF2	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
					<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE # 60 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING AND NEAP TIDE OF JULY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Very sparse
					<i>Lyngbya sp.</i>	B2	Very sparse
					<i>Oscillatoria sp.</i>	B3	Sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B4	Very sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B5	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Scattered
			Biddulphiales	Biddulphiaceae	Biddulphiasp	D2	Dominant
			Hemiaulales	Belleracheaceae	<i>Belleracheasp</i>	D3	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D4	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D5	Very sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetocerosp.</i>	D6	Sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylumsp</i>	D7	Abundant



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			Melosirales	Melosiraceae	<i>Melosiras</i>	D8	Very sparse
			Thalassiosirales	Thalassiosiraceae	Planktoniellasp	D9	Very sparse
				Lauderiaceae	<i>Lauderias</i>	D10	Very sparse
				Skeletonemataceae	<i>Skeletonemas</i>	D11	Very sparse
			Triceratiales	Triceratiaceae	Odontella sp.	D12	Sparse
					<i>Triceratium</i> sp.	D13	Very sparse
		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillarias</i>	D14	Very sparse
					Nitzschiasp	D15	Very sparse
					Pseudo-nitzschia sp.	D16	Very sparse
			Naviculales	Naviculaceae	<i>Naviculas</i>	D17	Very sparse
				Pinnulariaceae	<i>Pinnularias</i>	D18	Very sparse
				Pleurosigmataceae	<i>Pleurosigma</i> sp.	D19	Very sparse
			Surirellales	Surirellaceae	<i>Campylo discus</i> sp	D20	Very sparse
					<i>Surirella</i> sp.	D21	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsiss</i>	D22	Very sparse

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					Fragilariasp	D23	Very sparse
					Synedrasp	D24	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D25	Scattered
					<i>Thalassiothrix sp.</i>	D26	Abundant
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Dinophyceae	Peridiniales	Protopteridiniaceae	<i>Protopteridinium sp.</i>	DF1	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratiumfurca</i>	DF2	Very sparse
					<i>Ceratium tripos</i>	DF3	Very sparse

**TABLE # 61 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPTOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING SPRING TIDE OF JULY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B2	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Abundant
			Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D2	Scattered
			Hemiaulales	Belleracheaceae	<i>Belleracheasp</i>	D3	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D4	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D5	Very sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetocerossp</i>	D6	Sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylumsp</i>	D7	Dominant
			Thalassiosirales	Skeletonemataceae	<i>Detonula sp.</i>	D8	Very sparse
				Lauderiaceae	<i>Lauderiasp</i>	D9	Sparse
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D10	Scattered
					<i>Triceratiumsp.</i>	D11	Sparse

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		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D12	Very sparse
					<i>Nitzschia</i> sp	D13	Very sparse
			Naviculales	Naviculaceae	<i>Navicula</i> sp	D14	Very sparse
				<u>Pleurosigmataceae</u>	<i>Pleurosigma</i> sp	D15	Very sparse
				Pinnulariaceae	<i>Pinnularia</i> sp	D16	Very sparse
			Surirellales	Entomoneidaceae	<i>Entomoneis</i> sp.	D17	Very sparse
				Surirellaceae	<i>Surirella</i> sp.	D18	Very sparse
					<i>Campylodiscus</i> sp	D19	Very sparse
			Fragilariophyceae	Climacospheniales	Climacospheniaceae	<i>Climacosphenia</i> sp.	D20
		Fragilariales		Fragilariaceae	<i>Synedra</i> sp.	D21	Very sparse
		Striatellales		Striatellaceae	<i>Striatella</i> sp.	D22	Very sparse
		Thalassionematales		Thalassionemataceae	<i>Thalassionema</i> sp.	D23	Scattered
					<i>Thalassiothrix</i> sp.	D24	Scattered
		DINOFLAGELLATES	Dinoflagellata / Dinozoa	Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium</i> sp.
Dinophysales	Dinophysaceae				<i>Dinophysis</i> sp.	DF2	Very sparse
Gonyaulacales	Ceratiaceae				<i>Ceratiumfurca</i>	DF3	Very sparse
					<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE # 62 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPTOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND NEAP TIDE OF JULY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Cyanophyta	Cyanophyceae	Chroococcales	Chroococcaceae	<i>Merismopedia sp.</i>	B1	Very sparse
			Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B2	Very sparse
					<i>Oscillatoria sp.</i>	B3	Very sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B4	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D1	Scattered
					<i>Palmeria sp.</i>	D2	Very sparse
			Biddulphiales	Biddulphiaceae	Biddulphiasp	D3	Scattered
			Hemiaulales	Bellerocheaceae	<i>Bellerocheasp</i>	D4	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D6	Very sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetocerossp</i>	D7	Abundant
			Lithodesmiales	Lithodesmiaceae	<i>Ditylumsp</i>	D8	Dominant

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			Melosirales	Melosiraceae	<i>Melosirasp</i>	D9	Very sparse
			Thalassiosirales	Lauderiaceae	<i>Lauderiasp.</i>	D10	Very sparse
				Thalassiosiraceae	Planktoniellasp	D11	Very sparse
			Triceratiales	Triceratiaceae	Odontellasp	D12	Sparse
					<i>Triceratiumsp</i>	D13	Very sparse
		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillariasp.</i>	D14	Scattered
					Nitzschiasp	D15	Sparse
					Pseudonitzschiasp	D16	Very sparse
			Naviculales	Naviculaceae	<i>Naviculasp</i>	D17	Very sparse
				Pinnulariaceae	<i>Pinnulariasp</i>	D18	Very sparse
				Pleurosigmataceae	<i>Pleurosigma sp</i>	D19	Sparse
			Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D20	Very sparse
				Surirellaceae	<i>Campylodiscussp</i>	D21	Very sparse
					<i>Surirella sp.</i>	D22	Very sparse
		Fragilariophyceae	Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D23	Very sparse
			Fragilariales	Fragilariaceae	<i>Asterionellopsissp</i>	D24	Very sparse

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					<i>Synedra sp.</i>	D25	Sparse
			Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D26	Very sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D27	Scattered
					<i>Thalassiothrix sp.</i>	D28	Scattered
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
				Ceratiaceae	<i>Ceratium tripos</i>	DF2	Very sparse

**TABLE #63 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF JULY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE	
TINTINIDS	PROTOZOA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus</i> sp.	T1	Very sparse	
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse	
	<i>Tintinnopsis gracilis</i>				T3	Very sparse		
	<i>Tintinnopsis radix</i>				T4	Very sparse		
	Xystonellidae			<i>Favella</i> sp.	T5	Very sparse		
COPEPODS		Crustacea	Calanoida	Paracalanidae	<i>Acrocalanus</i> sp.	C1	Scattered	
					<i>Parvocalanus</i> sp.	C2	Very sparse	
	ARTHROPODA	Subclass: Copepoda		Acartiidae	<i>Acartia</i> sp.	C3	Very sparse	
				Clausocalanidae	<i>Clausocalanus</i> sp.	C4	Very sparse	
				Centropagidae	<i>Centropages</i> sp.	C5	Very sparse	
				Temoridae	<i>Temora</i> sp.	C6	Sparse	
				Cyclopoida	Oithonidae	<i>Oithona</i> sp.	C7	Abundant
				Harpacticoida	Ectinosomatidae	<i>Microsetella</i> sp.	C8	Scattered



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				Euterpinidae	<i>Euterpina sp.</i>	C9	Sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
UROCHORDATA	CHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse
	SUB PHYLUM UROCHORDATA						
CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium</i> <i>sp.</i>	CI1	Sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA	Copepoda			Nauplius larvae of copepods	L1	Dominant
	(CRUSTACEA)						
BRACHYURA LARVAE	ARTHROPODA	Malacostraca			Brachyuran zoea larvae	L2	Very sparse
	(CRUSTACEA)	Decapoda					
BARNACLE LARVAE	ATHROPODA CRUSTACEA	Maxillopoda			Cirripede larvae	L3	Very sparse
		Thecostraca					
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae	L5	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda			Opisthobranchia larvae	L6	Very sparse

TABLE # 64 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF JULY 2022

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus</i> sp.	T1	Very sparse
				Codonellidae	<i>Tintinnopsis acuminata</i>	T2	Very sparse
	<i>Tintinnopsisfailakkaensis</i>				T3	Sparse	
	<i>Tintinnopsisgracilis</i>				T4	Very sparse	
	<i>Tintinnopsis radix</i>				T5	Very sparse	
	Tintinnidae				<i>Eutintinnus</i> sp.	T6	Very sparse
	Xystonellidae			<i>Favella</i> sp.	T7	Very sparse	
	CILIOPHORA	Crustacea	Calanoida	Paracalanidae	<i>Acrocalanus</i> sp.	C1	Sparse
					<i>Parvocalanus</i> sp.	C2	Very sparse
Eucalanidae				<i>Subeucalanus</i> sp.	C3	Very sparse	
COPEPODS	ARTHROPODA	Subclass: Copepoda		Acartiidae	<i>Acartia</i> sp.	C4	Very sparse
				Clausocalanidae	<i>Clausocalanus</i> sp.	C5	Very sparse
				Centropagidae	<i>Centropages</i> sp.	C6	Very sparse

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				Temoridae	<i>Temora sp.</i>	C7	Sparse																																						
				Tortanidae	<i>Tortanus sp.</i>	C8	Very sparse																																						
				Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C9	Abundant																																					
				Harpacticoida	Clytemnestridae	<i>Clytemnestra sp.</i>	C10	Very sparse																																					
			Ectinosomatidae		<i>Microsetella</i> sp.	C11	Scattered																																						
			Euterpinae		<i>Euterpina sp.</i>	C12	Very sparse																																						
ROTIFERS	ROTIFERA	Rotifera	Superorder: Monogononta	Brachionidae	<i>Brachionus plicatilis</i>	R1	Sparse																																						
		Subclass: Eurotatoria	Order: Ploimida					ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse	CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium</i> sp.	C11	Very sparse	CRUSTACEAN LARVAE	ARTHROPODA	Copepoda			Nauplius larvae of copepods	L1	Dominant	(CRUSTACEA)	BRACHYURA	ARTHROPODA	Malacostraca	Decapoda		Brachyuran zoea larvae	L2	Very sparse	LARVAE	(CRUSTACEA)	BARNACLE LARVAE	ATHROPODA CRUSTACEA	Maxillopoda
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse																																						
CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium</i> sp.	C11	Very sparse																																						
CRUSTACEAN LARVAE	ARTHROPODA	Copepoda			Nauplius larvae of copepods	L1	Dominant																																						
	(CRUSTACEA)							BRACHYURA	ARTHROPODA	Malacostraca	Decapoda		Brachyuran zoea larvae	L2	Very sparse	LARVAE	(CRUSTACEA)	BARNACLE LARVAE	ATHROPODA CRUSTACEA	Maxillopoda			Cirripede larvae	L3	Very sparse	Thecostraca																			
BRACHYURA	ARTHROPODA	Malacostraca	Decapoda		Brachyuran zoea larvae	L2	Very sparse																																						
LARVAE	(CRUSTACEA)							BARNACLE LARVAE	ATHROPODA CRUSTACEA	Maxillopoda			Cirripede larvae	L3	Very sparse	Thecostraca																													
BARNACLE LARVAE	ATHROPODA CRUSTACEA	Maxillopoda			Cirripede larvae	L3	Very sparse																																						
		Thecostraca																																											

CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae	L5	Very sparse

**TABLE # 65 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPTOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING SPRING TIDE OF JULY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnussp.</i>	T1	Sparse
				Codonellidae	<i>Tintinnopsisfailakkaensis</i>	T2	Very sparse
					<i>Tintinnopsisgracilis</i>	T3	Sparse
					<i>Tintinnopsismortensenii</i>	T4	Very sparse
					<i>Tintinnopsis radix</i>	T5	Scattered
				Dictyocystidae	<i>Luminella sp.</i>	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C4	Very sparse

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				Eucalanidae	<i>Pareucalanus sp.</i>	C5	Very sparse
					<i>Subeucalanus sp.</i>	C6	Very sparse
				Temoridae	<i>Temora sp.</i>	C7	Very sparse
				Tortanidae	<i>Tortanus sp.</i>	C8	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C9	Abundant
			Harpacticoida	Clytemnestridae	<i>Clytemnestra sp.</i>	C10	Very sparse
				Euterpinidae	<i>Euterpina sp.</i>	C11	Sparse
				Ectinosomatidae	<i>Microsetellasp.</i>	C12	Sparse
			Poecilostomatoida	Corycaeidae	<i>Corycaeus sp.</i>	C13	Very sparse
				Oncaeidae	<i>Oncaea sp.</i>	C14	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
MYSIDS	ATHROPODA	Malacostraca	Mysida,	Penaeidae	<i>Metapenaeussp.</i>	M1	Very sparse
	CRUSTACEA		Decapoda	Solenoceridae	<i>Solenocerasp.</i>	M2	Very sparse
UROCHORDATA	CHORDATA	Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
	SUB PHYLUM UROCHORDATA			Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant

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ASCIDIAN LARVAE	CHORDATA SUBPHYLUM: TUNICATA	Ascidacea			Ascidian tadpole larvae	L2	Very sparse
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L3	Very sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L4	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L5	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L6	Sparse
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L7	Sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Rotalliidae	<i>Rotalia</i> sp.	F1	Very sparse

**TABLE # 66 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPTOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF JULY 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus</i> sp.	T1	Scattered
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Very sparse
					<i>Tintinnopsis mortensenii</i>	T4	Very sparse
					<i>Tintinnopsis radix</i>	T5	Abundant
				Xystonellidae	<i>Favella</i> sp.	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus</i> sp.	C1	Scattered
					<i>Parvocalanus</i> sp.	C2	Very sparse
				Clausocalanidae	<i>Clausocalanus</i> sp.	C3	Very sparse
				Temoridae	<i>Temora</i> sp.	C4	Very sparse
				Tortanidae	<i>Tortanus</i> sp.	C5	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona</i> sp.	C6	Scattered
			Harpacticoida	Clytemnestridae	<i>Clytemnestra</i> sp.	C7	Very sparse
				Euterpinae	<i>Euterpina</i> sp.	C8	Sparse

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				Ectinosomatidae	<i>Microsetellasp.</i>	C9	Very sparse
			Poecilostomatatoida	Oncaeidae	<i>Oncaea sp.</i>	C10	Very sparse
UROCHORDATA	CHORDATA	Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
	SUB PHYLUM UROCHORDATA			Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
ASCIDIAN LARVAE	CHORDATA SUBPHYLUM: TUNICATA	Ascidacea			Ascidian tadpole larvae	L2	Very sparse
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L3	Very sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L4	Very sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L5	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae	L6	Very sparse



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MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L7	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Scattered
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L9	Sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Rotalliidae	<i>Rotalia</i> sp.	F1	Very sparse
NEMATODE	NEMATODA				Unidentified nematodes	N1	Very sparse

## BENTHIC ORGANISMS:

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPT harbour region and nearby creek. The meio-benthic organisms during spring tide and Neap tide were represented by Polychaetes *Dasybranchus* sp., and *Prinisposp*. Population of benthic fauna was varying from 30-50 N/m<sup>2</sup> during spring tide and 10-60 N/m<sup>2</sup> during spring tide

**Table # 67 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING SPRING TIDE IN JULY 2022**

HARBOUR AREA CREEKS DURING SPRING TIDE IN JULY 2022						
REPRESENTATION BY GROUP	DPT HARBOUR			CREEKS		
Benthic fauna						
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family:Capitellidae Dasybranchussp.	10	20	40	10	20	NS
Family Spionidae Prinisposp.	20	20	10	20	20	NS
Total polychaetes N/M <sup>2</sup>	30	40	50	30	40	NS
TOTAL BenthicFauna NUMBER/ M <sup>2</sup>	30	40	50	30	40	

NS: No sample

**Table # 68 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING NEAP TIDE IN JULY 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPT HARBOUR			CREEKS		
Benthic fauna						
POLYCHAETES	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family :Capitellidae Dasybranchussp.	10	10	20	50	30	NS

Family Spionidae Prinisposp.	20	20	10	10	20	NS
Family :Nephtyidae Nephthys sp.	10	10	10	10	10	NS
Total Polychaetes N/M <sup>2</sup>	40	40	40	70	60	
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	40	40	10	70	60	

**Table # 69 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT OOT JETTY AREA, VADINAR DURING SPRING TIDE IN JULY 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family :Capitellidae <i>Notomastussp.</i>	40	0
Family :Capitellidae <i>Heteromastussp.</i>	10	0
Total polychaetes N/M <sup>2</sup>	50	0
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	50	0

## **12.0 Conclusive Summary and Remedial measures Suggested**

- The AAQ monitoring at five locations of Deendayal Port Kandla indicates that the mean  $PM_{10}$  and  $PM_{2.5}$  values for four locations viz. Marine Bhavan, Oil Jetty area, Estate Office and Coal storage area were found above the permissible limit (standards  $100 \mu\text{g}/\text{m}^3$ ,  $60 \mu\text{g}/\text{m}^3$ ). The higher concentration of Particulate matter at Marine Bhavan due to vehicles emissions during loading-unloading of food grains and timbers; at Oil Jetty area due to industries activities and heavy vehicles transportation; at Estate office due to construction work, vehicles emission produced from trucks, heavy duty vehicles that pass through the road outside Kandla port and Oil jetty area; while at Coal Storage area lifting of coal with grab and other coal handling processes. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. At Gopalpuri location, concentration of  $PM_{10}$  varied from  $86\text{--}135 \mu\text{g}/\text{m}^3$  and mean was  $107 \mu\text{g}/\text{m}^3$ , concentration of  $PM_{2.5}$  was ranges from  $42\text{--}82 \mu\text{g}/\text{m}^3$  and mean was  $58 \mu\text{g}/\text{m}^3$ . Tuna port for  $PM_{10}$  and  $PM_{2.5}$  were found within permissible limit.
- The AAQ monitoring Vadinar at Admin building, the concentration of monthly average  $PM_{10}$  value was found  $103 \mu\text{g}/\text{m}^3$  slightly higher at both sampling station (Standard Limit  $100 \mu\text{g}/\text{m}^3$ ) & concentration of  $PM_{2.5}$  within the limit at both sampling station (Limit  $60 \mu\text{g}/\text{m}^3$ ).
- Drinking water at all the twenty locations was found potable and was within permissible limits of BIS standards (IS 10500-2012).
- Noise quality was also within the set permissible standards of an Industrial Area. The noise level observed during day time was  $>75 \text{ dB (A)}$  and at night time was  $>70 \text{ dB (A)}$  during the entire monitoring period.
- The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) and Vadinar were in line with the standards set by the Gujarat Pollution Control Board.
- It was suggested to do treatment on regular basis to avoid flow of contamination / Pollutant water into the sea.
- The mean day time temperature for Deendayal Port was  $25.6^\circ\text{C}$ . The day-time maximum temperature was  $34.3^\circ\text{C}$ . The mean night time temperature recorded was  $28.4^\circ\text{C}$ . The Solar Radiation minimum was recorded  $0.23 \text{ w}/\text{m}^2$  in 27th July and maximum  $623.2$  18<sup>th</sup> July. The mean Solar Radiation in July month was  $115.72 \text{ w}/\text{m}^2$ . The mean Relative humidity was 88.15 % for the month of July. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 47 %. The average wind velocity for the entire month of July was  $1.56 \text{ m}/\text{s}$ . Maximum wind velocity was recorded  $13.8 \text{ m}/\text{s}$ . The wind direction was mostly North West.

### **Reasons for higher Values of PM<sub>10</sub>**

- The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.
- Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

### **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of July, 2022 were beyond the permissible limit at all locations mentioned above Except Tuna Port for PM<sub>10</sub>. Given below are the remedial measures suggest to minimize the Air pollution.

- During July, 2022 overall ambient air quality of the DPA was within GPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, Marine Bhavan, Estate Office and Oil Jetty area. To improve air quality the port was using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

**Solution towards the Green port:**

- The vehicles should be covered during transportation and the vehicle carrying the coal should not be overloaded by raising the height of carriage.
- The water sprinklers should be use during transportation of loaded heavy vehicles on raw road.
- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle- Mask advised in sensitive areas.
- Use of renewable energy like solar energy should be optimal and ensure to work continuously.
- Create awareness towards public.
- Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.
- Limit the Activity and time of Exposure in Sensitive Area.
- Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.
- New scanning technology and new high power Tugs are reducing operation timing and CO<sub>2</sub> Emission are good creativity.
- Initiate Natural Gas (CNG) as fuel by all buses and trucks.

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## ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY



**REPORT** : **DCPL/DPA/21-22/28**

**Mont** : **August**

**Issue** : **01**

**Revision** : **00**

**Prepare** : **DETOX CORPORATION PVT. LTD., SURAT**

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## EXECUTIVE SUMMARY

## ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTAL MONITORING REPORT- AUGUS, 2022

### 1. EXECUTIVE SUMMARY

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to understand status of various parameters in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### A) Ambient Air

The monitoring of Ambient Air quality at 6-locations at Deendayal Port Authority Kandla and 2- location at Vadinar Port on 24 hourly basis for TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> and NMHC in twice a week 24 hourly at uniform intervals (as per NAAQS) at Gopalpuri, Tuna Port, Marine Bhavan building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and Vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The TSPM values in month of August 2022 were found 562 µg/m<sup>3</sup> maximum at Coal Storage area on 08.08.2022 and minimum 102 µg/m<sup>3</sup> at Tuna Port on 16.08. 2022. The PM<sub>10</sub> values were found from 412 µg/m<sup>3</sup> maximum at Coal Storage area on 08.08.2022 and minimum 61 µg/m<sup>3</sup> at Tuna Port on 26.08. 2022. The PM<sub>2.5</sub> values were found from 146 µg/m<sup>3</sup> maximum at Coal Storage area on 08.08. 2022 and minimum 27 µg/m<sup>3</sup> at Tuna Port on 04.08 2022. The PM<sub>10</sub> and PM<sub>2.5</sub> values were found for four locations (Marine Bhavan Building, Coal Storage Area, Estate Building, and Oil Jetty) to exceed the permissible limit.

At Gopalpuri location concentration of PM<sub>10</sub> was found mostly within the permissible limit, the concentration of PM<sub>2.5</sub> was within the permissible limit. Only at Tuna port, all parameters of ambient air quality were found within the limit.

The AAQ monitoring Vadinar at Admin building and signal building the concentration of PM<sub>2.5</sub> had shown very slight increase and the PM<sub>10</sub> concentrations had shown the increasing trend.

The overall values of August for Gaseous SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> concentration were within the permissible limit at all location and NMHC were found BQL (Below Quantification Limit).

## **B) Weather**

The mean day time temperature at Deendayal Port was 29.81 °C. The day-time maximum temperature was 35.4°C and minimum was 25.7 °C. The mean night time temperature recorded was 27.57 °C. The mean Solar Radiation in August month was 109.08 w/m<sup>2</sup>. The maximum solar radiation was recorded 663.7 w/m<sup>2</sup> in 6<sup>th</sup> August, 2022 and the minimum solar radiation was recorded 0.23 w/m<sup>2</sup> in 5<sup>th</sup> August, 2022. The mean Relative humidity was 88.15 % for the month of August. Maximum Relative humidity was recorded 99.55 % and minimum Relative humidity was recorded 58 %. The average wind velocity for the entire month of August was 0.55 m/s. Maximum wind velocity was recorded 9.2 m/s. The wind direction was mostly West-South.

## **C) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:**

The results obtained from the study for the month of August 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) was not affected by Port activities.

## **D) Drinking Water Quality**

The drinking water being supplied to Deendayal Port was safe for drinking purpose. At all drinking water monitoring stations around port area were in line with the standard limit as per the drinking water specifications given in IS 10500:2012 as per tested parameters only.

The average results for 20 locations were as: pH were found Min 7.20 and maximum 7.60, TDS were found min 374.0 mg/l and Max found 490.0 mg/l, Chloride were found Min 150.33 mg/l and Max 215.48 mg/l, Total Hardness were found Min 370.0 mg/l and Max 500.0 mg/l and Calcium were found Min 40.08 mg/l and Max 72.14 mg/l, color found colorless and odor were odorless. In all water samples BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count ( E-coli & Coliform) is absent in all drinking water samples.

## **E) Monitoring Performance of Sewage Treatment Plant**

It was seen that the performance of STP at Deendayal Township, DPA STP Plant and Vadinar STP plant was satisfactory by overall. The treatment plant was well maintained during [August 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. At Gopalpuri STP, the pollutant removal efficiency for TSS, BOD and COD was ranged from 33-68%, 18-69% and 42-67% respectively. At Kandla STP, removal efficiency for TSS, BOD and COD was ranged from 43-61%, 14-66% and 41-63% respectively & at Vadinar STP removal efficiency for TSS, BOD and COD was ranged from

34-57%, 12-66% and 40-70% respectively. At all STP location the pH were ranged from 7.21-7.45, Total Suspended Solids were found 34.4-57.7 mg/l, Residual Chlorine were below Detection Limit (Less Than 0.5), COD were found 30-70 mg/l and 3day BOD @ 27 °C were found 6 to 22 mg/l.

#### **F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port ranged from 67.1 dB(A) to 74.8 dB(A) while at Vadinar port 3 location ranged from 58.0 dB(A) to 64.9 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port ranged from 62.3 dB to 69.5 dB(A) while at Vadinar port which was within the permissible limits of 70 dB(A) for the industrial area for the night time.



# **CHAPTER-1**

## **INTRODUCTION**

### **DEENDAYAL PORT AUTHORITY**

## **1.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 Kms. From the mouth of Gulf of Kachchh. Latitude: 23° 01" N Longitude: 70° 13"E. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rose to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15 consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 127.10 million metric tons of cargo during the FY 2021-22, as against 117.566 million metric tons in FY 2020-21. Showing a growth of 8.11 %. Incidentally, DPA is the only major Indian port of handle more than 127 MMT cargo throughout and it has also registered the highest cargo throughput in its history. While the port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in Sept. 2021. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural up-gradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32MMTPA Essar Oil Refinery in Jamnagar District. Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the prescribed standards by GPCB/CPCB/MoEF& CC. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port. The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.



## **CHAPTER-2**

### **AMBIENT AIR QUALITY MONITORING**

## **2. Introduction**

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth's atmosphere. It may cause diseases, allergies or death of humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty. The consequences of industrialization and the demand for improved quality of life has been increased exposure to air pollution (Vallero, 2014). An air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Any gas could qualify as pollution if it reached a high enough concentration to do harm. Theoretically, that means there are dozens of different pollution gases. In practice, about ten different substances cause most concern. Heavy metals represent a class of omnipresent pollutants, with toxic potential, in some cases even at low exposure levels. They concentrate in each tropic level because of their weak mobility, so the concentration in plants is higher than in soil, in herbivore animals higher than in plants, in carnivores' tissues higher than in herbivore, the highest concentration being reached at the end of the tropic chain, at big predacious and human bodies.

Globally, one of the main contributors to emissions of atmospheric pollutants and a significant user of energy is the industrial sector (Conti et al. 2015).

The concentration of air pollutants depends not only on the quantities that are emitted from the polluting sources, but also on the ability of the atmosphere to either absorb or disperse such emissions (USEPA, 2008).

Nowadays, the shipping sector provides low-cost and reliable delivery services in the economic field (Arunachalam et al. 2015). Nevertheless, shipping-related activities have a

considerable impact on air pollution, especially in coastal areas but also globally (Buccolieri et al. 2016). The primary air pollutants are PM, VOCs, NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub>, and CO (Bailey and Solomon 2004). As a consequence, a wide range of options toward “greener” seaports is needed (Bailey and Solomon 2004). Some of these measures are easy to adopt such as the regulation of fuel quality (by using low-sulfur alternative fuels), the speed reduction (Lack et al. 2011), and the use of alternative transportation equipment (Lai et al. 2011).

Clean air is the basic requirement of all living organisms. In recent times, due to population growth, urban sprawl, industrial development, and vehicular boom, the quality of air is deteriorating and being polluted. Pollutants of major public health concerns include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, which pose serious threats to human health and hygiene. In the present study, prime particulate pollutants (PM<sub>10</sub>, PM<sub>2.5</sub>), and gaseous pollutants (SO<sub>2</sub>, and NO<sub>2</sub>) were estimated at seven stations in and around Dahej Port, Gujarat, India (Soni and Jagruti Patel, 2017).

Among particulate pollutants, particulate matter (PM) is a ubiquitous entity, and is especially a grave problem due to its higher suspension rate into the atmosphere, and adverse health effects on plants, animals, humans, and materials in the form of visibility reduction, soiling of buildings, etc. (Horaginamani and Ravichandran, 2010; Chaurasia *et al.*, 2013).

The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

## 2.1 Ambient Air Quality Monitoring

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

**Table: 1. Ambient Air Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Marine Bhavan	AL-1	23° 0' 26.524"N	70° 13' 22.414"E	<b>DPA-Kandla</b>
2.	Oil Jetty	AL-2	23° 1' 45.613"N	70° 13' 11.052"E	
3.	Estate Office	AL-3	23° 1' 11.273"N	70° 12' 48.657"E	
4.	Gopalpuri Hospital	AL-4	23° 4' 53.551"N	70° 8' 7.047"E	
5.	Coal Storage Area	AL-5	22° 59' 31.812"N	70° 13' 9.979"E	
6.	Tuna Port	AL-6	22° 59' 15.291"N	70° 58' 57.018"E	
7.	Signal Building	AL-7	22° 26' 26.750"N	69° 40' 22.127"E	<b>DPA-Vadinar</b>
8.	Admin Building	AL-8	22° 26' 25.223"N	69° 40' 19.358"E	

### ● Air Quality Monitoring Methodology

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> & Benzene and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours for gaseous parameters. The absorbing reagents for SO<sub>2</sub>:- Absorbing Reagent TCM (Potassium Tetrachloromercurate 0.04M): Mercuric Chloride, Potassium Chloride and EDTA used. For NO<sub>2</sub>:- Absorbing Reagent Sodium Hydroxide (NaOH): Sodium Hydroxide and Sodium Arsenite used. For NH<sub>3</sub> need Conc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>. The GFA filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected two consecutive days a week as per CPCB guidelines, from all the eight locations as mentioned in the EMP.

## 2.2 Results

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of August 2022 are given in Tables 2 to 7. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building &Nr. Signal Building) are given in Tables 8 to 9.

The Movement of heavy transport with uncovered coal transportation, raw road around ambient location may be causes fugitive dust emission from dry conditions. Particulate Matter then enters the atmosphere through the action of wind, vehicular movement, or other activities. The dust produces tends to float in air and spread all around the vicinity. Direction and speed of wind affect the dispersion of the dust particulate matter. Humidity of air also has strong effect on the spreading of particulate matter. With increasing humidity, moisture particles eventually grow in size to a point where 'dry deposition' occurs, reducing PM<sub>10</sub> concentrations in the atmosphere.

Location 1: Marine Bhavan (AL1)

Table 2 : Results of Air Pollutant Concentration at Marine Bhavan										
Sampling Period	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL1 – 1	01.08.2022	311	204	97	6.04	5.14	18.47	16.54	3.34	5.79
					4.23		14.43		6.79	
					5.14		16.74		7.25	
AL1 – 2	04.08.2022	364	248	112	5.14	5.24	13.27	18.28	6.22	6.37
					6.65		14.43		7.83	
					3.93		27.12		5.06	
AL1 – 3	08.08.2022	414	260	125	3.17	3.75	27.12	24.62	5.41	5.18
					5.19		28.86		5.87	
					2.88		17.89		4.26	
AL1 – 4	12.08.2022	366	245	115	3.02	4.33	16.74	15.58	6.56	7.07
					5.74		14.43		7.98	
					4.23		15.58		6.68	
AL1 – 5	16.08.2022	289	195	84	5.44	4.23	17.89	19.43	2.42	4.34
					4.23		18.47		5.41	
					3.02		21.93		5.18	
AL1 - 6	20.08.2022	315	201	98	3.93	4.84	16.16	15.00	4.72	2.76
					4.84		19.62		2.42	
					5.74		9.23		1.15	
AL1 - 7	23.08.2022	365	254	109	4.84	4.33	12.12	16.35	6.68	5.22
					3.63		20.20		4.72	
					4.53		16.74		4.26	
AL1 – 8	26.08.2022	329	217	101	5.14	4.03	24.82	23.85	4.95	3.53
					3.02		27.70		2.53	
					3.93		19.04		3.11	
AL1 – 9	29.08.2022	170	106	59	3.93	4.73	19.04	19.04	7.94	6.91
					4.84		16.74		5.99	
					5.44		21.35		6.79	
Monthly Average		325	214	100		4.49		18.71		5.03
Standard Deviation		69	48	20		0.53		3.70		1.44

**Table 2 : Results of Air Pollutant Concentration at Marine Bhavan**

Parameter	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>	ppm	4.0 mg/m <sup>3</sup>	-
AL1 – 1	01.08.2022	1.03	BQL	2.09	388
AL1 – 2	04.08.2022	1.18	BQL	1.35	1099
AL1 – 3	08.08.2022	1.02	BQL	1.6	2350
AL1 – 4	12.08.2022	1.23	BQL	1.62	1126
AL1 – 5	16.08.2022	1.02	BQL	1.63	1921
AL1 - 6	20.08.2022	1.14	BQL	1.95	383
AL1 - 7	23.08.2022	1.13	BQL	2.14	1621
AL1 - 8	26.08.2022	1.03	BQL	1.41	1036
AL1 - 9	29.08.2022	1.05	BQL	2.02	958
<b>Monthly Average</b>		<b>1.10</b>	<b>-</b>	<b>1.72</b>	<b>1241</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.30</b>	<b>694</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 325 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 214 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 100 µg/m<sup>3</sup> which is above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.49 µg/m<sup>3</sup>, 18.71 µg/m<sup>3</sup> & 5.01 µg/m<sup>3</sup> respectively; these values were within the permissible limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.80 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup> prescribed by NAAQS.

**Location 2: Oil Jetty (AL2)**

**Table 3 : Results of Air Pollutant Concentration at Oil Jetty**

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL2 -1	01.08.2022	200	121	72	5.44	4.23	13.85	13.47	6.10	6.52
					4.23		10.97		7.83	
					3.02		15.58		5.64	
AL2 -2	04.08.2022	202	121	70	3.63	3.73	10.97	11.16	3.34	4.72
					4.23		9.81		5.29	
					3.32		12.70		5.53	
AL2 -3	08.08.2022	220	138	72	2.88	2.98	30.59	23.28	1.84	3.11
					3.46		17.31		3.11	
					2.59		21.93		4.37	
AL2 -4	12.08.2022	221	142	70	3.32	3.93	16.16	14.81	3.22	4.11
					3.93		14.43		4.83	
					4.53		13.85		4.26	
AL2 – 5	16.08.2022	206	138	67	3.32	4.03	15.58	16.93	4.37	3.53
					5.14		23.66		2.42	
					3.63		11.54		3.80	
AL2 – 6	20.08.2022	257	165	85	4.53	4.03	20.78	14.43	2.42	3.61
					3.32		8.08		3.80	
					4.23		14.43		4.60	
AL2 – 7	23.08.2022	256	163	87	2.42	2.01	21.93	18.85	4.49	4.68
					1.51		14.43		5.76	
					2.12		20.20		3.80	
AL2 -8	26.08.2022	186	126	53	2.42	2.92	14.43	16.16	2.65	3.84
					1.81		21.93		4.14	
					4.53		12.12		4.72	
AL1 – 9	29.08.2022	225	148	67	2.72	3.63	19.62	17.89	6.79	5.53
					4.53		17.31		4.49	
					3.63		16.74		5.29	
Monthly Average		219	140	71		3.48		16.13		4.26
Standard Deviation		24	16	10		0.77		3.70		1.07



**Table 3 : Results of Air Pollutant Concentration at Oil Jetty**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
NAAQMS limit					
AL2 -1	01.08.2022	1.1	BQL	1.88	420
AL2 -2	04.08.2022	1.09	BQL	1.35	1181
AL2 -3	08.08.2022	1	BQL	1.19	1156
AL2 -4	12.08.2022	1.04	BQL	1.19	1160
AL2 -5	16.08.2022	1.14	BQL	1.52	2302
AL2 -6	20.08.2022	1.01	BQL	1.99	492
AL2 -7	23.08.2022	1.03	BQL	2.17	987
AL2 -8	26.08.2022	1.11	BQL	1.28	1076
AL2 -8	29.08.2022	1.11	BQL	1.93	1261
Monthly Average		1.07	-	1.57	1097
Standard Deviation		0.05	-	0.39	574

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

Oil Jetty Area, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> was mainly by motor vehicle emission produced from various types of vehicles at Oil Jetty Area. The mean TSPM value at Oil Jetty was 219 µg/m<sup>3</sup>. The mean PM<sub>10</sub> value was 140 µg/m<sup>3</sup>, PM<sub>2.5</sub> value was 71 µg/m<sup>3</sup> which is above the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit prescribed by NAAQS. The mean concentration of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.48 µg/m<sup>3</sup>, 16.13 µg/m<sup>3</sup> and 4.26 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.07 µg/m<sup>3</sup> which was well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.57 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

Location 3: Kandla Colony – Estate Office (AL-3)

Table 4 : Results of Air Pollutant Concentration at Estate Office										
Sampling Period	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit				100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3	
AL3 – 1	01.08.2022	166	100	65	6.95	5.54	18.47	15.58	6.33	7.52
					5.74		16.74		7.83	
					3.93		11.54		8.40	
AL3 – 2	04.08.2022	181	113	66	3.02	4.03	11.54	11.93	6.45	4.18
					5.74		9.81		3.22	
					3.32		14.43		2.88	
AL3 – 3	08.08.2022	182	110	61	3.75	3.65	19.62	22.12	3.80	2.92
					4.32		26.55		3.22	
					2.88		20.20		1.73	
AL3 – 4	12.08.2022	205	128	62	3.02	4.33	19.04	16.74	5.76	4.34
					4.84		14.43		4.37	
					5.14		16.74		2.88	
AL3 – 5	16.08.2022	209	122	69	1.51	2.42	21.93	22.51	4.37	17.23
					3.02		31.16		4.72	
					2.72		14.43		42.59	
AL3 – 6	20.08.2022	227	144	77	4.23	3.53	19.04	19.04	4.60	3.72
					2.72		14.43		4.26	
					3.63		23.66		2.30	
AL3 – 7	23.08.2022	317	212	97	3.63	3.53	20.20	17.31	5.41	5.26
					3.02		16.16		5.41	
					3.93		15.58		4.95	
AL3 – 8	26.08.2022	259	159	90	3.32	3.32	15.00	15.97	5.18	3.95
					3.93		15.58		4.26	
					2.72		17.31		2.42	
AL1 – 9	29.08.2022	228	150	75	2.72	2.72	16.74	19.62	4.72	5.41
					3.32		19.04		5.41	
					2.12		23.08		6.10	
Monthly Average		219	137	74		3.79		17.65		6.14
Standard Deviation		47	34	12		0.90		3.51		4.69

**Table 4 : Results of Air Pollutant Concentration at Estate Office**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
NAAQMS limit					
AL3 -1	01.08.2022	1.24	BQL	2.2	418
AL3 -2	04.08.2022	1.01	BQL	1.65	1758
AL3 -3	08.08.2022	1.14	BQL	1.24	2059
AL3 -4	12.08.2022	1.18	BQL	1.87	1755
AL3 – 5	16.08.2022	1.08	BQL	2.07	2277
AL3 – 6	20.08.2022	1.01	BQL	1.75	1066
AL3 – 7	23.08.2022	1.04	BQL	1.85	1802
AL3 – 8	26.08.2022	1.06	BQL	1.42	940
AL3 – 9	29.08.2022	1.17	BQL	1.75	776
Monthly Average		1.10	-	1.76	1509
Standard Deviation		0.08	-	0.32	634

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Kandla Port Colony (Estate Office) was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Kandla port Colony were 219 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 137 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 74 µg/m<sup>3</sup> which is above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.79 µg/m<sup>3</sup>, 17.05 µg/m<sup>3</sup> and 6.14 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.10 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide was 1.76 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 4: Gopalpuri Hospital (AL-4)**

**Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital**

Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
Sampling Period	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit				100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3	
AL4 -1	01.08.2022	145	97	45	5.14	4.53	10.39	8.27	4.37	3.57
					3.02		7.50		3.45	
					5.44		6.93		2.88	
AL4 -2	04.08.2022	176	119	55	4.84	4.03	5.77	9.23	2.42	3.53
					3.02		10.39		3.68	
					4.23		11.54		4.49	
AL4 -3	08.08.2022	169	104	52	4.61	3.36	6.93	8.46	1.96	2.19
					2.88		10.97		2.42	
					2.59		7.50		2.19	
AL4 -4	12.08.2022	151	99	50	1.21	1.71	9.23	9.04	3.22	2.53
					2.12		11.54		1.84	
					1.81		6.35		2.53	
AL4 – 5	16.08.2022	151	94	49	2.42	2.42	14.43	13.27	2.42	3.11
					1.81		8.08		4.03	
					3.02		17.31		2.88	
AL4 – 6	20.08.2022	175	101	59	1.51	1.81	12.70	11.73	2.42	4.07
					2.12		8.08		4.37	
					1.81		14.43		5.41	
AL4 – 7	23.08.2022	146	99	44	1.51	2.22	17.31	15.58	3.11	3.03
					2.42		13.27		3.80	
					2.72		16.16		2.19	
AL4 – 8	26.08.2022	140	89	49	1.81	2.52	10.97	10.97	3.57	4.03
					3.32		11.54		4.14	
					2.42		10.39		4.37	
AL1 – 9	29.08.2022	170	106	59	3.02	2.32	8.66	9.43	3.22	4.53
					2.12		12.12		4.72	
					1.81		7.50		5.64	
Monthly Average		158	101	51		2.83		10.82		3.26
Standard Deviation		14	8	6		1.04		2.60		0.67

<b>Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>NAAQMS limit</b>					
<b>AL4 -1</b>	01.08.2022	1.2	BQL	1.99	403
<b>AL4 -2</b>	04.08.2022	1.11	BQL	1.26	1375
<b>AL4 -3</b>	08.08.2022	1.06	BQL	1.23	1531
<b>AL4 -4</b>	12.08.2022	1.16	BQL	1.84	2314
<b>AL4 -5</b>	16.08.2022	1.05	BQL	1.58	1383
<b>AL4 -6</b>	20.08.2022	1	BQL	2.12	623
<b>AL4 -7</b>	23.08.2022	1.1	BQL	1.61	910
<b>AL4 -8</b>	26.08.2022	1.01	BQL	1.64	1324
<b>AL4 -9</b>	29.08.2022	1.03	BQL	1.92	1149
<b>Monthly Average</b>		<b>1.09</b>	<b>-</b>	<b>1.66</b>	<b>1233</b>
<b>Standard Deviation</b>		<b>0.07</b>	<b>-</b>	<b>0.32</b>	<b>594</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 158 µg/m<sup>3</sup>, the PM<sub>10</sub> value was found mostly within the permissible limit but mean value was 101 µg/m<sup>3</sup> which is slightly exceed the permissible limit, PM<sub>2.5</sub> value was 51 µg/m<sup>3</sup> which is within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 2.88 µg/m<sup>3</sup>, 10.82 µg/m<sup>3</sup> and 3.26 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.09 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon monoxide concentration was 1.66 mg/m<sup>3</sup> which is well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 5: Coal Storage Area (AL-5)**

**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area										
Sampling Period	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit		100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3	
AL6 – 1	01.08.2022	455	325	130	7.25	6.04	21.93	21.93	4.95	6.56
					6.04		23.08		6.91	
					4.84		20.78		7.83	
AL6 – 2	04.08.2022	508	352	142	6.95	5.34	19.04	18.28	7.48	7.67
					5.14		22.51		8.06	
					3.93		13.27		7.48	
AL6 – 3	08.08.2022	562	412	146	5.77	4.52	21.93	25.20	3.80	3.49
					4.32		23.08		3.22	
					3.46		30.59		3.45	
AL6 – 4	12.08.2022	529	379	136	6.04	6.04	16.16	15.97	5.87	5.76
					7.55		12.70		4.03	
					4.53		19.04		7.37	
AL6 – 5	16.08.2022	480	331	127	6.35	4.94	19.62	20.01	7.71	6.56
					4.84		17.31		6.33	
					3.63		23.08		5.64	
AL6 – 6	20.08.2022	491	354	131	6.04	4.63	15.00	16.35	7.60	7.06
					3.32		13.85		7.37	
					4.53		20.20		6.22	
AL6 – 7	23.08.2022	555	399	145	6.95	5.24	12.70	15.58	8.17	5.99
					5.14		17.89		4.37	
					3.63		16.16		5.41	
AL6 – 8	26.08.2022	439	303	122	4.23	5.24	23.08	20.97	5.18	6.06
					6.35		17.89		6.33	
					5.14		21.93		6.68	
AL1 – 9	29.08.2022	554	408	133	5.74	5.04	26.55	22.12	8.06	8.25
					6.35		23.08		7.48	
					3.02		16.74		9.21	
Monthly Average		508	363	135		5.25		19.29		6.14
Standard Deviation		45	39	8		0.57		3.37		1.24

**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
NAAQMS limit					
AL5 – 1	01.08.2022	1.03	BQL	2.08	524
AL5 – 2	04.08.2022	1.04	BQL	1.58	1040
AL5 – 3	08.08.2022	1.18	BQL	1.28	2322
AL5 – 4	12.08.2022	1.03	BQL	1.37	962
AL5 – 5	16.08.2022	1.06	BQL	1.75	1074
AL5 – 6	20.08.2022	1.14	BQL	1.66	590
AL5 – 7	23.08.2022	1.18	BQL	1.61	920
AL5 – 8	26.08.2022	1.20	BQL	1.53	854
AL5 – 9	29.08.2022	1.11	BQL	1.29	580
Monthly Average		1.11	-	1.61	1036
Standard Deviation		0.07	-	0.24	557

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 508 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 363 µg/m<sup>3</sup>, the PM<sub>2.5</sub> value was 135 µg/m<sup>3</sup> which was well above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 5.25 µg/m<sup>3</sup>, 19.29 µg/m<sup>3</sup> and 6.14 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.11 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.61 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

Location 6: Tuna Port (AL-6)

Table 7 : Results of Air Pollutant Concentration at Tuna Port

Table 7 : Results of Air Pollutant Concentration at Tuna Port										
Sampling Period	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL5 -1	01.08.2022	104	69	34	4.53	3.42	11.54	9.62	4.49	3.57
					3.02		9.81		3.91	
					2.72		7.50		2.30	
AL5 – 2	04.08.2022	106	69	27	2.42	1.91	7.50	8.27	2.65	3.61
					1.81		9.23		3.45	
					1.51		8.08		4.72	
AL5 – 3	08.08.2022	107	64	36	2.59	2.11	6.35	10.39	3.11	2.92
					1.73		11.54		2.07	
					2.02		13.27		3.57	
AL5 – 4	12.08.2022	127	76	41	1.21	1.31	8.66	10.97	2.42	2.95
					0.91		11.54		3.57	
					1.81		12.70		2.88	
AL5 – 5	16.08.2022	102	68	32	1.81	2.82	13.27	11.73	5.76	5.45
					3.63		11.54		5.53	
					3.02		10.39		5.06	
AL5 – 6	20.08.2022	136	81	46	3.02	2.42	30.01	25.97	4.72	11.02
					2.72		20.78		15.57	
					1.51		27.12		12.76	
AL5 – 7	23.08.2022	119	71	39	3.02	2.52	14.43	12.31	4.49	4.60
					1.81		10.39		4.26	
					2.72		12.12		5.06	
AL5 – 8	26.08.2022	119	61	39	3.63	2.52	15.58	14.81	4.72	4.49
					2.12		10.97		3.80	
					1.81		17.89		4.95	
AL1 – 9	29.08.2022	143	98	39	2.42	2.22	10.39	11.16	4.49	3.41
					3.02		12.12		3.34	
					1.21		10.97		2.42	
Monthly Average		118	73	37		2.38		13.01		4.83
Standard Deviation		15	11	6		0.63		5.58		2.65



**Table 7 : Results of Air Pollutant Concentration at Tuna Port**

		C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL6 -1	01.08.2022	1.19	BQL	2.24	947
AL6 – 2	04.08.2022	1	BQL	1.85	751
AL6 – 3	08.08.2022	1.09	BQL	1.18	1331
AL6 – 4	12.08.2022	1.13	BQL	2.08	777
AL6 – 5	16.08.2022	1	BQL	1.83	962
AL6 – 6	20.08.2022	1.11	BQL	1.68	1336
AL6 – 7	23.08.2022	1.19	BQL	2.05	761
AL6 – 8	26.08.2022	1.07	BQL	1.86	556
<b>Monthly Average</b>		<b>1.10</b>	<b>-</b>	<b>1.85</b>	<b>928</b>
<b>Standard Deviation</b>		<b>0.07</b>	<b>-</b>	<b>0.32</b>	<b>281</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port was 118 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 73 µg/m<sup>3</sup>, the mean PM<sub>2.5</sub> value was 37 µg/m<sup>3</sup> which is within the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 2.38 µg/m<sup>3</sup>, 13.01 µg/m<sup>3</sup> and 4.83 µg/m<sup>3</sup> respectively and were all within the permissible limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.10 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.85 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 7: Admin Building (Vadinar) (AL-7)**

**Table 8 : Results of Air Pollutant Concentration at Admin Building**

Sampling Period	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL7 -1	02.08.2022	180	111	59	3.02	5.14	10.39	16.54	6.45	5.79
					5.44		14.43		4.83	
					2.72		11.54		8.17	
AL7 -2	05.08.2022	205	127	69	3.93	5.24	13.27	18.28	9.44	6.37
					4.84		10.97		7.94	
					3.02		15.00		7.02	
AL7 -3	09.08.2022	188	120	65	4.53	3.75	16.16	24.62	6.79	5.18
					3.32		18.47		7.60	
					2.72		13.27		5.99	
AL7 -4	12.08.2022	204	123	68	5.14	4.33	10.97	15.58	8.52	7.07
					6.65		10.39		7.94	
					3.93		7.50		8.06	
AL7 -5	16.08.2022	177	119	54	3.32	4.23	11.54	19.43	6.79	4.34
					3.63		15.00		7.25	
					4.84		9.81		6.10	
AL7 -6	19.08.2022	205	130	69	3.02	4.84	10.97	15.00	9.32	2.76
					2.72		13.85		8.75	
					4.53		9.23		9.67	
AL1 -7	23.08.2022	200	125	65	3.63	4.33	8.66	16.35	5.87	5.22
					5.14		10.97		7.25	
					3.93		7.50		6.33	
AL1-8	26.08.2022	207	132	70	4.23	4.03	12.12	23.85	8.29	3.53
					2.72		14.43		6.91	
					5.44		16.16		5.99	
AL1-9	29.08.2022	194	127	65	3.32	4.73	11.54	19.04	8.63	6.91
					4.84		10.39		7.94	
					6.04		7.50		7.14	
Monthly Average		195	124	65		4.51		18.75		5.24
Standard Deviation		11	6	5		0.50		3.46		1.48

**Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
NAAQMS limit					
AL7 -1	02.08.2022	1.1	BQL	1.94	387
AL7 -2	05.08.2022	1.06	BQL	1.71	420
AL7 -3	09.08.2022	1.04	1.81	1.81	411
AL7 -4	12.08.2022	1.15	BQL	1.65	529
AL7 -5	16.08.2022	1.15	BQL	1.6	533
AL7 -6	19.08.2022	1.04	BQL	1.95	352
AL7 -7	23.08.2022	1.07	BQL	1.9	384
AL7 -8	26.08.2022	1.15	BQL	1.69	432
AL7 -9	29.08.2022	1.05	BQL	1.36	390
Monthly Average		1.09	-	1.73	426
Standard Deviation		0.05	-	0.19	64

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Admin Building, Vadinar the mean TSPM value was 195 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 124 µg/m<sup>3</sup> which was exceed the permissible limit, the mean PM<sub>2.5</sub> value was 65 µg/m<sup>3</sup> which was also slightly exceed from the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were 4.51 µg/m<sup>3</sup>, 18.75 µg/m<sup>3</sup> and 5.24 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.09 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.73 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

Location 8: Signal Building (Vadinar) (AL-8)

Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL8 -1	02.08.2022	153	98	48	3.93	5.64	14.43	14.81	5.29	7.10
					3.32		17.31		7.14	
					1.81		12.70		4.49	
AL8 -2	05.08.2022	179	114	63	2.42	4.10	10.97	27.70	5.76	5.45
					3.02		15.00		4.95	
					3.63		13.27		6.45	
AL8 -3	09.08.2022	170	111	58	4.23	3.88	15.00	16.35	8.29	6.27
					3.32		11.54		6.33	
					4.84		13.85		5.64	
AL8 -4	12.08.2022	164	106	54	2.72	4.63	9.81	17.31	5.06	4.83
					3.93		11.54		6.10	
					5.14		13.27		7.94	
AL8 -5	16.08.2022	161	107	49	3.63	3.93	16.16	19.24	4.14	4.11
					5.44		11.54		5.29	
					6.04		9.23		6.56	
AL8 -6	19.08.2022	176	116	58	3.02	4.73	12.12	13.85	8.98	4.18
					2.72		15.58		7.14	
					4.84		17.31		8.17	
AL8 -7	23.08.2022	178	115	58	6.04	4.23	15.00	23.08	6.79	3.91
					5.44		12.70		7.60	
					3.93		10.39		7.02	
AL8-8	26.08.2022	187	121	59	5.14	4.23	9.23	18.28	6.22	5.68
					3.93		11.54		7.14	
					3.02		12.12		8.06	
AL8-9	29.08.2022	218	137	76	4.23	5.44	11.54	21.35	6.79	6.79
					5.14		13.27		8.17	
					6.35		10.97		6.33	
Monthly Average		176	114	58		4.54		19.11		5.37
Standard Deviation		19	11	8		0.64		4.36		1.19

**Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar**

	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
<b>AL8 -1</b>	02.08.2022	1.19	BQL	2.21	425
<b>AL8 -2</b>	05.08.2022	1.11	BQL	2.13	422
<b>AL8 -3</b>	09.08.2022	1.02	BQL	1.59	464
<b>AL8 -4</b>	12.08.2022	1.16	BQL	1.74	509
<b>AL8 -5</b>	16.08.2022	1.07	BQL	2.06	485
<b>AL8 -6</b>	19.08.2022	1.19	BQL	1.42	342
<b>AL8 -7</b>	23.08.2022	1.03	BQL	1.6	590
<b>AL8 -8</b>	26.08.2022	1.14	BQL	1.43	270
<b>AL8 -9</b>	29.08.2022	1.17	BQL	2.02	528
<b>Monthly Average</b>		<b>1.12</b>	<b>-</b>	<b>1.80</b>	<b>448</b>
<b>Standard Deviation</b>		<b>0.07</b>	<b>-</b>	<b>0.31</b>	<b>97</b>

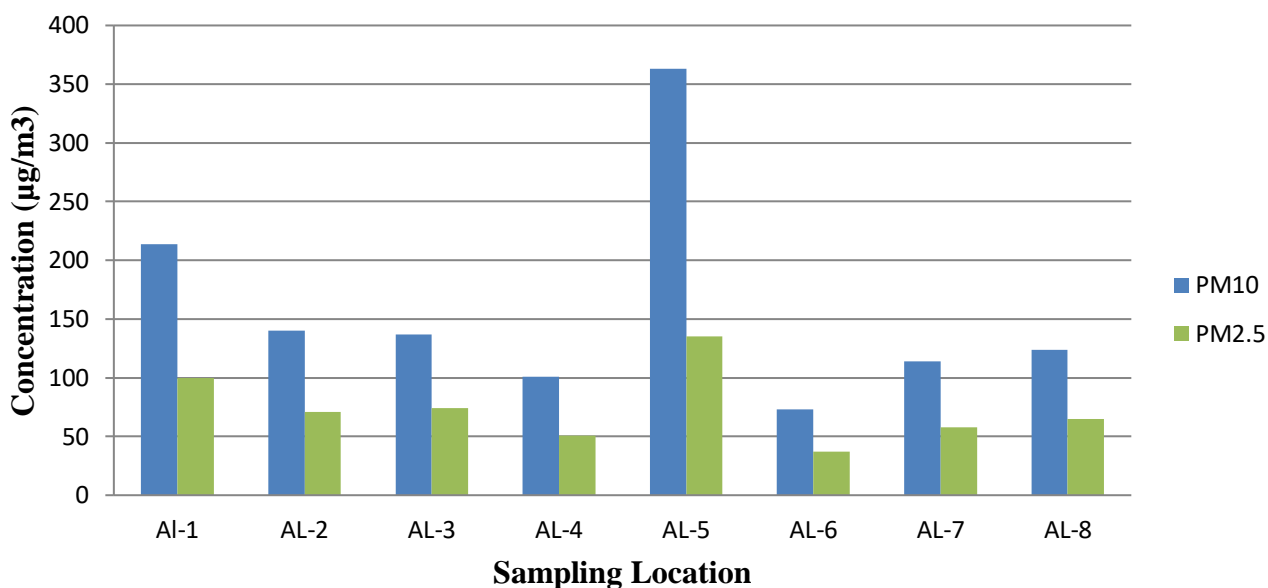
\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

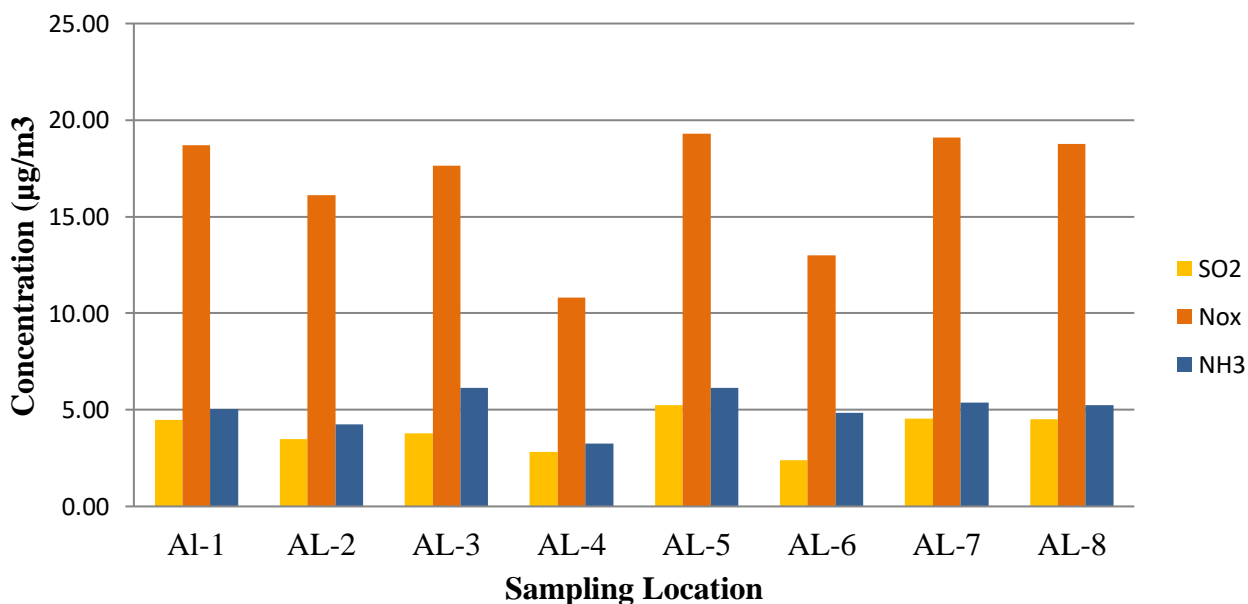
The mean TSPM value at Signal Building Vadinar was 176 µg/m<sup>3</sup>. The mean PM<sub>10</sub> values were 114 µg/m<sup>3</sup> which was slightly exceed from the permissible limit, PM<sub>2.5</sub> value was 58 µg/m<sup>3</sup> which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.54 µg/m<sup>3</sup>, 19.11 µg/m<sup>3</sup> and 5.37 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Admin Building, Vadinar Port. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.80 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

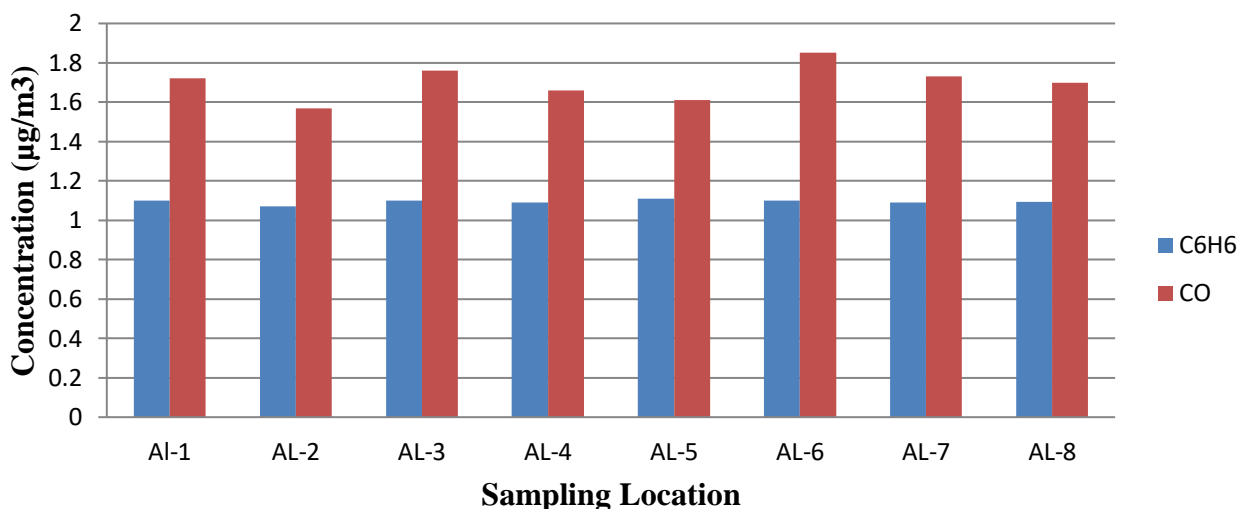
**Fig. No:-1 Average Ambient Air Qulaity (PM) at DPA and Vadinar Sampling Station**



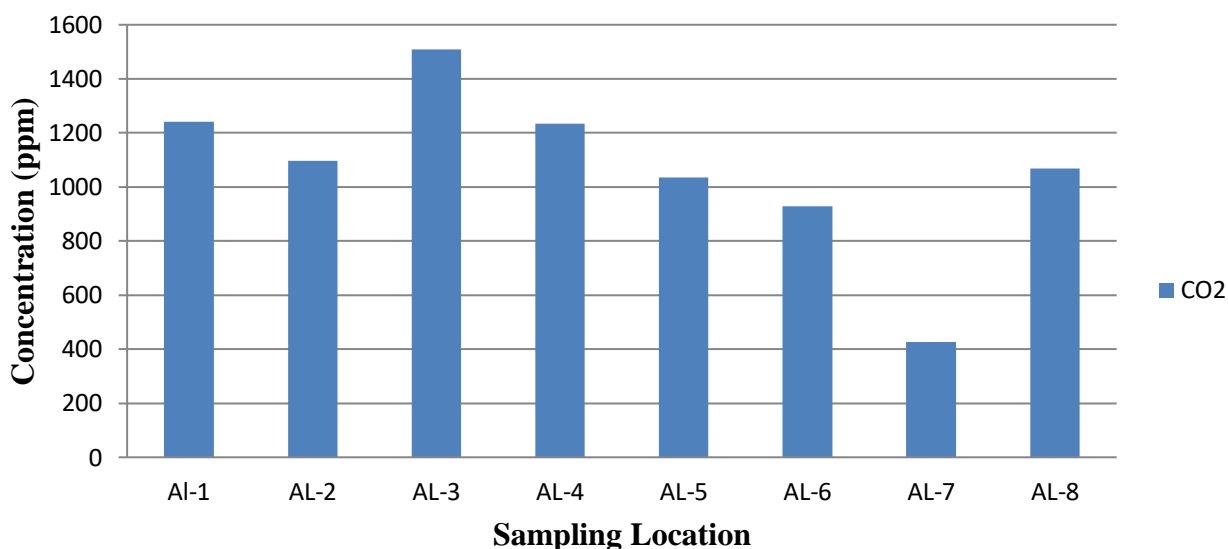
**Fig. No:-2. Average ambient air qulaity (Gaseous) month of August-2022 at DPA and Vadinar sampling location**



**Fig. No:-3. Average ambient air quality (Gaseous) month of August-2022 at DPA and Vadinar sampling location**



**Fig. No:-4. Average ambient air quality (Gaseous) month of August-2022 at DPA and Vadinar sampling location**



### **2.3 Observations and Conclusion**

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Total Suspended Particulate matter as TSPM, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan, Estate Office and Oil Jetty.

The concentration of PM<sub>10</sub> was slightly exceeded at Admin building Vadinar & Signal building Vadinar while the mean concentration of PM<sub>2.5</sub> was found 58 µg/m<sup>3</sup> within permissible limit at Signal Building. At Gopalpuri location concentration of PM<sub>10</sub> was found mostly within the permissible limit but mean value was 101 µg/m<sup>3</sup> which is very close the permissible limit, the average value of PM<sub>2.5</sub> was 51 µg/m<sup>3</sup> which is within the permissible limit. Only at Tuna port, all parameters of ambient air quality were found within the limit.



## **CHAPTER-3**

### **METEOROLOGICAL OBSERVATIONS**

#### **4.1 Meteorological Data**

Automatic Weather station (ID KAZPHOEN424) have been installed in Seva Sadan-3 at the Deendayal Port which records the data on Temperature ( $^{\circ}\text{C}$ ), Relative Humidity (%), Wind speed (kmph), Wind Direction ( $^{\circ}$ ), Solar radiation ( $\text{w}/\text{m}^2$ ) and Rainfall mm.

Meteorological factors play an important role in environmental pollution studies particularly in pollutant transport irrespective of their entry into the environment. The wind speed and direction play a major role in dispersion of environment pollutants. Effects of pollution on receptors animate and inanimate depends on atmospheric condition.

##### **Temperature**

At Deendayal Port, the day time temperature was found range  $25.7\text{--}35.4^{\circ}\text{C}$ . The average day time temperature was  $29.81^{\circ}\text{C}$ . The night time temperature was range from  $25.4\text{--}32.8^{\circ}\text{C}$ . The mean night time temperature recorded was  $27.57^{\circ}\text{C}$ .

##### **Solar Radiation**

The mean Solar Radiation in August month was  $109.08\text{ w}/\text{m}^2$ . The maximum solar radiation was recorded  $663.7\text{ w}/\text{m}^2$  in 6<sup>th</sup> August, 2022 and the minimum solar radiation was recorded  $0.23\text{ w}/\text{m}^2$  in 5<sup>th</sup> August, 2022.

##### **Rainfall**

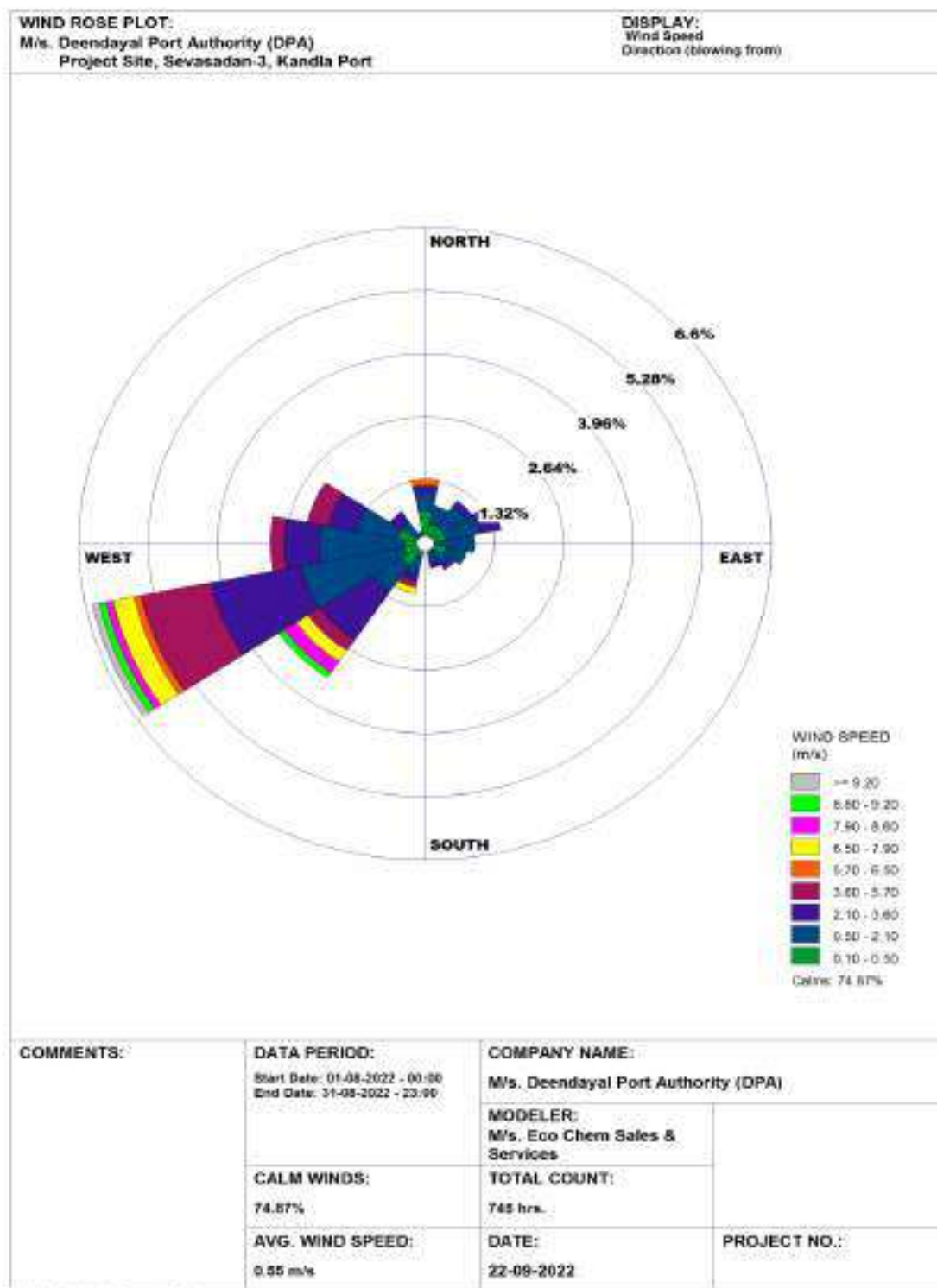
August falls in rainy season with an average rainfall was recorded 79.55 mm.

##### **Relative Humidity**

The mean Relative humidity was 85.55 % for the month of August. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 58 %.

##### **Wind Velocity and Wind Direction**

Velocity and direction of wind have a significant role in the dispersion of air borne materials and therefore determines the air quality of the area. The average wind velocity for the entire month of August was 0.55 m/s. Maximum wind velocity was recorded 9.2 m/s. The wind direction was mostly West-South.



## CHAPTER-4

### DRINKING WATER QUALITY MONITORING

#### 4.0 Drinking Water Quality Monitoring

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

**Table No:-10. Drinking Water Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude
1.	Nirman Building	DL-1	23° 0' 27"N	70° 13' 21"E
2.	P & C Building	DL-2	23° 0' 33"N	70° 13' 20"E
3.	North Gate	DL-3	23° 0' 26.97"N	70° 13' 21.87"E
4.	KPT-Canteen	DL-4	23° 2' 17.2674"N	70° 13'18.2814"E
5.	West Gate	DL-5	23° 59' 40.48"N	70° 12' 50.96"E
6.	Wharf Area	DL-6	22° 59' 52.2"N	70° 13' 22.95"E
7.	Sevasadan-3	DL-7	23° 0' 22.55"N	70° 13' 15.34"E
8.	Workshop	DL-8	23° 0' 33.74"N	70° 13' 20.05"E
9.	Custom Building	DL-9	23° 1' 8.70"N	70° 12' 52.0"E
10.	Kandla Colony	DL-10	23° 11' 14.9"N	70° 12' 48.4"E
11.	KPT Hospital	DL-11	23° 1' 5.02"N	70° 12' 44.38"E
12.	A.O. Building	DL-12	23° 3' 42.89"N	70° 8' 41.5"E
13.	Gopalpuri School	DL-13	23° 5' 1.03"N	70° 7' 55.42"E
14.	Gopalpuri Guest House	DL-14	23° 4' 43.14"N	70° 7' 51.92"E
15.	E-Type Quarters	DL-15	23° 4' 59.90"N	70° 7' 56.72"E
16.	F-Type Quarters	DL-16	23° 4' 38.45"N	70° 8' 8.63"E
17.	Gopalpuri Hospital	DL-17	23° 4' 54.09"N	70° 8' 7.5"E
18.	Tuna Port	DL-18	23° 58' 23.06"N	70° 5' 35.6"E
19.	Vadinar Jetty	DL-19	22° 25' 51.73"N	69° 41' 36.62"E
20.	Vadinar Colony	DL-20	22° 30' 26.25"N	69° 39' 45.03"E

#### **4.1 Drinking Water Monitoring Methodology**

Samples for physico-chemical analysis were collected in 2 Carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS: 3025 Part-1, analysis was done as per IS: 3025/APHA standard methods and, the analysis results compare with IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate, Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (CFU) .

#### **4.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 11 to Table No. 17

**Table 11: Drinking Water Quality Monitoring Parameters for Nirman Building, P & C Building and Main Gate (North) at Kandla.**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C Building	Main Gate North	Acceptable Limits as per IS 10500 :2012	Permissible Limits in the absence of Alternate Source as
1	pH	-	7.3	7.4	7.5	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved	mg/l	445	456	449	500	2000
3	Turbidity	NTU	1	0	1	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	941	908	892	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	185.41	190.42	210.47	250	1000
9	Total Hardness	mg/l	390	420	460	200	600
10	Calcium	mg/l	48.10	52.10	48.90	75	200
11	Salinity	‰	0.33	0.34	0.38	NS*	NS*
12	Mg as Mg	mg/l	65.61	70.47	82.134	30	100
13	Fluorides as F	mg/l	0.25	0.39	0.31	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	25.18	22.87	18.94	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	2.08	1.21	6.04	45	No Relaxation
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
18	Sodium as Na	mg/l	107.82	107.29	110.44	NS*	NS*
19	Potassium as K	mg/l	3.61	3.55	3.47	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Table 12: Drinking Water Quality Monitoring Parameters for Canteen, West Gate – I & Wharf Area at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per IS	Permissible Limits in the absence of Alternate Source as per IS
1	pH	-	7.3	7.4	7.2	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	470	452	466	500	2000
3	Turbidity	NTU	1	0	1	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	936	904	933	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	215.48	195.43	150.33	250	1000
9	Total Hardness	mg/l	500	420	470	75	600
10	Calcium	mg/l	55.31	58.52	49.70	30	200
11	Salinity	‰	0.39	0.35	0.27	NS*	NS*
12	Mg as Mg	mg/l	87.966	66.582	84.078	0.3	100
13	Fluorides as F	mg/l	0.33	0.24	0.35	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	30.03	29.80	18.94	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	4.16	2.55	6.17	45	No Relaxation
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
18	Sodium as Na	mg/l	113.91	109.93	111.24	NS*	NS*
19	Potassium as K	mg/l	5.02	3.37	5.06	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



**Table 13: Drinking Water Quality Monitoring Parameters for Sewa sadan-3, Workshop I and Custom Building at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.3	7.4	7.6	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	458	454	374	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	915	908	747	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	176.39	185.41	180.40	250	1000
9	Total Hardness	mg/l	490	390	420	200	600
10	Calcium	mg/l	44.09	72.14	68.14	75	200
11	Salinity	‰	0.32	0.33	0.33	NS*	NS*
12	Mg as Mg	mg/l	92.34	51.03	60.75	30	100
13	Fluorides as F	mg/l	0.27	0.28	0.23	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	26.80	22.18	35.12	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	3.49	1.28	1.34	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	110.08	108.70	93.00	NS*	NS*
19	Potassium as K	mg/l	3.45	3.34	3.22	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 14: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla and A.O. Building at Gandhidham.**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 :
1	pH	-	7.5	7.2	7.3	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	454	400	411	500	2000
3	Turbidity	NTU	0	1	1	1	5
4	Odour	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	911	800	823	NS*	NS*
7	BOD	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	195.43	180.40	160.36	250	1000
9	Total Hardness	mg/l	460	380	460	200	600
10	Calcium	mg/l	64.13	72.14	64.13	75	200
11	Salinity	‰	0.35	0.33	0.29	NS*	NS*
12	Mg as Mg	mg/l	72.9	48.6	72.9	30	100
13	Fluorides as F	mg/l	0.27	0.27	0.38	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	24.49	32.81	41.58	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.68	4.09	0.40	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	110.12	102.64	104.59	NS*	NS*
19	Potassium as K	mg/l	3.33	3.46	3.20	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 15: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House) and E - Type Quarter at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.5	7.6	7.4	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	407	420	459	500	2000
3	Turbidity	NTU	1	0	1	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	814	846	908	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	200.45	160.36	190.42	250	1000
9	Total Hardness	mg/l	480	430	370	200	600
10	Calcium	mg/l	44.09	52.10	40.08	75	200
11	Salinity	‰	0.36	0.29	0.34	NS*	NS*
12	Mg as Mg	mg/l	89.91	72.9	65.61	30	100
13	Fluorides as F	mg/l	0.25	0.25	0.11	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	26.11	22.64	11.09	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.48	1.28	0.60	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	100.96	104.36	106.73	NS*	NS*
19	Potassium as K	mg/l	3.27	3.08	3.30	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 16: Drinking Water Quality Monitoring Parameters for F-Type Quarter, Hospital Gopalpuri and Tuna Port.**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.2	7.3	7.4	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	490	404	1473	500	2000
3	Turbidity	NTU	0	1	0	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	880	805	2940.0	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	160.36	155.35	701.56	250	1000
9	Total Hardness	mg/l	400	460	560	200	600
10	Calcium	mg/l	44.09	72.14	112.22	75	200
11	Salinity	‰	0.29	0.28	1.27	NS*	NS*
12	Mg as Mg	mg/l	70.47	68.04	68.04	30	100
13	Fluorides as F	mg/l	0.27	0.30	2.70	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	45.28	22.87	136.50	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.41	1.74	6.71	45	100
17	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	107.30	102.85	265.00	NS*	NS*
19	Potassium as K	mg/l	3.09	3.11	4.48	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 17: Drinking Water Quality Monitoring Parameters for Vadinar Jetty and Port Colony at Vadinar.**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.5	7.6	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	460	456	500	2000
3	Turbidity	NTU	1.00	1.00	1	5
4	Odor	-			Agreeable	Agreeable
5	Color	-			5	15
6	Conductivity	µs/cm	780	772	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	140.31	110.25	250	1000
9	Total Hardness	mg/l	420	380	200	600
10	Calcium	mg/l	84.17	72.14	75	200
11	Salinity	‰	0.25	0.20	NS*	NS*
12	Mg as Mg	mg/l	51.03	48.60	30	100
13	Fluorides as F	mg/l	0.28	0.22	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	63.40	51.20	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.82	0.72	45	100
17	Iron as Fe	mg/l	BQL	BQL	0.3	1.0
18	Sodium as Na	mg/l	55.6	52.2	NS*	NS*
19	Potassium as K	mg/l	2.39	2.11	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **4.3 Results & Discussion**

The colour of all drinking water samples was found Colourless and odour of the samples also agreeable. All parameters were found within the specified limit as per the Drinking water Standard.

#### **pH**

The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. The pH values for drinking water samples were ranges from 7.20-7.60 and mean value was 7.38. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Total Dissolved Solids (TDS)**

TDS values in the studied area varied between 374-490 mg/l. The average TDS value was found 439 mg/l. The TDS values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of August ranged from 747-941  $\mu\text{S}/\text{cm}$  and mean value was 874.76  $\mu\text{S}/\text{cm}$ .

#### **BOD**

BOD value in the studied area was found Below Quantification Limit (2.0 mg/l). IS 10500:2012 does not show any standard values for BOD in drinking water.

#### **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. Chloride value in the studied area varied between 150.33– 215.48 mg/l and mean value was 181.93 mg/l. The Chloride was found within the Permissible limit of the Drinking Water Standard.

#### **Calcium**

Calcium value in the studied area varied between 40.08–72.14 mg/l and mean was 55.88 mg/l. The Calcium values were found to be within the Permissible limit of the Drinking Water Standard. If calcium is present beyond the maximum acceptable limit, it causes incrustation of pipes.

### **Magnesium**

Magnesium value in the studied area varied between 48.60 – 92.34 mg/l and mean value was 71.90 mg/l. All the locations had Magnesium within the prescribed limits of 30-100 mg/L.

### **Total Hardness**

Hardness value in the studied area varied between 370- 500 mg/l and mean was 434.29 mg/l. The values of total hardness were found within the Permissible limit of the Drinking Water Standard (200-600 mg/L).

### **Iron**

Iron value in the studied area was found Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards is 0.3 mg/L. The excess amount of iron causes slight toxicity; gives stringent taste to water.

### **Fluoride**

Fluoride value in the studied area varied between 0.11 – 0.39 mg/l and mean was 0.29 mg/l. The Fluoride values were well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphates**

Sulphate value in the studied area varied between 11.09 – 45.28 mg/l and mean was 26.87 mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

Nitrite values in all the water samples were found Below Quantification Limit (0.1 mg/l). There were no specified standard values for Nitrites in Drinking water. The minimum Nitrate value in drinking water of DPA was ranges from 0.40-6.17 mg/l which was well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected ranged from 0.27 to 0.39 ‰. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected ranged from 93.00- 113.91 mg/l while average was 106.59 mg/l and Potassium salts ranged from 3.08 to 5.06 mg/l while average was 3.53 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards Similar values observed by Mistry et al., 2019.

### **Bacteriological Study**

Analysis of the bacteriological parameter (E-coli and total coliform) at all location shows that Bacteria were not detectable. This shows that drinking water samples were safe for human consumption as per tested parameters.

## **4.4 Conclusions**

These results were compared with acceptable limits as prescribed in IS 10500:2012 – Drinking Water Specification. It was seen from the analysis data that during the study period the water was safe for human consumption as per analyzed parameters only at all drinking water monitoring stations.



## CHAPTER-5

### NOISE MONITORING

## 5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 5.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 5.2 Results

**Table 18: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A) 6:00 am to 10:00 PM	Night Time Average Noise Level (SPL) in dB(A) 10:00PM to 6:00 AM
	<b>Sampling Time</b>		
1	Marine Bhavan	73.6	68.4
2	Nirman Building 1	70.0	68.0
3	Tuna Port	68.9	67.5
4	Main Gate North	71.5	68.3
5	West Gate I	69.3	65.1
6	Canteen Area	67.1	62.3
7	Main Road	74.8	69.5
8	ATM Building	73.2	67.8
9	Wharf Area /Jetty Area	70.1	68.1
10	Port & Custom Office	69.7	63.2
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	58.0	57.1
12	Nr. Port Colony, Vadinar	64.9	44.7
13	Nr. Vadinar Jetty	61.0	57.4

### 5.3 Conclusions

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships.

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port ranged from 67.1 dB(A) to 74.8 dB(A) while at Vadinar port 3 location ranged from 58.0 dB(A) to 64.9 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port ranged from 62.3 dB to 69.5 dB(A) while at Vadinar port which was within the permissible limits of 70 dB(A) for the industrial area for the night time.

## CHAPTER-6

### SOIL MONITORING

## 6.0 Soil Monitoring

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

**Table No.:-19. Soil Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Tuna Port	SL-1	22° 58' 10.18"N	70° 6' 3.7"E	Near main gate of Port
2.	IFFCO Plant	SL-2	23° 26' 8.37"N	70° 13' 4.4"E	10 m away from main gate
3.	Khori creek	SL-3	22° 58' 10.18"N	70° 6' 3.7"E	Sand from creek after tide
4.	Nakti Creek	SL-4	23° 2' 1.10"N	70° 9' 33.6"E	
5.	DPA admin site	SL-5	22° 26' 30.9"N	69° 40' 37.03"E	Vadinar
6.	DPA colony	SL-6	22° 23' 57.09"N	69° 42' 49.42"E	

## 6.1 Methodology

The soil samples were collected in the month of August 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

## 6.2 Results

**Table-20: Chemical Characteristics of Soil in the Study Area for Tuna port, IFFCO, Khori Creek, Nakti Creek, DPA admin site, DPA colony.**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main gate	Sand from creek after tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	7.50	7.90	7.90	8.00	7.6	7.40
3	Electrical Conductivity	µs/cm	15,330.00	2,000.00	6,490.00	16,000.0	635.0	590.0
4	Moisture	%	15.00	3.00	16.00	14.00	6.00	7.00
5	Total Organic	%	0.28	0.16	0.40	0.70	0.42	0.28
6	Alkalinity	mg/kg	500.00	600.00	500.00	700.00	300.00	400.00
7	Total Nitrogen	%	0.02	0.01	0.03	0.06	0.04	0.02
8	Chloride	mg/kg	2,730.0	1,067.0	2,078.0	2,419.0	443.0	265.0
9	Sulphate	mg/kg	1,053.00	520.00	1,500.00	536.00	45.0	48.0
10	Phosphorus	mg/kg	4.20	3.10	4.80	2.30	BQL	BQL
11	Potassium	mg/kg	145.00	78.00	100.00	207.00	26.00	37.00
12	Sodium	mg/kg	2,104.00	1,224.00	1,900.00	1,185.00	91.00	207.00
13	Calcium	mg/kg	2,765.00	1,783.00	2,104.00	2,044.00	1,252.00	1,617.00
14	Copper as Cu	mg/kg	23.40	108.40	22.70	22.60	49.90	44.00
15	Lead as Pb	mg/kg	7.30	BQL	11.70	15.60	BQL	BQL
16	Nickel as Ni	mg/kg	31.30	23.00	23.00	13.70	24.60	22.90
17	Zinc as Zn	mg/kg	45.60	47.40	48.70	51.80	32.80	28.60
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	1.1	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg)

### 6.3 Discussion

- The data shows that value of pH ranges from 7.4 at DPA Colony (Vadinar) to 8.0 at (Nakti Creek) at Deendayal Port. The average value was 7.72 that all soil samples were neutral to slight basic. Nakti Creek sample showed maximum conductivity of 16000  $\mu\text{S}/\text{cm}$  and minimum was 590  $\mu\text{S}/\text{cm}$  while mean was 638  $\mu\text{S}/\text{cm}$ .
- Total organic Carbon ranged from 0.16 % to 0.70 % and mean was 0.37 %.
- The concentration of Phosphorus and Potassium in the soil samples varies from 2.30 mg/kg at Nakti Creek to 4.8 mg/kg at Khori Creek and 26 mg at DPA Admin Site (Vadinar) to 207 mg/kg at Nakti Creek and mean was 98.83 mg/kg. The concentration of Phosphorous was found BQL at Vadinar and DPA Kandala phosphorus values were ranged from 3.1-4.8.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) were coastal soil; where as other locations are inland locations and have different chemical properties.

### Heavy Metals in the Soil

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### 7.4 Conclusion

The soils of Deendayal Port and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

## **CHAPTER-7**

### **SEWAGE TREATMENT PLANT MONITORING**



## 7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guidelines of State Pollution Control Board and other statutory bodies.

### 7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

**Table No. 21. Sewage Treatment Plant**

Sr. No.	Location of STP	Types of Treatment	STP Capacity	Treated water Utilization
1.	Gopalpuri Township	MBBR	450 KLD	Plantation and Gardening
2.	Deendayal Port, Kandla	MBBR	600 KLD	Discharge to marine through pipeline, Plantation, Gardening
3.	Vadinar Port Colony	MBBR	1.5 MLD	Plantation and Gardening

## 7.2 Results

**Table 22: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	02.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.48	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	100	47.6	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	91	50	100
5	BOD @ 27 °C	mg/l	28.0	14.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	10.0		
7	MLVSS	%	87.0		

**Table 23: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	08.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.51	7.38	6.5 - 8.5
2	Total Suspended Solids	mg/l	120.2	48.9	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	111	40	100
5	BOD @ 27 °C	mg/l	33.0	11.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	12.0		
7	MLVSS	%	89.0		

**Table 24: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

Date of Sampling	16.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.39	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	129.8	49.9	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	110	50	100
5	BOD @ 27 °C	mg/l	34.0	16.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l		10.0	
7	MLVSS	%		85.0	

**Table 25: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

Date of Sampling	23.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.54	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	104	43.6	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	111	70	100
5	BOD @ 27 °C	mg/l	35.0	21.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l		14.0	
7	MLVSS	%		88.0	

**Table 26: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>		02.08.2022			
Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.53	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	87	57.7	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	70	40	100
5	BOD @ 27 °C	mg/l	12.0	6.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	14.0		
7	MLVSS	%	77.0		

**Table 27: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>		06.08.2022			
Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.48	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	109.6	34.4	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	92.0	30.0	100
5	BOD @ 27 °C	mg/l	26.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	21.0		
7	MLVSS	%	80.0		

**Table 28: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	16.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.58	7.41	6.5 - 8.5
2	Total Suspended Solids	mg/l	119.6	38.7	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	90	30	100
5	BOD @ 27 °C	mg/l	27.0	10.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	11.0		
7	MLVSS	%	82.0		

**Table 29: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	23.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.49	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	99.4	38.5	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	91	40	100
5	BOD @ 27 °C	mg/l	29.0	11.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	12.0		
7	MLVSS	%	90.0		

**Table 30: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	02.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.49	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	83.3	47.8	100
3	Residual Chlorine	mg/		<0.5	-
4	COD	mg/l	90.0	30	100
5	BOD @ 27 °C	mg/l	30.0	10.0	30

**Table 31: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	06.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.58	7.39	6.5 - 8.5
2	Total Suspended Solids	mg/l	82.8	53.8	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	88	40	100
5	BOD @ 27 °C	mg/l	26.0	12.0	30

**Table 32: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	16.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.68	7.45	6.5 - 8.5
2	Total Suspended Solids	mg/l	99.7	42.4	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	130	70	100
5	BOD @ 27 °C	mg/l	39.0	22.0	30

**Table 33: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	23.08.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.49	7.37	6.5 - 8.5
2	Total Suspended Solids	mg/l	107.9	53.6	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	108	68	100
5	BOD @ 27 °C	mg/l	32.0	20.0	30

### **7.3 Conclusions:**

The GPCB specification for pH, TSS, Residual Chlorine, COD and BOD for STP outlet were 6.5 to 8.5, 100 mg/l, 0.5 mg/l, 100 mg/l and 30 mg/l respectively. The outlet values for pH were ranges from 7.21-7.41, 7.21-7.38, and 7.32-7.45 at Gopalpuri, DPA and Vadinar respectively. The Total Suspended Solids values were 34.4-57.7 mg/l, 43.6-49.9 mg/l, and 42.4-53.8 mg/l at Gopalpuri, DPA and Vadinar respectively. The COD values were ranges from 30-40 mg/l, 11-21 mg/l, and 42.4-53.8 at Gopalpuri, DPA and Vadinar respectively. The BOD values were ranges from 6-11 mg/l, 11-21 mg/l, and 10-22 mg/l at Gopalpuri, DPA and Vadinar respectively. At all sampling locations Residual Chlorine were found below detectable limit. All parameters for STP outlet are within limit.



## **CHAPTER-8**

### **MARINE WATER MONITORING**

## **8.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of ‘green thinking’. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the “fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”.

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at “integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources.” The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 05<sup>th</sup> & 06<sup>th</sup> August-2022 in harbor regions of DPA & Vadinar during Neap tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 12<sup>th</sup> & 16<sup>th</sup> August-2022 in harbor regions of DPA & Vadinar during Spring tide period first quarter of Lunar Cycle.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbor area and two stations in Nakti creek and one station in Khorī creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation

of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

### **Sampling Locations**

<b>Offshore monitoring requirement</b>	<b>Number of locations</b>
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khorī creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### **8.1 Marine Water Quality and Results**

Marine water quality of marine waters of Deendayal Port Harbor waters, Khorī & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 34 to 41. During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.

**Table 34: Marine Water Quality Monitoring Parameters for location near DPA colony**

Sr. No.	Parameters	Unit	Kandla Creek Near DPA colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.42	7.53	7.36	7.42
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	32.6	33.9	33.0	33.9
5	Turbidity	NTU	45	41	46	41
6	Total Dissolved Solids	mg/l	44479	46712	37902.0	38329.0
7	Total Suspended Solids	mg/l	399	336	708	650.9
8	Total Solids	mg/l	54878	53304	43002.0	41470.0
9	DO	mg/l	5.2	5.1	5.5	5.2
10	COD	mg/l	88.0	80.0	90.0	88.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.40	0.20	0.46	0.36
13	Phosphate	mg/l	0.31	0.35	0.37	0.04
14	Sulphate	mg/l	2194.5	1640.1	2183	1594
15	Nitrate	mg/l	1.48	2.15	2.15	1.81
16	Nitrite	mg/l	0.13	0.11	0.15	0.15
17	Calcium	mg/l	641.28	721.44	721.44	761.52
18	Magnesium	mg/l	1773.9	1555.2	1628.1	1652.4
19	Sodium	mg/l	8744.0	9175.0	9489.0	10005.0
20	Potassium	mg/l	314.0	304.0	394.0	399.0
21	Iron	mg/l	3.53	2.00	0.82	0.76
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 35: Marine Water Quality Monitoring Parameters for location near passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.38	7.41	7.31	7.51
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	34.4	34.9	33.5	31.2
5	Turbidity	NTU	38	39	43	39
6	Total Dissolved Solids	mg/l	45846	47471	35126.0	37344.0
7	Total Suspended Solids	mg/l	338	763	701.2	670.7
8	Total Solids	mg/l	51696	53886	36372.0	38582.0
9	DO	mg/l	4.9	4.8	5	5.3
10	COD	mg/l	76.0	80.0	72.0	70.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.58	0.20	0.64	0.24
13	Phosphate	mg/l	0.24	0.38	0.30	0.42
14	Sulphate	mg/l	1986.6	1686.3	1917	1594
15	Nitrate	mg/l	3.49	3.29	4.56	2.82
16	Nitrite	mg/l	0.09	BQL	0.11	0.06
17	Calcium	mg/l	601.20	561.12	681.36	641.28
18	Magnesium	mg/l	1725.3	1603.8	1701	1676.7
19	Sodium	mg/l	9698.0	9777.0	10209.0	10707.0
20	Potassium	mg/l	321.0	323.0	398.0	312.0
21	Iron	mg/l	0.27	BQL	3.24	0.81
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Nitrite: 0.05mg/l Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 36: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.48	7.28	7.48	7.26
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	33.0	33.5	32.6	33.0
5	Turbidity	NTU	47	42	45	43
6	Total Dissolved Solids	mg/l	45002	48675	38044.0	38337.0
7	Total Suspended Solids	mg/l	379	540	644.4	812.4
8	Total Solids	mg/l	53900	52430	40806.0	39676.0
9	DO	mg/l	4.7	4.6	4.8	4.9
10	COD	mg/l	82.0	78.0	78.0	74.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.66	0.36	0.84	0.48
13	Phosphate	mg/l	0.22	0.34	0.31	0.38
14	Sulphate	mg/l	1755.6	2102.1	1675	2056
15	Nitrate	mg/l	2.95	2.01	2.28	1.95
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	681.36	601.20	681.36	721.44
18	Magnesium	mg/l	1506.6	1603.8	1749.6	1701
19	Sodium	mg/l	8903.0	10695.0	10366.0	10110.0
20	Potassium	mg/l	327.0	315.0	367.0	320.0
21	Iron	mg/l	BQL	BQL	0.37	0.49
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 37: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	DPA 4			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.35	7.31	7.38	7.43
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	33.9	33.0	33.9	34.4
5	Turbidity	NTU	43	45	40	44
6	Total Dissolved Solids	mg/l	51513	54554	43382.0	43962.0
7	Total Suspended Solids	mg/l	429	677	802.5	771.1
8	Total Solids	mg/l	53302	56146	47570.0	44902.0
9	DO	mg/l	4.5	5	5.1	5.4
10	COD	mg/l	60.0	52.0	62.0	57.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.60	0.68	0.66	0.80
13	Phosphate	mg/l	0.23	0.28	0.27	0.31
14	Sulphate	mg/l	2055.9	1790.25	1917	1698
15	Nitrate	mg/l	2.82	4.56	3.22	4.77
16	Nitrite	mg/l	BQL	BQL	0.07	0.10
17	Calcium	mg/l	761.52	681.36	641.28	721.44
18	Magnesium	mg/l	1603.8	1628.1	1701	1628.1
19	Sodium	mg/l	10287.0	10094.0	10236.0	10922.0
20	Potassium	mg/l	319.0	322.0	331.0	265.0
21	Iron	mg/l	BQL	BQL	1.23	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 38: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.43	7.38	7.26	7.21
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	33.5	33.9	33.0	32.6
5	Turbidity	NTU	43	42	45	38
6	Total Dissolved Solids	mg/l	52618	55692	37078.0	38995.0
7	Total Suspended Solids	mg/l	414	321	727.6	760.1
8	Total Solids	mg/l	54138	58860	38012.0	40230.0
9	DO	mg/l	5.3	5.1	5.6	5.7
10	COD	mg/l	92.0	88.0	90.0	87.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.52	0.40	0.56	0.52
13	Phosphate	mg/l	0.31	0.19	0.34	0.23
14	Sulphate	mg/l	1871.1	2148.3	1698	2056
15	Nitrate	mg/l	4.83	3.29	4.50	2.95
16	Nitrite	mg/l	0.05	0.08	0.06	0.10
17	Calcium	mg/l	641.28	561.12	761.52	641.28
18	Magnesium	mg/l	1749.6	1749.6	1652.4	1701
19	Sodium	mg/l	10930.0	10903.0	10481.0	10121.0
20	Potassium	mg/l	312.0	314.0	289.0	340.0
21	Iron	mg/l	BQL	BQL	0.58	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).



**Table 39: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.52	Sampling not possible during Low Tide	7.55	Sampling not possible during Low Tide
2	Color	-	Colorless		Colorless	
3	Odor	-	Odorless		Odorless	
4	Salinity	‰	34.9		33.5	
5	Turbidity	NTU	41		46	
6	Total Dissolved Solids	mg/l	47273		42444.0	
7	Total Suspended Solids	mg/l	817		797.7	
8	Total Solids	mg/l	49186		44304.0	
9	DO	mg/l	4.6		5.3	
10	COD	mg/l	110.0		106.0	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	0.72		0.68	
13	Phosphate	mg/l	0.38		0.38	
14	Sulphate	mg/l	2829.75		2795	
15	Nitrate	mg/l	3.76		3.42	
16	Nitrite	mg/l	0.10		0.11	
17	Calcium	mg/l	641.28		601.2	
18	Magnesium	mg/l	1773.9		1773.9	
19	Sodium	mg/l	10735.0		8053.0	
20	Potassium	mg/l	318.0		272.0	
21	Iron	mg/l	BQL		0.28	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		BQL	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 40: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.45	7.32	7.43	7.36
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	33.9	33.5	33.9	33.5
5	Turbidity	NTU	39	40	43	45
6	Total Dissolved Solids	mg/l	53711	54732	36344.0	34479.0
7	Total Suspended Solids	mg/l	357	331	694.3	641.9
8	Total Solids	mg/l	55404	55480	37996.0	35268.0
9	DO	mg/l	4.5	4.3	5.6	5.3
10	COD	mg/l	80.0	76.0	74.0	72.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.80	0.64	0.84	0.66
13	Phosphate	mg/l	0.36	0.38	0.40	0.42
14	Sulphate	mg/l	2841.3	2691.15	3095	2564
15	Nitrate	mg/l	4.83	5.50	4.16	5.30
16	Nitrite	mg/l	0.08	0.07	0.10	0.09
17	Calcium	mg/l	681.36	721.44	561.12	601.2
18	Magnesium	mg/l	1530.9	1458	1749.6	1773.9
19	Sodium	mg/l	11900.0	10708.0	10202.0	10436.0
20	Potassium	mg/l	4436.0	474.0	473.0	474.0
21	Iron	mg/l	BQL	BQL	0.21	0.23
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	0.41	0.78	0.36

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 41: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr. Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.28	7.21	7.47	7.33
2	Color	-	Colorless	Colorless	Colorless	Colorless
3	Odor	-	Odorless	Odorless	Odorless	Odorless
4	Salinity	‰	34.4	33.0	34.4	34.9
5	Turbidity	NTU	43.0	46.0	42	44
6	Total Dissolved Solids	mg/l	54703.0	52022.0	36956.0	41939.0
7	Total Suspended Solids	mg/l	263.3	251.3	670.4	699.7
8	Total Solids	mg/l	55716.0	53868.0	38388.0	42668.0
9	DO	mg/l	4.6	4.4	5.4	5.2
10	COD	mg/l	96.0	94.0	92.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.80	0.72	0.78	0.80
13	Phosphate	mg/l	0.41	0.50	0.49	0.54
14	Sulphate	mg/l	2379.3	2795.1	2287	2888
15	Nitrate	mg/l	2.82	3.76	2.28	3.02
16	Nitrite	mg/l	0.05	BQL	0.07	0.05
17	Calcium	mg/l	761.52	641.28	721.44	681.36
18	Magnesium	mg/l	1385.1	1482.3	1628.1	1628.1
19	Sodium	mg/l	11630.0	11510.0	11437.0	12000.0
20	Potassium	mg/l	421.0	426.0	433.0	504.0
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.2	BQL	0.15	0.11

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1 mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l)

## **8.2 Results & Discussion for Marine water samples**

Marine water quality of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

### **Turbidity**

During spring tide the Turbidity values was ranges from 38-47 NTU at DPA Kandla and 39-46 NTU at Vadinar while during Neap Tide pH values was ranges from 38-46 NTU at DPA Kandla and 42-45 NTU at Vadinar. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity (Yap et al, 2011). Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler, 2004).

### **Color and Odor**

All marine samples for Odor and Color were found agreeable at all locations.

### **pH**

During spring tide the pH values was ranges from 7.28-7.53 at DPA Kandla and 7.21-7.45 at Vadinar while during Neap Tide pH values was ranges from 7.21-7.55 at DPA Kandla and 7.33-7.47 at Vadinar.

### **Total Dissolved Solids (TDS)**

TDS values in the studied area during Spring Tide varied between 44479 to 55692 mg/l at DPA Kandla and 52022 to 54732 mg/l at Vadinar while during Neap Tide TDS values was varied 35125 to 43962 mg/l at DPA Kandla and 34479 to 41939 mg/l at Near Vadinar.

### **Calcium**

Calcium value in the studied area during Spring Tide varied between 561.1 to 761.5 mg/l at DPA Kandla and 641.3 to 761.5 mg/l at Vadinar while during Neap Tide calcium values between 601.2 to 761.5 mg/l at DPA Kandla and 561.1 to 721.4 at Vadinar.

### **Magnesium**

Magnesium value in the studied area during Spring Tide varied between 1506.6 to 1773.9 mg/l at DPA Kandla and 1385.1 to 1530.9 mg/l at Vadinar while during Neap Tide magnesium values between 1628.10 to 1773.90 mg/l at DPA Kandla and 1628.10 to 1773.90 at Vadinar. Calcium and magnesium both play an important role in antagonizing the toxic effects of various ions and neutralizing the excess acid produced (Narayan R. et. al., 2007)

### **Nitrate**

Nitrate value in the studied area during Spring Tide varied between 1.5-4.8 mg/l at DPA Kandla and 2.8-5.5 mg/l at Vadinar while during Neap Tide Nitrate values between 1.81-4.77 mg/l at DPA Kandla and 2.28-5.3 at Vadinar.

The variations were observed due to variation in phytoplankton excretion, oxidation of ammonia, reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007).

### **Iron**

Iron values in the studied area during Spring Tide was found 0.3 to 3.5 mg/l at DPA Kandla and below quantification limit (BQL) at Vadinar while during Neap Tide the iron values was varied 0.28 to 3.24 mg/l at DPA Kandla and 0.21 to 0.23 at Vadinar.

### **Sulphates**

Sulphate values in the studied area during Spring Tide was found 1640.1 to 2829.8 mg/l at DPA Kandla and 2379.3 to 2841.3 mg/l at Vadinar while during Neap Tide the Sulphate values was varied 1594.0 to 2795.0 mg/l at DPA Kandla and 2287.0 to 3095.0 at Vadinar.

### **Salinity**

Salinity values in the studied area during Spring Tide was found 32.6 to 34.9 ‰ at DPA Kandla and 33.0 to 34.4 ‰ at Vadinar while during Neap Tide the Salinity values was varied 31.2 to 34.4 ‰ at DPA Kandla and 33.5 to 34.8 ‰ at Vadinar.

### **Sodium and Potassium Salts**

During Spring Tide the Sodium values ranged from 8744.0-10930.0 mg/l at DPA Kandla & 10708.0-11900.0 mg/l at Vadinar and Potassium salts ranged from 304.0-327.0 mg/l at DPA Kandla & 265.0-399.0 mg/l at Vadinar while during Neap Tide the sodium values was ranges from 10708.0-11900.0 mg/l at DPA Kandla & 10202-12000 mg/l at Vadinar and Potassium salts ranged from 421.0-474.0 mg/l at DPA Kandla & 433.0-504.0 mg/l at Vadinar.

## **DO**

The DO refers to the amount of oxygen dissolved in the water and it is particularly important in limnology (aquatic ecology) (Weiss 1970). The fate and behavior of DO is of critical importance to marine organisms in determining the severity of adverse impacts (Best et al. 2007). The major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best et al. 2007). From the studied samples, DO in marine water during Spring Tide was found in ranges from 4.5-5.3 mg/l at DPA Kandla and 4.8-5.7 mg/l at Vadinar while during Neap Tide 4.3-4.6 mg/l at DPA Kandla and 5.2-5.6 mg/l at Vadinar.

## **BOD**

BOD in marine water at all sampling location in the studied samples was found Below Quantification limit. BOD shows the amount of dissolved oxygen needed by microorganisms to decompose or decompose organic matter under aerobic conditions (Salmin, 2005).

## **Heavy Metals in Marine Water**

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

The heavy metal pollution from industry, domestic activities, transportation and natural sources from rocks flow to the river or ocean waters and accumulate in the waters and marine biota. The heavy metals in waters at certain concentrations will change their function to toxic to the life of waters (Murtini et al., 2001).

## **9.3 Conclusion**

In the present study period marine water samples were analyzed and found inline as per Primary Water Quality criteria for class-IV WATERS (For Harbour Waters).

## CHAPTER-9

### MARINE SEDIMENT MONITORING

## **9.0 Marine Sediments**

The deep-sea ocean floor is made up of sediment. This sediment is composed of tiny particles such as fine sand, silt, clay, or animal skeletons that have settled on the ocean bottom. Over long periods of time, some of these particles become compressed and form stratified layers. Scientists that study these layers look at particle size, particle composition, and origin to help them create historical records of the deep ocean floor. This process is called weathering. Weathering can be either mechanical or chemical. Mechanical weathering can occur as ice, wind, or water wears away the rock's surface. Chemical weathering can occur as rocks are dissolved by a chemical such as acid rain. The particles created as a result of weathering are called terrigenous sediments. These particles are transported to the ocean by wind and by rivers and streams. Once the particles enter the ocean, they are dispersed by waves, currents, and tides. The heaviest and largest particles that reach the oceans, such as sand, settle very quickly to the bottom as a result of gravity. Sand is deposited near the coast whereas the smaller silt and clay particles are transported farther distances offshore before they settle to the bottom. Sediments are an important component of aquatic ecosystems because they provide nutrients and habitat for aquatic organisms (Benhamed et al. 2016). However, human activities result in accumulation of toxic substances such as heavy metals in marine sediments. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulation. Metals affect the ecosystem because they are not removed from water by self-purification, but accumulate in sediments and enter the food chain (Astakhov et al. 2015).

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Benthic surface grab samplers look like giant metal jaws. They dig into the bottom and take a bite of the sediment. These samplers are good for collecting softer, sandy or silty sediments that do not contain rocks. A box corer is a cross between a surface sampler and a sediment corer. It is a special device that is used to collect an undisturbed sample of the very top surface layers and the sediment underneath. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.



### 10.1 Results

The Sediment Quality results are given in below from table no. 41 & 42.

**Table 41: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.21	1.07	1.38	1.31	1.09	1.29	1.03
3	Organic Carbon	mg/kg	0.12	0.62	0.80	0.76	0.63	0.75	0.60
4	Inorganic Phosphate	mg/kg	90.00	106.00	90.00	100.00	108.00	80.00	90.00
5	Moisture	%	4.80	16.00	14.00	21.60	19.20	5.20	7.40
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	7.90	7.20	9.80	5.60	10.60	13.20	15.20
8	Phosphate	mg/kg	2.80	2.09	2.10	1.80	1.96	6.80	5.20
9	Sulphate	mg/kg	522.00	500.00	580.00	480.00	460.00	470.00	410.00
10	Nitrite	mg/kg	0.11	0.11	0.12	0.11	0.11	0.12	0.10
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	6.80	7.90
12	Calcium	mg/kg	1705.00	1619.00	1520.00	1216.00	1343.00	1765.00	1918.00
13	Magnesium	mg/kg	886.00	1336.00	640.00	761.00	720.00	796.00	822.00
14	Sodium	mg/kg	590.00	990.00	422.00	390.00	440.00	1106.00	1290.00
15	Potassium	mg/kg	270.00	310.00	120.00	190.00	270.00	310.00	280.00
16	Chromium	mg/kg	54.60	19.70	20.40	26.70	37.30	33.60	25.20
17	Nickel	mg/kg	10.80	9.20	9.80	13.00	16.70	15.10	11.40
18	Copper	mg/kg	BQL	BQL	BQL	5.70	6.80	7.00	5.50
19	Zinc	mg/kg	5.20	7.60	6.80	11.90	17.50	15.30	8.80
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	10.90	BQL	BQL	BQL	BQL	9.30	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

**Table 42 : Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.83	0.52	0.38	0.71	0.86	0.64	0.71
3	Organic Carbon	mg/kg	0.48	0.30	0.22	0.41	0.50	0.37	0.41
4	Inorganic Phosphate	mg/kg	116.00	80.00	90.00	100.00	100.00	106.00	100.00
5	Moisture	%	24.00	24.00	15.00	23.00	30.00	22.00	17.00
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	10.20	8.80	9.20	7.60	10.30	12.20	18.00
8	Phosphate	mg/kg	2.76	2.03	1.92	2.51	2.13	8.78	7.47
9	Sulphate	mg/kg	531.00	501.00	501.00	515.00	502.00	499.00	480.00
10	Nitrite	mg/kg	0.11	0.12	0.11	0.10	0.12	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	10.80	11.02
12	Calcium	mg/kg	2254.00	1503.00	1763.00	1643.00	1603.00	1603.00	1863.00
13	Magnesium	mg/kg	990.00	1312.00	607.00	680.00	826.00	760.00	935.00
14	Sodium	mg/kg	528.00	967.00	395.00	373.00	394.00	1196.00	1353.00
15	Potassium	mg/kg	288.00	317.00	140.00	202.00	286.00	384.00	335.00
16	Chromium	mg/kg	138.60	28.70	16.20	30.00	29.50	62.80	18.20
17	Nickel	mg/kg	33.30	13.30	7.40	14.80	14.10	42.50	8.00
18	Copper	mg/kg	21.30	8.40	BQL	BQL	6.90	25.80	6.90
19	Zinc	mg/kg	31.30	12.60	BQL	17.30	10.40	34.30	BQL
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg,Cd: 1.0mg/kg,Hg: 1.0mg/kg, As: 1.0mg/kg)

## **9.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

## **9.3 Conclusion**

The sediment types are majority Sandy loamy. Also all heavy metals found below Quantification limit wise Al, Pb, Cd, Hg , As and Nitrate for some locations.

## CHAPTER-11

### MARINE ECOLOGICAL MONITORING

## 10.0 INTRODUCTION:

### *Sampling Stations:*

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 05<sup>th</sup> August 2022 in harbour region of DPA at Kandla Creek, and on 06<sup>th</sup> August 2022 in creeks near by the port during Neap tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 12<sup>th</sup> August, 2022 in harbour region of DPA at Kandla Creek and on 13<sup>rd</sup> August, 2022 in creeks near by the port during spring tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period. The same sampling schedule was repeated during consecutive spring and neap tide in same month.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during Neap tide on 06/08/2022 and Spring tide period on 13/08/2022. Collected water samples were processed for estimation of Chlorophyll-a, Pheophytin-a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplankton density and their population).

**TABLE 43. SAMPLING LOCATIONS**

monitoring requirement	Number of locations
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near I <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

### 11.1 Sampling methodology adopted:

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest.

The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample were taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with nylon bolt cloth of 20 µm mesh size.

#### **Samples Processing for chlorophyll estimation:**

Samples for the chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminum foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grinded in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 2017).

#### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is general term for organisms have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplankton is free floating organisms that are capable of photosynthesis and zooplankton is the various free floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, *plankton* and *nekton* (Lalli and Parsons, 1997). *Plankton* consists of all organisms drifting in the water and is unable to swim against water currents, whereas *Nekton* includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887),

Plankton, (Greek word: *planktos* meaning “passively drifting or wandering”) is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

**Phytoplankton in the marine environment:**

Phytoplankton is free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio purifier and bio indicators of the aquatic ecosystems of which diverse array of the life depends .They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are diatoms (Bacillariophyceae) and dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; diatoms and dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

**Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes

(Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

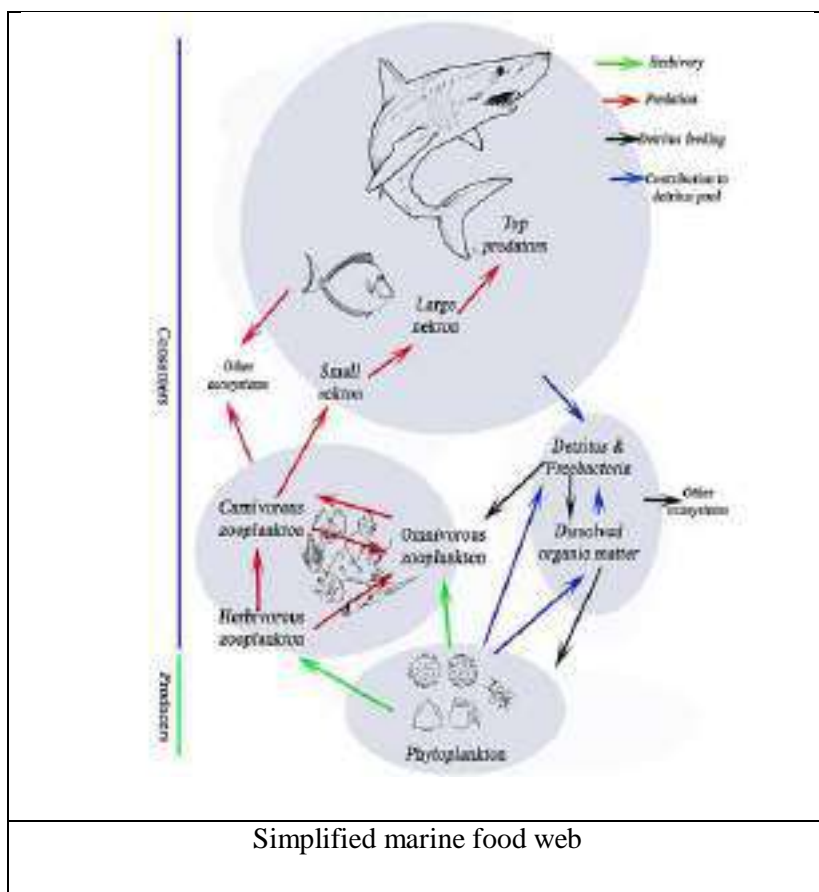
Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely diverse, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominates than others; members of sub class copepods (Phylum Arthropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991;)



It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplankton is efficient grazers of the phytoplankton and is referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilometres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton in AUGUST also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

**Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight .After the tow of about 15-30minutes, plankton net was pulled up and washed down to the tail and collected the plankton adhered to plankton net in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward.

**Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

**Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

**Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of zooplankton that were encountered

**Cell counts by drop count method:**

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22x 60mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton

present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total number of plankton in the original volume of sample filtered was calculated as units/L.

#### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment–water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42 $\mu$  in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes

#### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

#### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

#### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

#### **DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A. E. (1988)

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species within a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carroll H.R. *et al.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. The diversity measures that incorporate the two concepts may be termed heterogeneity measures (Magurran, 2004).

Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate species richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness ( $S$ ) and evenness ( $J$ )

#### **Simpson's diversity index**

Simpson's index ( $D$ ) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

The formula for calculating  $D$  is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where  $n_i$  = the total number of organisms of each individual species

$N$  = the total number of organisms of all species

The value of  $D$  ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When  $D$  increases diversity decreases. Simpson's index is therefore usually expressed as  $1-D$  or  $1/D$ . (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat

- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment
- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

### Species richness indices

The species richness ( $S$ ) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness may be concomitant with severe or chronic human-induced perturbation (Fair 1990,) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness ( $S$ ) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index ( $d$ ), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximised when all types are equally abundant (Rosenzweig, M. L. (1995).

### Shannon-Wiener's index:

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index ( $H$ ), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index ( $H$ ) reproduces community parameters to a single number by using an equation.

Shannon and Wiener index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and

$$H' = - \sum_{j=1}^S \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

## **11.2 RESULTS:**

### **CHLOROPHYLL-a:**

Algal biomass was estimated by converting Chlorophyll value. In the sub surface water chlorophyll-a was varying from 0.342-0.51 mg/m<sup>3</sup> with an average value 0.424 mg/m<sup>3</sup> of in harbour region of DPA in Kandla Creek during sampling done in spring tide period of August 2022. In the nearby creeks chlorophyll-a was varying from 0.179 - 0.662 mg/m<sup>3</sup>, with an average value 0.416mg/m<sup>3</sup>. Pheophytin-a level was below detectable limit- the all the sampling stations during spring tide.

In the sub surface water chlorophyll-a was varying from 0.452-0.676 mg/m<sup>3</sup> with an average value 0.561 mg/m<sup>3</sup>, in harbour region of DPA in Kandla Creek during sampling done in Neap tide period of August 2022. In the nearby creeks chlorophyll-a was varying from 0.476-0.762 mg/m<sup>3</sup> with an average value 0.616mg/m<sup>3</sup>. Pheophytin-a level was below detectable limit- the all the sampling stations.

In the sub surface water chlorophyll-a was varying from 0.526-0.818 mg/m<sup>3</sup> in harbour region of DPA OOT (Vadinar) in path finder Creek during sampling done in spring tide period of August 2022. In the sub surface water chlorophyll-a was varying from 0.555-0.646 mg/m<sup>3</sup>. in harbour region of DPA OOT in path finder Creek during sampling done in Neap Tide period of August, 2022

**Table No.:-44 VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK, NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINARDURING SPRING TIDE IN AUGUST 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	DPA1	High tide	0.510	BDL	34.17
		Low tide	0.450	BDL	30.15
2	DPA 2	High tide	0.399	BDL	26.73
		Low tide	0.417	BDL	27.94
3	DPA 3	High tide	0.426	BDL	28.54
		Low tide	0.342	BDL	22.91
CREEKS					
4	DPA-4 Khor-I	High tide	0.662	BDL	44.35
		Low tide	0.392	BDL	26.26
5	DPA-5 Nakti-I	High tide	0.417	BDL	27.94
		Low tide	0.432	BDL	28.94
6	DPA-6 Nakti-II	High tide	0.179	BDL	11.99
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.757	BDL	50.72
8		Low tide	0.654	BDL	43.82
9	SPM	High tide	0.818	BDL	54.81
10	SPM	Low tide	0.526	BDL	35.24

BDL: Below Detectable Limit.

**Table No.:- 45 VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA ,NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN AUGUST 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll l method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	DPA1	High tide	0.452	BDL	30.28
		Low tide	0.676	BDL	45.29
2	DPA 2	High tide	0.578	BDL	38.73
		Low tide	0.454	BDL	30.42
3	DPA 3	High tide	0.642	BDL	43.01
		Low tide	0.565	BDL	37.86
CREEKS					
4	DPA-4 Khor-I	High tide	0.762	BDL	51.05
		Low tide	0.543	BDL	36.38
5	DPA-5 Nakti-I	High tide	0.672	BDL	45.02
		Low tide	0.629	BDL	42.14
6	DPA-6 Nakti-II	High tide	0.476	BDL	31.89
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.646	BDL	43.28
8		Low tide	0.630	BDL	42.21
9	SPM	High tide	0.613	BDL	41.07
10	SPM	Low tide	0.555	BDL	37.19

BDL: Below Detectable Limit.



### **PHYTOPLANKTON POPULATION:**

For the evaluation of the Phytoplankton population in DPA harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algaen algae and Dinoflagellates during spring tide period. Diatoms were represented by 27 genera. Blue green algaen was represented by 4 genera and Dinoflagellates were represented by 4 genera during the sampling conducted in spring tide in AUGUST, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 37-357 units/ L during high tide period and 132-215 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algaen algae and Dinoflagellates during Neap tide period. Diatoms were represented by 27 genera, Blue green algaen algae were represented 4 genera and Dinoflagellates with 3 genera during the sampling conducted in Neap tide in AUGUST, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 65-211 units/ L during high tide period and 75-158 units/ L during low tide of Neap Tide.

For the evaluation of the Phytoplankton population in DPA OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; jetty area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algaen algae and Dinoflagellates during spring tide period. Diatoms were represented by 32 genera, Blue green algaen algae by 3 genera and Dinoflagellates 4 genera each during the sampling conducted in spring tide in AUGUST, 2022. Phytoplankton of the sampling stations at sub surface layer in the (harbour area was 156 units/ L during high tide period and 263 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the *SPM area* was varying from 275 units/ L during high tide period and 210 units/ L during low tide of Spring Tide.)

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algaen and Dinoflagellates during Neap tide period. Diatoms were represented by 28 genera and Blue green algaen algae by 2 genera and Dinoflagellates by 3 genera during the sampling conducted in Neap tide in AUGUST, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty (Vadinar) was varying from 183 units/ L during high tide period and 204 units/ L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near *SPM area* was varying from 128 units/ L during high tide period and 180 units/ L during low tide of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness)**

Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 2.216- 3.597 with an average of 2.901 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.048- 2.979 with an average of 2.580 during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 2.311- 3.41 with an average of 2.982 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.548 - 3.903 with an average of 3.102 during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 5.149 at OOT jetty area and 5.163 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 5.743 and 4.488 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 3.455 at OOT jetty area and 3.091 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 3.949 and SPM area was 3.466 during the consecutive low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.557- 0.816 between selected sampling stations with an average value of 0.727 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.629-0.748 between selected sampling stations with an average value of 0.687 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.703–0.867 between selected sampling stations with an average value of 0.796 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.711- 0.824 between selected sampling

stations with an average value of 0.773 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.854 at OOT jetty (Vadinar) area and 0.799 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.051 and 0.809 at SPM during the consecutive low tide period.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.884 at OOT jetty (Vadinar) area and 1.013 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.843 and at SPM area was 0.896 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.506- 0.838 between selected sampling stations with an average of 0.701 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.592- 0.753 between selected sampling stations with an average of 0.686 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during Neap tide also, which was varying from 0.710 - 0.814 with an average value of 0.762 between selected sampling stations during high tide period and 0.715- 0.782 varying from with an average value of 0.753 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.733 at OOT jetty area and 0.678 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.813 and 0.739 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.812 at OOT jetty area and 0.888 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.748 and at SPM area was 0.822 during the consecutive low tide period.

Low species diversity suggests a relatively few successful species in this habitat. The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment. Any change in the environment would probably have quite serious effects.

**Table No.:-46 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% Of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	260	21/35	60.00	3.597	0.8159	0.7253
	2	156	14/35	40.00	2.574	0.723	0.7361
	3	208	17/35	48.57	2.998	0.7342	0.6929
	4	357	19/35	54.29	3.062	0.557	0.5064
	5	160	16/35	45.71	2.956	0.7237	0.7074
	6	37	9/35	25.71	2.216	0.8095	0.8378
LOW TIDE	1	215	17/35	48.57	2.979	0.6291	0.5923
	2	182	16/35	45.71	2.882	0.6631	0.6387
	3	140	14/35	40.00	2.631	0.7477	0.7487
	4	132	11/35	31.43	2.048	0.658	0.6997
	5	163	13/35	37.14	2.356	0.7383	0.7526

**Table No.:-47 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING NEAP TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	141	14/34	41.18	2.627	0.7025	0.7095
	2	180	13/34	38.24	2.311	0.7174	0.7217
	3	171	18/34	52.94	3.306	0.8196	0.7642
	4	196	19/34	55.88	3.41	0.8279	0.7792
	5	211	19/34	55.88	3.363	0.8671	0.7859
	6	65	13/34	38.24	2.875	0.8435	0.8135
LOW TIDE	1	75	12/34	35.29	2.548	0.7374	0.7571
	2	142	15/34	44.12	2.825	0.7749	0.7429
	3	158	16/34	47.06	2.963	0.7114	0.7151
	4	130	20/34	58.82	3.903	0.8235	0.7684
	5	98	16/34	47.06	3.272	0.8179	0.7818

**Table No.:- 48 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN AUGUST2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	37-347	27/35	77.14
			BLUE GREEN ALGAEN	2-4	4/35	11.43
			DINOFLAGELLATES	3-9	4/35	11.43
			TOTAL PHYTO PLANKTON	<b>37-357</b>		
LOW TIDE	Sub surface	5	DIATOMS	130-211	27/35	77.14
			BLUE GREEN ALGAEN	2-4	4/35	11.43
			DINOFLAGELLATES	1-3	4/35	11.43
			TOTAL PHYTO PLANKTON	<b>132-215</b>	<b>35</b>	-

**Table No.:-49 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN AUGUST 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	57-205	27/34	79.41
			BLUE GREEN ALGAEN	2-8	4/34	11.76
			DINOFLAGELLATES	4-5	3/34	8.83
			TOTAL PHYTO PLANKTON	<b>65-211</b>		
LOW TIDE	Sub surface	5	DIATOMS	74-156	27/34	79.41
			BLUE GREEN ALGAEN	1-4	4/34	11.76
			DINOFLAGELLATES	2-4	3/34	8.83
			TOTAL PHYTO PLANKTON	<b>75-158</b>	<b>34</b>	-

**Table No.:-50 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	jetty	156	27/39	69.23	5.149	0.854	0.733
	SPM	275	30/39	76.92	5.163	0.799	0.678
LOW TIDE	jetty	263	33/39	84.62	5.743	1.051	0.813
	SPM	210	25/39	64.10	4.488	0.809	0.739

**Table No.:-51 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	183	19/33	57.58	3.455	0.884	0.812
	SPM	128	16/33	48.48	3.091	1.013	0.888
LOW TIDE	Jetty	204	22/33	66.67	3.949	0.8431	0.748
	SPM	180	19/33	57.58	3.466	0.8957	0.822

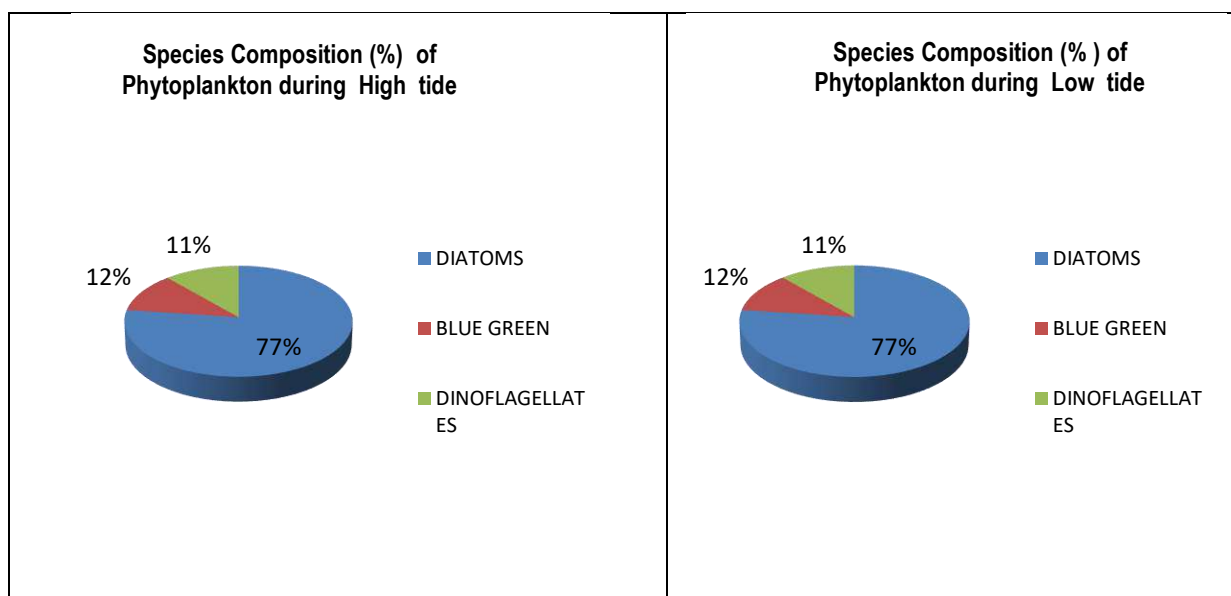
**Table No.:-52 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN AUGUST 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAEN	1-2	3/39	7.69
			DIATOMS	152-270	32/39	82.05
			DINOFLAGELLATES	3-4	4/39	10.26
			TOTAL PHYTO PLANKTON	156-275		
LOW TIDE	Sub surface	2	BLUE GREEN ALGAEN	1-8	3/39	7.69
			DIATOMS	207-250	32/39	82.05
			DINOFLAGELLATES	2-5	4/39	10.26
			TOTAL PHYTO PLANKTON	210-263	39	

**Table No.:- 53 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK, VADINAR & NEAR BY SPM, DURING NEAP TIDE IN AUGUST 2022**

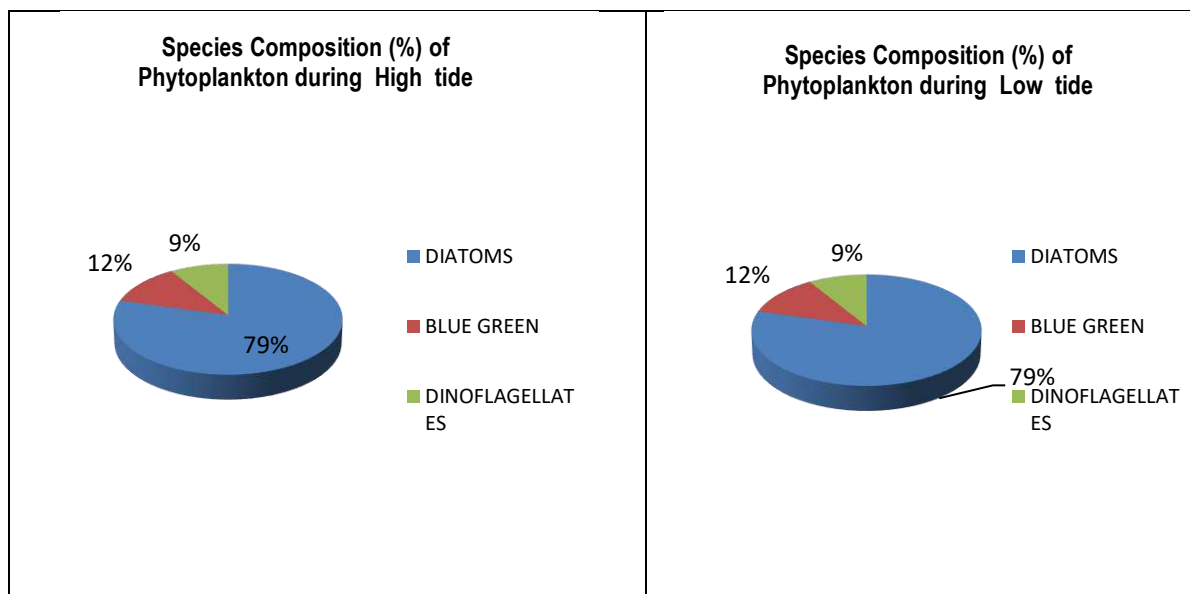
Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAEN	1-1	2/33	6.06
			DIATOMS	127-180	28/33	84.85
			DINOFLAGELLATES	2-4	3/33	9.09
			TOTAL PHYTO PLANKTON	<b>128-183</b>		
LOW TIDE	Sub surface	2	BLUE GREEN ALGAEN	2-15	2/33	6.06
			DIATOMS	164-202	28/33	84.85
			DINOFLAGELLATES	2-4	3/33	9.09
			TOTAL PHYTO PLANKTON	<b>180-204</b>	33	

**Species Composition (%) of Phytoplankton during High tide and Low tide period during spring tide in Kandala creek and nearby creeks**

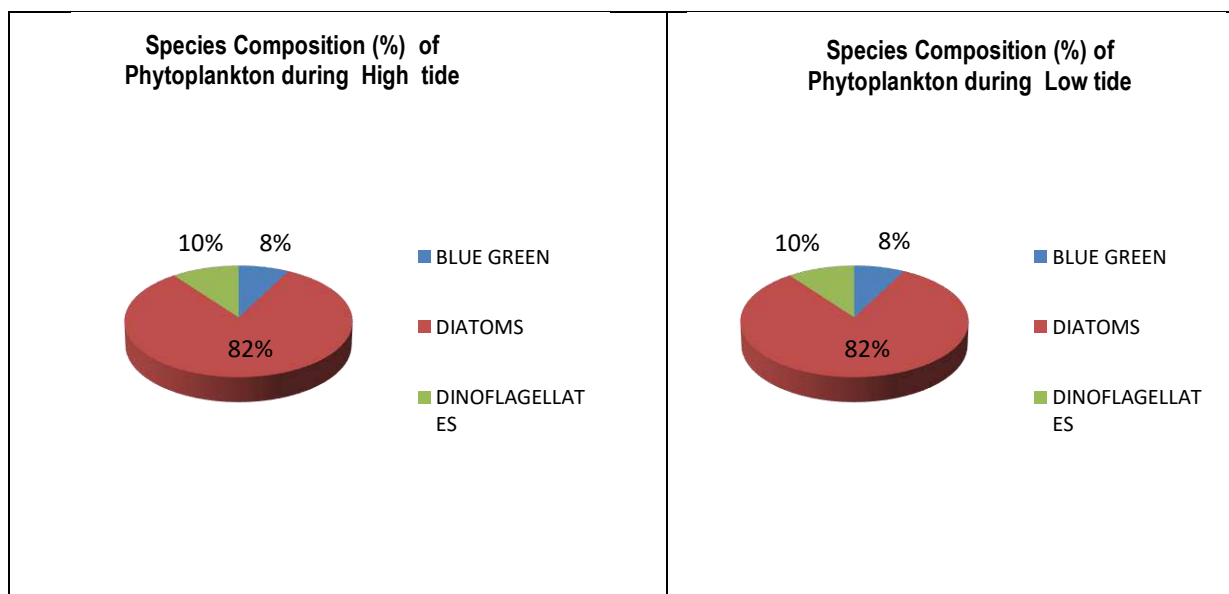




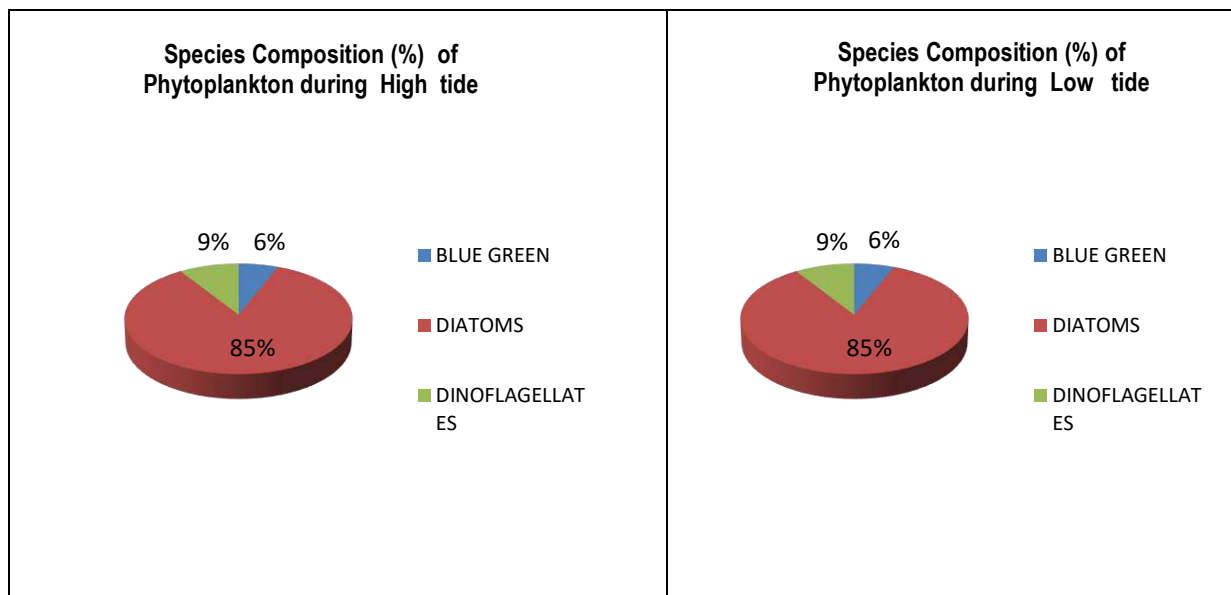
**Species Composition (%) of Phytoplankton during High tide and Low tide period during Neap tide in Kandla creek and nearby creeks**



**Species Composition (%) of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



**Species Composition (%) of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar**



**ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPA harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khoricreek) during high tide period and low tide period of spring tide and Neap tide in August, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly nine groups; Tintinids, Copepods, Rotifers, Arrow worms, Mysids, Urochordata, Ciliates, Foraminiferans, Nematodes and 8 larval forms. The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly seven groups; Tintinids, Copepods, Mysids, Urochordata, Arrow worms, Ciliates, Nematode and 9 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $30-90 \times 10^3 \text{ N/ m}^3$  during high tide and  $40-49 \times 10^3 \text{ N/ m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $15-134 \times 10^3 \text{ N/ m}^3$  during high tide and  $42-98 \times 10^3 \text{ N/ m}^3$  during low tide of Neap Tide period.

For the evaluation of the Zooplankton population in DPA OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM).

During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly Six groups Titinids, Copepods, Arrow worms, Urochordata, Mysids, Medusa and 5 larval forms. The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly seven groups, Tintinnids, Copepods, Arrow worms, Mysids, Urochordata, Foraminifera, Nematode and 8 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT Jetty area of path finder creek was  $91 \times 10^3$  N/m<sup>3</sup> during high tide and  $142 \times 10^3$  N/m<sup>3</sup> during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPASPM area of path finder creek was  $131 \times 10^3$  N/ m<sup>3</sup> during high tide and  $118 \times 10^3$  N/ m<sup>3</sup> during low tide of spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA OOT jetty area in path finder creek was recorded  $111 \times 10^3$  N/ m<sup>3</sup> during high tide and  $117 \times 10^3$  N/ m<sup>3</sup> during consecutive low tide period of Neap tide. Zooplankton of the sampling stations at sub surface layer in the DPASPM area in path finder creek was recorded  $68 \times 10^3$  N/m<sup>3</sup> during high tide and  $72 \times 10^3$  N/m<sup>3</sup> during consecutive low tide period of Neap Tide.

#### **Species Richness Indices and Diversity Indices:**

##### **Margalef's diversity index (Species Richness) S**

Margalef's diversity index (Species Richness) of Zooplankton communities in the stations Kandla creek region and nearby creeks were varying from 2.058- 3.778 with an average of 2.988 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities varying from 2.338- 3.524 with an average of 2.801 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations were varying from 2.373- 3.497 with an average of 2.876 during the sampling conducted in high tide and varying from 2.006- 3.49 with an average of 2.683 during the sampling conducted in low tide during Neap tide period.

(pending) Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 5.986 and 5.448 respectively. Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 4.308 and 3.354 respectively.

Margalef's diversity index (Species Richness) S of Zooplankton communities near Jetty at Path finder creek was varying from 3.61- 3.36 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) of

Zooplankton communities near SPM at Path finder creek were varying from 3.555-2.806 respectively during the consecutive High tide and low tide period.

**Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.742-0.894 between selected sampling stations with an average value of 0.829 during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.816-1.016 between selected sampling stations with an average value of 0.889 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.785-0.927 between selected sampling stations with an average value of 0.860 during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 0.680- 0.984 of between selected sampling stations with an average value of 0.827 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.238-1.262 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.105-1.029 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.969-1.002 respectively during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 1.012-0.825 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

**Simpson's diversity index:**

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.724-0.82 between selected sampling stations with an

average of 0.794 during high tide period and was varying from 0.823- 0.895 with an average value of 0.852 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of Neap tide except few, which was varying from 0.760- 0.847 between selected sampling stations with an average of 0.824 during high tide period and was varying from 0.684--0.869 with an average value of 0.796 between selected sampling stations during consecutive low tide .This species diversity suggests a relatively few successful species in this habitat during AUGUST2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.922 and 0.921 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.904 and 0.895 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.846- 0.872 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.885 and 0.794 respectively.

**Table No.:- 54 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	73	15/32	46.88	3.263	0.8942	0.82
	2	50	15/32	46.88	3.579	0.8864	0.7984
	3	71	14/32	43.75	3.05	0.8603	0.8197
	4	90	18/32	56.25	3.778	0.8124	0.7238
	5	60	10/32	31.25	2.198	0.7786	0.796
	6	30	8/32	25.00	2.058	0.7424	0.8046
LOW TIDE	1	40	14/32	43.75	3.524	0.9659	0.8667
	2	49	14/32	43.75	3.34	1.016	0.8946
	3	47	10/32	31.25	2.338	0.8175	0.8233
	4	40	10/32	31.25	2.44	0.818	0.8321
	5	45	10/32	31.25	2.364	0.8256	0.8414

**Table No.:- 55 ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In $No \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	134	15/32	46.88	2.858	0.8817	0.8268
	2	103	12/32	37.50	2.373	0.8644	0.8471
	3	96	15/32	46.88	3.067	0.9265	0.841
	4	97	17/32	53.13	3.497	0.8411	0.7599
	5	92	14/32	43.75	2.875	0.8602	0.8323
	6	15	8/32	25.00	2.585	0.7846	0.8381
LOW TIDE	1	50	11/32	34.38	2.556	0.7817	0.7959
	2	54	9/32	28.13	2.006	0.7598	0.775
	3	98	17/32	53.13	3.49	0.9844	0.8687
	4	77	15/32	46.88	3.223	0.9308	0.8554
	5	42	9/32	28.13	2.14	0.6804	0.6841

**Table No.:- 56 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING  
STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS  
DURING SPRING TIDE IN AUGUST 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	4-10	6/32	18.74
			Copepods	16-40	9/32	28.12
			Rotifers	1-2	1/32	3.13
			Arrow worms	0-2	1/32	3.13
			Mysids	2-4	1/32	3.13
			Urochordata	2-3	2/32	6.25
			Ciliates	1-4	1/32	3.13
			Larval forms	12-50	8/32	25.00
			Foraminiferans	0-1	2/32	6.24
			Nematode	0	1/32	3.13
			TOTAL ZOOPLANKTON N/ M <sup>3</sup>	<b>30-90</b>	<b>32</b>	
LOW TIDE	Sub surface	5	Tintinids	2-8	6/32	18.74
			Copepods	18-29	9/32	28.12
			Rotifers	0-4	1/32	3.13
			Arrow worms	1-2	1/32	3.13
			Mysids	1-2	1/32	3.13
			Urochordata	2-4	1/32	6.25
			Ciliates	1-2	1/32	3.13
			Larval forms	13-21	8/32	25.00
			Foraminiferans	1-4	2/32	6.24
			Nematode	0-1	1/32	3.13
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>40-49</b>	<b>32</b>	

**Table No.:- 57 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN AUGUST 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	4-10	5/32	15.62
			Copepods	4-50	11/32	34.37
			Arrow worms	1-2	1/32	3.13
			Mysids	1-3	2/32	6.25
			Urochordata	2-4	2/32	6.25
			Ciliates	0-1	1/32	3.13
			Larval forms	9-81	9/32	28.12
			Nematode	1-2	1/32	3.13
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>15-134</b>	<b>32</b>	
LOW TIDE	Sub surface	5	Tintinids	8-12	5/32	15.62
			Copepods	8-45	11/32	34.37
			Arrow worms	0-1	1/32	3.13
			Mysids	0-4	2/32	6.25
			Urochordata	0-2	2/32	6.25
			Ciliates	0-1	1/32	3.13
			Larval forms	31-50	9/32	28.12
			Nematode	0	1/32	3.13
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>42-98</b>	<b>32</b>	

**Table No.:- 58 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In $\times 10^3$ N / m <sup>3</sup>	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	91	28/29	96.55	5.986	1.238	0.922
	SPM	131	22/29	75.86	4.308	1.105	0.904
LOW TIDE	Jetty	142	28/29	96.55	5.448	1.262	0.921
	SPM	118	17/29	58.62	3.354	1.029	0.895



**Table No.:- 59 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN AUGUST 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	111	18/31	58.06	3.61	0.969	0.846
	SPM	68	16/31	51.61	3.555	1.012	0.885
LOW TIDE	Jetty	117	17/31	54.84	3.36	1.002	0.872
	SPM	72	13/31	41.94	2.806	0.825	0.794

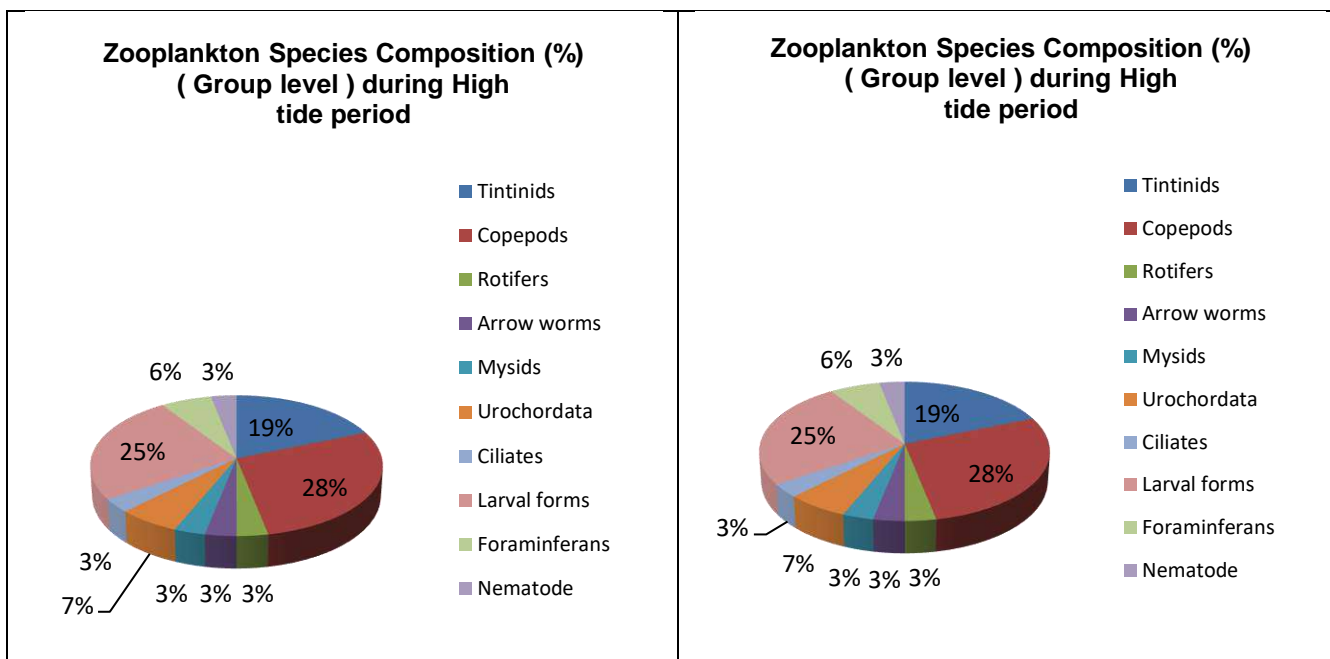
**Table No.:- 60 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN AUGUST 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	9-24	5/29	17.24
			Copepods	34-56	13/29	44.82
			Arrow worms	1-2	1/29	3.45
			Mysids	2-3	2/29	6.90
			Urochordata	4-5	2/29	6.90
			Medusa	0-1	1/29	3.45
			Larval forms	39-42	5/29	17.24
			TOTAL ZOOPLANKTON NO/L	<b>91-131</b>	<b>29</b>	
LOW TIDE	Sub surface	2	Tintinids	19-29	5/29	17.24
			Copepods	50-54	13/29	44.82
			Arrow worms	1-4	1/29	3.45
			Mysids	1-4	2/29	6.90
			Urochordata	1-6	2/29	6.90
			Medusa	0-1	1/29	3.45
			Larval forms	41-49	5/29	17.24
			TOTAL ZOOPLANKTON NO/L	<b>118-142</b>	<b>29</b>	

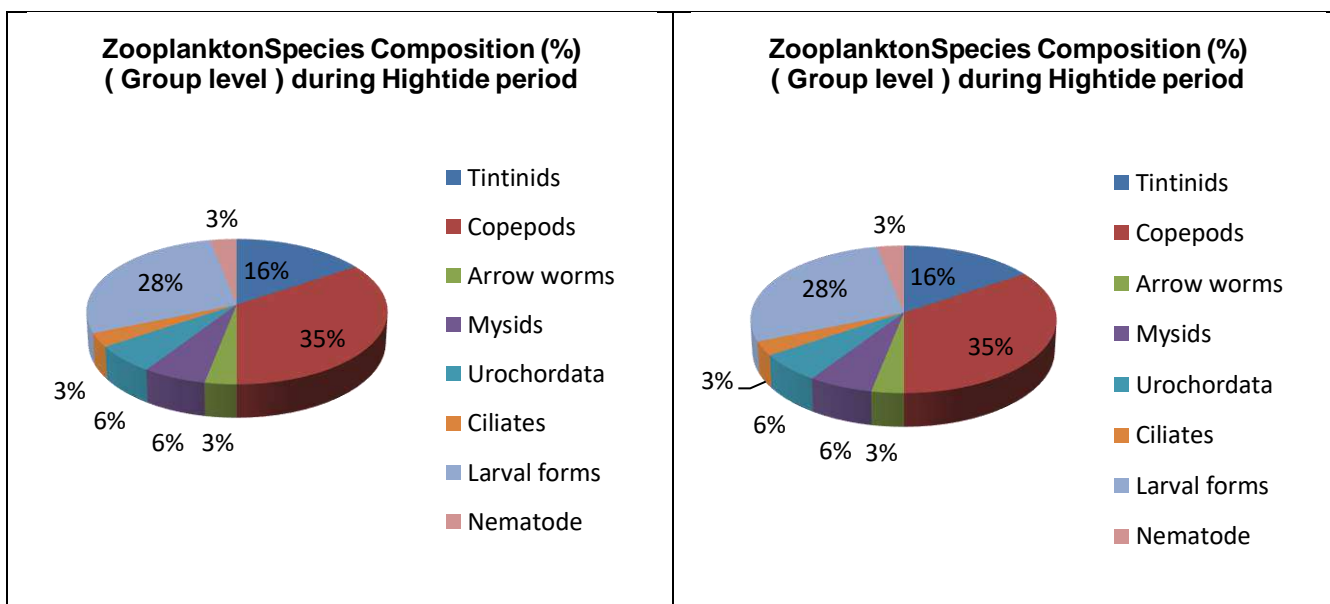
**Table No.:- 61 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN AUGUST 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	12-18	6/31	19.34
			Copepods	17-22	12/31	38.70
			Arrow worms	0-1	1/31	3.23
			Mysids	0	1/31	3.23
			Urochordata	0-1	1/31	3.23
			Larval forms	32-74	8/31	25.81
			Foraminifera	0-1	1/31	3.23
			Nematode	0-1	1/31	3.23
LOW TIDE	Sub surface	2	TOTAL ZOOPLANKTON	<b>68-111</b>	<b>31</b>	
			Tintinids	3-17	6/31	19.34
			Copepods	27-34	12/31	38.70
			Arrow worms	0	1/31	3.23
			Mysids	0-2	1/31	3.23
			Urochordata	0	1/31	3.23
			Larval forms	42-64	8/31	25.81
			Foraminifera	0	1/31	3.23
			Nematode	0	1/31	3.23
			TOTAL ZOOPLANKTON	<b>72-117</b>	<b>31</b>	

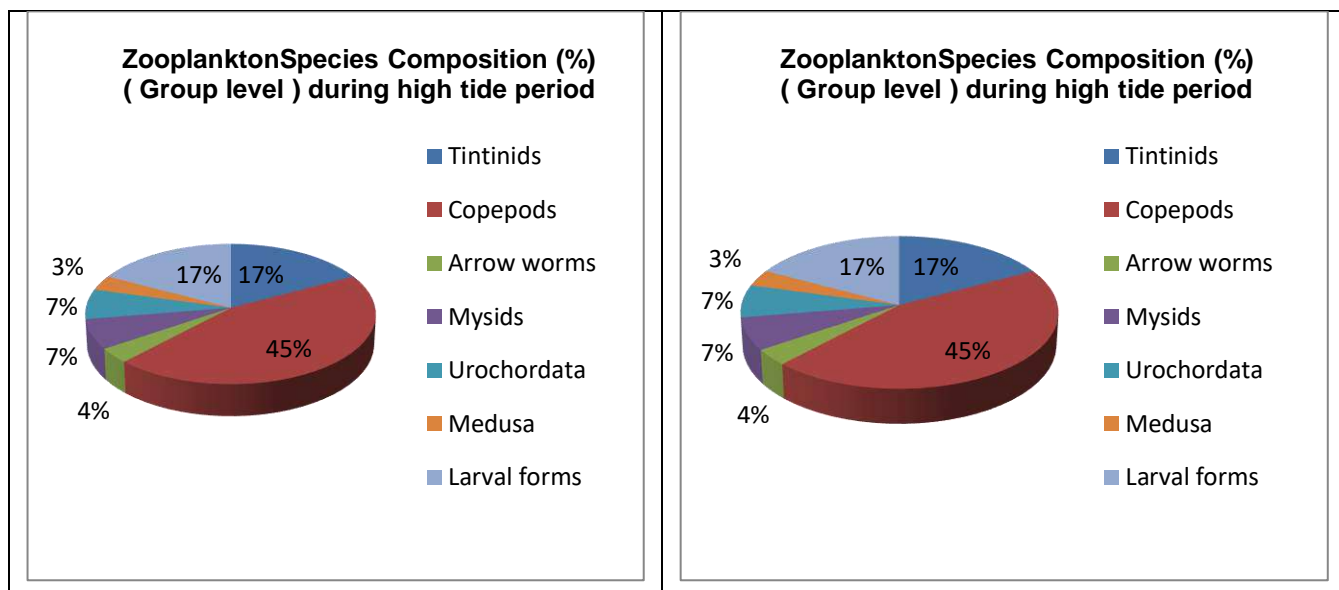
**Species Composition (%) of Zooplankton during High tide and Low tide period of Spring tide  
In Kandla Creek and nearby Creeks**



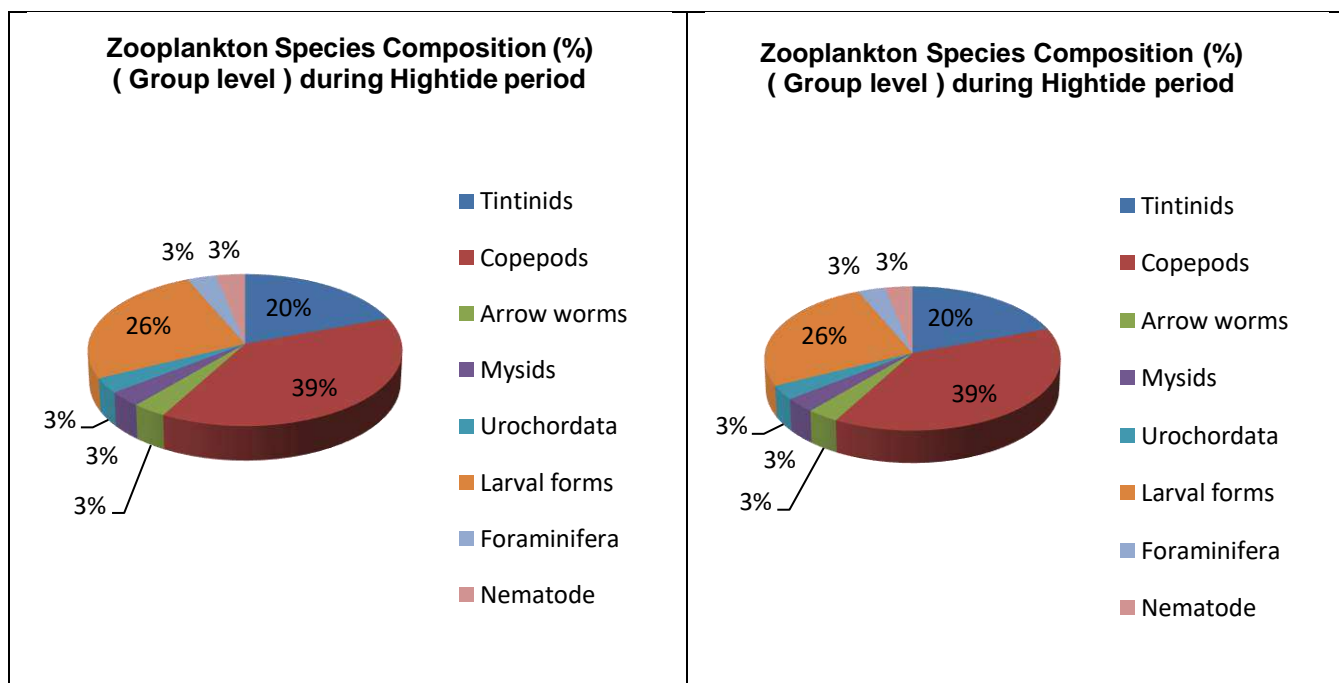
**Species Composition (%) of Zooplankton during High tide and Low tide period of Neap tide In  
Kandla Creek and nearby Creeks**



**Species Composition (%) of Zooplankton during High tide and Low tide period of Spring tide  
In Path Finder Creek and near Jetty**



**Species Composition (%) of Zooplankton during High tide and Low tide period of Neap tide In  
Path Finder Creek near jetty and nearby SPM**



**Table No.:- 62 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF AUGUST 2022**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Very sparse
					<i>Lyngbya sp.</i>	B2	Very sparse
					<i>Oscillatoria sp.</i>	B3	Very sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B4	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D1	Scattered
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Abundant
			Coscinodiscals	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D3	Scattered
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp.</i>	D4	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Very sparse
					<i>Hemiaulus sp.</i>	D6	Very sparse
				Streptothecaceae	<i>Helicotheca sp.</i>	D7	Very sparse
			Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp.</i>	D8	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D9	Dominant
			Rhizosoleniales	Rhizosoleniaceae	<i>Dactyliosolen sp.</i>	D10	Very sparse
					<i>Rhizosolenia sp.</i>	D11	Very sparse
			Thalassiosirales	Lauderiaceae	<i>Lauderia sp.</i>	D12	Very sparse
				Thalassiosiraceae	<i>Planktoniella sp.</i>	D13	Very sparse
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D14	Very sparse
					<i>Triceratium sp.</i>	D15	Very sparse
		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D16	Very sparse
					<i>Nitzschiasp.</i>	D17	Very sparse
					<i>Pseudo-nitzschia sp.</i>	D18	Sparse
			Naviculales	Naviculaceae	<i>Navicula sp.</i>	D19	Very sparse
				Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D20	Sparse
				Pinnulariaceae	<i>Pinnularia sp.</i>	D21	Very sparse
			Surirellales	Surirellaceae	<i>Surirella sp.</i>	D22	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp.</i>	D23	Sparse
					<i>Fragilarias sp.</i>	D24	Very sparse

					<i>Synedrasp</i>	D25	Sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D26	Very sparse
					<i>Thalassiothrix sp.</i>	D27	Scattered
DINO FLAGELLATES	Dinoflagellata / Dinzoa	Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
			Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF2	Very sparse
				Ceratiaceae	<i>Ceratium furca</i>	DF3	Sparse
					<i>Ceratium tripos</i>	DF4	Sparse

**Table No.:- 63 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING AND NEAP TIDE OF AUGUST 2022:**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Very sparse
					<i>Oscillatoria sp.</i>	B2	Sparse
			Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B3	Very sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B4	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D1	Abundant
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Sparse
			Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D3	Scattered
			Hemiaulales	Bellerocheaceae	<i>Bellerochea sp</i>	D4	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Sparse
				Streptothecaceae	<i>Helicotheca sp</i>	D6	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D7	Very sparse
					<i>Guinardia sp.</i>	D8	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D9	Dominant
			Thalassiosirales	Thalassiosiraceae	<i>Planktoniellasp</i>	D10	Very sparse
				Lauderiaceae	<i>Lauderia sp</i>	D11	Very sparse
				Skeletonemataceae	<i>Skeletonema sp</i>	D12	Very sparse
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D13	Scattered
					<i>Triceratium sp.</i>	D14	Very sparse

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		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D15	Very sparse
					<i>Nitzschia</i> sp	D16	Very sparse
					<i>Pseudo-nitzschia</i> sp.	D17	Very sparse
			Naviculales	Naviculaceae	<i>Navicula</i> sp	D18	Very sparse
				Pleurosigmataceae	<i>Pleurosigma</i> sp.	D19	Very sparse
			Surirellales	Surirellaceae	<i>Campylodiscus</i> sp	D20	Very sparse
					<i>Surirella</i> sp.	D21	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp	D22	Very sparse
					<i>Fragilariasp</i>	D23	Very sparse
					<i>Synedrasp</i>	D24	Sparse
			Licmophorales	Licmophoraceae	<i>Licmophora</i> sp.	D25	Very sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassionema</i> sp.	D26	Sparse
					<i>Thalassiothrix</i> sp.	D27	Scattered
DINO FLAGELLATES	Dinoflagellata / Dinzoa	Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF1	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF2	Very sparse
					<i>Ceratium tripos</i>	DF3	Very sparse

**Table No.:- 64 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA OOT AREA AT PATH  
FINDER CREEK AND NEARBY SPM AT VADINARDURING SPRING TIDE OF AUGUST 2022:**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
					<i>Oscillatoria sp.</i>	B2	Very sparse
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B3	Very sparse
DIATOMS	Bacillariophyta	Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D1	Scattered
			Chaetocerotales	Chaetocerotaceae	<i>Bacteriastrum sp</i>	D2	Very sparse
					<i>Chaetoceros sp</i>	D3	Dominant
			Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D4	Scattered
					<i>Palmeria sp.</i>	D5	Very sparse
			Corethrales	Corethraceae	<i>Corethron sp</i>	D6	Very sparse
			Hemiaulales	Belleracheaceae	<i>Bellerachea sp.</i>	D7	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D8	Very sparse
			Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp</i>	D9	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D10	Abundant
			Melosirales	Melosiraceae	<i>Melosira sp</i>	D11	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D12	Very sparse
			Thalassiosirales	Skeletonemataceae	<i>Skeletonema sp.</i>	D13	Very sparse
				Lauderiaceae	<i>Lauderia sp</i>	D14	Sparse
			Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D15	Scattered
					<i>Triceratium sp.</i>	D16	Sparse
		Bacillariophyceae	Achnanthes	Achnanthaceae	<i>Achnanthes sp</i>	D17	Very sparse
			Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D18	Sparse
					<i>Nitzschia sp</i>	D19	Very sparse
					<i>Pseudo-nitzschiasp</i>	D20	Sparse
			Naviculales	Naviculaceae	<i>Meuniera sp.</i>	D21	Very sparse
					<i>Navicula sp</i>	D22	Very sparse
				Pleurosigmataceae	<i>Pleurosigma sp</i>	D23	Very sparse
				Pinnulariaceae	<i>Pinnularia sp</i>	D24	Very sparse
			Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D25	Very sparse



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				Surirellaceae	<i>Surirella</i> sp.	D26	Very sparse
					<i>Campylodiscus</i> sp	D27	Very sparse
		Fragilariophyceae	Climacospheniales	Climacospheniaceae	<i>Climacosphenia</i> sp.	D28	Very sparse
			Fragilariales	Fragilariaceae	<i>Synedra</i> sp.	D30	Very sparse
			Striatellales	Striatellaceae	<i>Striatella</i> sp.	D31	Very sparse
			Thalassionematales	Thalassionemataceae	<i>Thalassionema</i> sp.	D32	Very sparse
					<i>Thalassiothrix</i> sp.	D33	Very sparse
		Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF1	Very sparse
			Dinophysales	Dinophysaceae	<i>Dinophysis</i> sp.	DF2	Very sparse
			Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
DINOFLAGELLATES	Dinoflagellata / Dinozoa				<i>Ceratium tripos</i>	DF4	Very sparse

**Table No.:- 65 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPAOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND NEAP TIDE OF AUGUST 2022:**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAEN ALGAE	Cyanophyta	Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Scattered
			Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B2	Very sparse
DIATOMS	Bacillariophyta	Coccinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D1	Sparse
			Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Abundant
			Coccinodiscales	Coccinodiscaceae	<i>Coccinodiscus sp.</i>	D3	Scattered
			Hemiaulales	Bellerucheaceae	<i>Belleruche sp.</i>	D4	Very sparse
				Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Very sparse
				Streptothecaceae	<i>Helicotheca sp.</i>	D6	Very sparse
			Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D7	Dominant
			Melosirales	Melosiraceae	<i>Melosira sp.</i>	D8	Very sparse
			Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D9	Very sparse
			Thalassiosirales	Lauderiaceae	<i>Lauderia sp.</i>	D10	Very sparse
				Thalassiosiraceae	<i>Planktoniellasp</i>	D11	Very sparse
					<i>Thalassiosira sp.</i>	D12	Very sparse
			Triceratiales	Triceratiaceae	<i>Odontellasp</i>	D13	Sparse
					<i>Triceratium sp.</i>	D14	Very sparse
		Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D15	Scattered
					<i>Nitzschia sp.</i>	D16	Sparse
					<i>Pseudo-nitzschiasp</i>	D17	Very sparse
			Naviculales	Naviculaceae	<i>Navicula sp.</i>	D18	Very sparse
				Pinnulariaceae	<i>Pinnularia sp.</i>	D19	Very sparse
				Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D20	Sparse
			Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D21	Very sparse
				Surirellaceae	<i>Campylodiscus sp.</i>	D22	Very sparse
					<i>Surirella sp.</i>	D23	Very sparse
		Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Fragilariasp</i>	D24	Very sparse
					<i>Synedra sp.</i>	D25	Dominant

			Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D26	Scattered
			Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D27	Very sparse
					<i>Thalassiothrix sp.</i>	D28	Scattered
DINO FLAGELLATES	Dinoflagellata / Dinozoa	Dinophyceae	Peridiniales	Protopteridiniaceae	<i>Protopteridinium sp.</i>	DF1	Very sparse
				Ceratiaceae	<i>Ceratium furca</i>	DF2	Very sparse
					<i>Ceratium tripos</i>	DF3	Very sparse

**Table No.:- 66 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF AUGUST 2022:**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Very sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Very sparse
					<i>Tintinnopsis radix</i>	T4	Very sparse
				Tintinnidae	<i>Amphorellopsis sp.</i>	T5	Very sparse
				Xystonellidae	<i>Favella sp.</i>	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
				Temoridae	<i>Temora sp.</i>	C6	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C7	Abundant
			Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C8	Sparse
				Euterpinae	<i>Euterpina sp.</i>	C9	Very sparse
ROTIFERS	ROTIFERA	Rotifera Subclass: Eurotatoria	Superorder: Monogononta Order:Ploimida	Brachionidae	<i>Brachionus plicatilis</i>	R1	Very Sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse

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MYSIDS	ATHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Solenoceridae	<i>Solenocera sp.</i>	M1	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
				Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
FISH LARVAE	CHORDATA SUBPHYLUM: VERTEBRATA	Superclass: Pisces			Fish larvae	L5	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae	L6	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L7	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very sparse
				Rotallidae	<i>Rotalia sp.</i>	F2	Very sparse
NEMATODE	NEMATODA				Unidentified nematodes	N1	Very sparse

**Table No.:- 67 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF AUGUST 2022:**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Very sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Very sparse
					<i>Tintinnopsis radix</i>	T4	Very sparse
				Xystonellidae	<i>Favella sp.</i>	T5	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Abundant
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
				Eucalanidae	<i>Pareucalanus sp.</i>	C6	Very sparse
					<i>Subeucalanus sp.</i>	C7	Very sparse
				Temoridae	<i>Temora sp.</i>	C8	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C9	Abundant
				Ectinosomatidae	<i>Microsetella sp.</i>	C10	Scattered
				Euterpinae	<i>Euterpina sp.</i>	C11	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
MYSIDS	ARTHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
				Solenoceridae	<i>Solenocera sp.</i>	M2	Sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
				Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
CILIATES	CILIOPHORA	Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca	Decapoda		Brachyuran zoea larvae	L2	Very sparse
BARNACLE	ARTHROPODA	Maxillopoda			Cirripede larvae	L3	Abundant

LARVAE	CRUSTACEA	Thecostraca					
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
FISH LARVAE	CHORDATA SUBPHYLUM: VERTEBRATA	Superclass: Pisces			Fish larvae	L5	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae	L6	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L7	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L8	Scattered
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L9	Very sparse
NEMATODE	NEMATODA				Unidentified nematodes	N1	Very sparse

**Table No.:- 68 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF AUGUST 2022:**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus sp.</i>	T1	Sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Sparse
					<i>Tintinnopsis radix</i>	T4	Scattered
				Dictyocystidae	<i>Luminella sp.</i>	T5	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Abundant
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse

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				Eucalanidae	<i>Pareucalanus sp.</i>	C5	Very sparse
					<i>Subeucalanus sp.</i>	C6	Very sparse
			Cyclopoida	Temoridae	<i>Temora sp.</i>	C7	Very sparse
				Oithonidae	<i>Oithona sp.</i>	C8	Abundant
			Harpacticoida	Clytemnestridae	<i>Clytemnestra sp.</i>	C9	Very sparse
				Euterpinidae	<i>Euterpina sp.</i>	C10	Scattered
				Ectinosomatidae	<i>Microsetella sp.</i>	C11	Sparse
			Poecilostomatatoida	Corycaeidae	<i>Corycaeus sp.</i>	C12	Very sparse
				Oncaeidae	<i>Oncaea sp.</i>	C13	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
MYSIDS	ARTHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
				Solenoceridae	<i>Solenocera sp.</i>	M2	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
				Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
MEDUSA	PHYLUM CNIDARIA	Hydrozoa			Unidentified medusa	ME1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
BRACHYURA LARVAE	ARTHROPODA (CRUSTACEA)	Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L3	Very sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L4	Scattered
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L5	Sparse

**Table No.:- 69 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPAOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF AUGUST 2022:**

GROUP	PHYLUM	CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
TINTINIDS	PROTOZOA CILIOPHORA	Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus sp.</i>	T1	Very sparse
				Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
					<i>Tintinnopsis gracilis</i>	T3	Scattered
					<i>Tintinnopsis radix</i>	T4	Sparse
					<i>Tintinnopsis tocaninensis</i>	T5	Very sparse
				Xystonellidae	<i>Favella sp.</i>	T6	Very sparse
COPEPODS	ARTHROPODA	Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
					<i>Parvocalanus sp.</i>	C2	Very sparse
				Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
				Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
				Eucalanidae	<i>Subeucalanus sp.</i>	C5	Very sparse
				Temoridae	<i>Temora sp.</i>	C6	Very sparse
			Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C7	Scattered
			Harpacticoida	Clytemnestridae	<i>Clytemnestra sp.</i>	C8	Very sparse
				Euterpinidae	<i>Euterpina sp.</i>	C9	Sparse
				Ectinosomatidae	<i>Microsetella sp.</i>	C10	Sparse
			Poecilostomatoida	Corycaeidae	<i>Corycaeus sp.</i>	C11	Very sparse
				Oncaeidae	<i>Oncaea sp.</i>	C12	Very sparse
ARROW WORMS	CHAETOGNATHA	Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
MYSIDS	ARTHROPODA CRUSTACEA	Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
UROCHORDATA	CHORDATA SUB PHYLUM UROCHORDATA	Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse
CRUSTACEAN LARVAE	ARTHROPODA (CRUSTACEA)	Copepoda			Nauplius larvae of copepods	L1	Dominant
ASCIDIAN	CHORDATA	Ascidacea			Ascidian tadpole	L2	Very sparse



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LARVAE	SUBPHYLUM: TUNICATA				larvae		
BARNACLE LARVAE	ARTHROPODA CRUSTACEA	Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
CYPHONAUTES LARVAE	BRYOZOA				Cyphonautes larvae	L4	Very sparse
ECHINODERMATA LARVAE	ECHINODERMATA				Ophiopluteus larvae	L5	Very sparse
MOLLUSCAN LARVAE	MOLLUSCA	Gastropoda Streptoneura			Opisthobranchia larvae	L6	Sparse
POLYCHAETE LARVAE	ANNELIDA	Polychaeta			Trochophore larvae	L7	Abundant
BIVALVE LARVAE	MOLLUSCA	Pelecypoda			Veliger larvae of bivalves	L8	Sparse
FORAMINIFERA	FORAMINIFERA	Globothalamea	Rotaliida	Globigerinidae	<i>Globigerina sp.</i>	F1	Very sparse
NEMATODE	NEMATODA				Unidentified nematodes	N1	Very sparse

# **BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPA harbour region and nearby creek. The meio-benthic organisms during spring tide and Neap tide were represented by Polychaetes *Dasybranchus* sp., *Notomastus* sp., and *Paraonis* sp. Population of benthic fauna was varying from 10-60 N/m<sup>2</sup> during spring tide and 0-40 N/m<sup>2</sup> during Neap tide

**Table No.:- 70 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR  
AREA CREEKS DURING SPRING TIDE IN AUGUST 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family : Capitellidae <i>Dasybranchus</i> sp.	10	0	0	20	40	-
Family Spionidae <i>Prinispo</i> sp.	10	10	20	10	20	-
Total Polychaetes N/M <sup>2</sup>	20	10	20	30	60	-
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	10	20	30	60	-

NS : No sample

**Table No.:- 70 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR  
AREA CREEKS DURING NEAP TIDE IN AUGUST 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family : Capitellidae <i>Dasybranchus</i> sp.	20	0	0	0	10	-
Family Spionidae <i>Prinispo</i> sp.	20	0	0	10	30	-
Total Polychaetes N/M <sup>2</sup>	40	0	0	10	30	
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	40	0	0	10	30	

## CHAPTER-11

### CONCLUSIVE SUMMARY & REMEDIAL MEASURES

## 11.0 Conclusive Summary and Remedial measures Suggested

- The AAQ monitoring of five locations at Deendayal Port Kandla indicates that the mean  $PM_{10}$  and  $PM_{2.5}$  values for four locations viz. Marine Bhavan, Oil Jetty area, Estate Office and Coal storage area were found higher than the permissible limit (standards  $100 \mu\text{g}/\text{m}^3$ ,  $60 \mu\text{g}/\text{m}^3$ ). The higher concentration of Particulate matter at Marine Bhavan may be due to vehicles emissions during loading-unloading of food grains and timbers; at Oil Jetty area due to industrial activities and heavy vehicles transportation; at Estate office due to construction work, vehicles emission produced from trucks, heavy duty vehicles that pass through the road outside Kandla port and Oil jetty area; while at Coal Storage area lifting of coal from grab yard and other coal handling processes. Moreover, the transportation of coal produces pollution from heavy vehicles. At Gopalpuri location, concentration of  $PM_{10}$  varied from  $89-119 \mu\text{g}/\text{m}^3$  and mean value was observed  $101 \mu\text{g}/\text{m}^3$ , concentration of  $PM_{2.5}$  was ranged from  $44-59 \mu\text{g}/\text{m}^3$  and mean was found  $51 \mu\text{g}/\text{m}^3$ . At Tuna port  $PM_{10}$  and  $PM_{2.5}$  were found within permissible limit of NAAQS.
- The AAQ monitoring signal building concentration of  $PM_{10}$  exceed the permissible limit and  $PM_{2.5}$  was found within limit while at admin building had  $PM_{10}$  concentration was exceed the permissible limit and  $PM_{2.5}$  shown slight increased.
- The concentration of monthly average of value was found  $124$  and  $114 \mu\text{g}/\text{m}^3$  exceed higher (Standard Limit  $100 \mu\text{g}/\text{m}^3$ ). The average concentration of  $PM_{2.5}$  at Admin building was found  $65 \mu\text{g}/\text{m}^3$  which was exceed standard limit and at Signal building was found  $58 \mu\text{g}/\text{m}^3$  within the limit ( $60 \mu\text{g}/\text{m}^3$ ).
- Further, precautionary measures and management strategies to minimize the effect of particulate as well as gaseous pollutants have also been suggested for achieving its ambient levels in and around Kandla Port and Vadinar Port, Gujarat, India.
- Drinking water at all the twenty locations was found potable and it was found within in line of BIS standards (IS 10500-2012).
- Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. All sampling location were within the permissible limit day time  $75 \text{ dB(A)}$  and night time  $70 \text{ dB (A)}$  for the industrial area.

- The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) and Vadinar were in line with the standards set by the Gujarat Pollution Control Board.
- It was suggested to monitor the STP performance on regular basis to avoid flow of contamination / Polluted water into the sea.
- Good species diversity suggests a relatively successful species in this habitat. A greater number of successful species and a more stable ecosystem. More ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole.
- The mean day time temperature at Deendayal Port was 29.81 °C. The day-time maximum temperature was 35.4°C and minimum was 25.7 °C. The mean night time temperature recorded was 27.57 °C. The mean Solar Radiation in August month was 109.08 w/m<sup>2</sup>. The maximum solar radiation was recorded 663.7 w/m<sup>2</sup> in 6<sup>th</sup> August, 2022 and the minimum solar radiation was recorded 0.23 w/m<sup>2</sup> in 5<sup>th</sup> August, 2022. The mean Relative humidity was 88.15 % for the month of August. Maximum Relative humidity was recorded 99.55 % and minimum Relative humidity was recorded 58 %. The average wind velocity for the entire month of August was 0.55 m/s. Maximum wind velocity was recorded 9.2 m/s. The wind direction was mostly West-South.

#### **Reasons for higher Values of PM<sub>10</sub>**

- The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.
- Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

#### **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of August, 2022 were beyond the permissible limit at all locations mentioned above Except Gopalpuri and Tuna Port. Given below are the remedial measures suggest to minimize the Air pollution.

- During August, 2022 overall ambient air quality of the DPA was within GPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, Marine Bhavan, Estate Office and Oil Jetty area. To improve air quality the port was using number of precautionary measures,

such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

### **Solution towards the Green port:**

Today, it is increasingly recognized that air pollution hurts human health. Consequently, efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits.

The guidelines can be considered a basis for governments for the implementation of a strategic plan focused on the reduction of multi pollutant emission, as well as of the overall air pollution related risk.

- The plantation should be all along the periphery of the port and inside and outside the port along with the road. Trees having high dust trapping efficiency (*Azadirachta indica*, *Cassia fistula*, *Delonix regia*, *Ficus religiosa*, *Pterocarpus marsupium*) are to be grown alongside the roads.
- The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.
- The vehicles should be covered during transportation and the vehicle carrying the coal should not be overloaded by raising the height of carriage.
- The water sprinklers should be use during transportation of loaded heavy vehicles on raw road.
- It should be ensure that regular sweeping of coal internal, main road and space a free circulation.
- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle- Mask advised in sensitive areas.
- Department for use maintenance should have a routine checkup noise level by replacing bearings, tights of all loose parts that can vibrate.
- Speed control is also an effective way to mitigate noise pollution, the lowest sound emission arise from vehicles moving smoothly.
- Use of renewable energy like solar energy should be optimal and ensure to work continuously.

- Keep neat and clean public transport and all basic items at public interaction places as much as possible.
- Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.
- Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.
- Initiate Natural Gas (CNG) as fuel by all buses and trucks.

### **Green Ports Initiative**

- Deendayal Port is committed to sustainable development and adequate measures are being taken to maintain the Environmental well-being of the Port and its surrounding environs. Weighing in the environmental perspective for sustained growth, the Ministry of Shipping had started „Project Green Ports“ which will help in making the Major Ports across India cleaner and greener. „Project Green Ports“ will have two verticals - one is „Green Ports Initiatives“ related to environmental issues and second is „Swachh Bharat Abhiyaan“.
- The Green Port Initiatives include twelve initiatives such as preparation and monitoring plan, acquiring equipments required for monitoring environmental pollution, acquiring dust suppression system, setting up of waste water treatment plants/ garbage disposal plant, setting up Green Cover area, projects for energy generation from renewable energy sources, completion of shortfalls of Oil Spill Response (OSR) facilities (Tier-I), prohibition of disposal of almost all kind of garbage at sea, improving the quality of harbour wastes etc.
- Deendayal port has also appointed GEMI as an Advisor for “Making Deendayal Port a Green Port - Intended Sustainable Development under the Green Port Initiatives.
- Deendayal Port has also signed MOU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Trust. The plantation is being carried out by the Social Forestry division of Kachchh.



## **CHAPTER-12**

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## ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY



**REPORT** : **DCPL/DPA/21-22/29**

**Mont** : **September**

**Issue** : **01**

**Revision** : **00**

**Prepare** : **DETOX CORPORATION PVT. LTD.,**

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## EXECUTIVE SUMMARY

## **ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTAL MONITORING REPORT- SEPTEMBER, 2022**

### **1. EXECUTIVE SUMMARY**

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to understand status of various parameters in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### **A) Ambient Air**

The monitoring of Ambient Air quality at 6-locations at Deendayal Port Authority Kandla and 2- location at Vadinar Port on 24 hourly basis for TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> and NMHC in twice a week 24 hourly at uniform intervals (as per NAAQS) at Gopalpuri, Tuna Port, Marine Bhavan building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and Vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The Maximum TSPM values in month of September 2022 were found 588 µg/m<sup>3</sup> at Coal Storage area on 29.09.2022 and minimum 85 µg/m<sup>3</sup> at Tuna Port on 01.09. 2022. The Maximum PM<sub>10</sub> values were 434 µg/m<sup>3</sup> at Coal Storage area on 29.09.2022 and minimum was 53 µg/m<sup>3</sup> at Tuna Port on 01.09. 2022. The PM<sub>2.5</sub> values were found from 144 µg/m<sup>3</sup> maximum at Coal Storage area on 29.09. 2022 and minimum was 24 µg/m<sup>3</sup> at Tuna Port on 01.09. 2022. The PM<sub>10</sub> and PM<sub>2.5</sub> values were found for four locations (Marine Bhavan Building, Coal Storage Area and Estate Office Building) to exceed the permissible limit.

At Oil Jetty location concentration of PM<sub>10</sub> was found slightly exceed the permissible limit, the concentration of PM<sub>2.5</sub> was within the permissible limit. Gopalpuri and Tuna port, all parameters of ambient air quality were found within the limit.

The AAQ monitoring for Vadinar at Admin building mean value of PM<sub>10</sub> had shown slightly exceed while PM<sub>2.5</sub> was within the permissible limit and signal building the concentration of PM<sub>10</sub> and PM<sub>2.5</sub> was within the limit.

The overall values of September for Gaseous SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> concentration were within the permissible limit at all location and NMHC were found BQL (Below Quantification Limit).

## **B) Weather**

The mean day time temperature at Deendayal Port was 29.11 °C. The day-time maximum temperature was 34.4°C and minimum was 24.9 °C. The mean night time temperature recorded was 27.51 °C. The mean Solar Radiation in September month was 199.87 w/m<sup>2</sup>. The maximum solar radiation was recorded 942.3 w/m<sup>2</sup> in 28<sup>th</sup> September, 2022 and the minimum solar radiation was recorded 0.93 w/m<sup>2</sup> in 12<sup>th</sup> September, 2022. The mean Relative humidity was 84.81 % for the month of September. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 64.0 %. The average wind velocity for the entire month of September was 5.64 m/s. Maximum wind velocity was recorded 28.1 m/s. The wind direction was mostly West-South.

## **C) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:**

The results obtained from the study for the month of September 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

## **D) Drinking Water Quality**

The drinking water being supplied to Deendayal Port was safe for drinking purpose. At all drinking water monitoring stations around port area were in line with the standard limit as per the drinking water specifications given in IS 10500:2012 as per tested parameters only.

The average results for 20 locations were as: pH were found Min 7.28 and maximum 7.6, TDS were found min 374.0 mg/l and Max found 1473.0 mg/l, Chloride were found Min 130.29 mg/l and Max 651.45 mg/l, Total Hardness were found Min 380.0 mg/l and Max 568.0 mg/l and Calcium were found Min 36.07 mg/l and Max 101.80 mg/l, color were colorless and odor were odorless. In all water samples BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count (E-coli & Coliform) is absent in all drinking water samples.

## **E) Monitoring Performance of Sewage Treatment Plant**

It was seen that the performance of STP at Deendayal Township, DPA STP Plant and Vadinar STP plant was satisfactory by overall. The treatment plant was well maintained during [September 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. At Gopalpuri STP, the pollutant removal efficiency for Average values of TSS, BOD and COD were 62%, 64% and 66% respectively. At Kandla STP, removal efficiency for TSS, BOD and COD were 52%, 60% and 63% respectively & at Vadinar STP removal efficiency for TSS, BOD and COD was 46%, 42% and 42%

respectively. At all STP location the outlet pH were ranged from 7.21-7.42, Total Suspended Solids were found 24.6-57.5 mg/l, Residual Chlorine were below Detection Limit (Less Than 0.5), COD were found 20-60mg/l and 3day BOD @ 27 °C were found 6-18.2 mg/l.

#### **F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 58.7 dB(A) to 74.2 dB(A) while at Vadinar port 3 location ranged from 57.1 dB(A) to 60.5 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 55.9 dB to 67.7 dB(A) while at Vadinar port ranged from 50.9 dB (A) to 54.8 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.

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# **CHAPTER-1**

## **INTRODUCTION**

### **DEENDAYAL PORT AUTHORITY**

## **1.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 Kms. From the mouth of Gulf of Kachchh. Latitude: 23° 01" N Longitude: 70° 13"E. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rise to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15 consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 127.10 million metric tons of cargo during the FY 2021-22, as against 117.566 million metric tons in FY 2020-21. Showing a growth of 8.11 %. Incidentally, DPA is the only major Indian port of handle more than 127 MMT cargo throughout and it has also registered the highest cargo throughput in its history. While the port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in Sept. 2021. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTA, which was first of its kind in India. Further, significant. Quantum of infrastructural up-gradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32MMTPA Essar Oil Refinery in Jamnagar District. Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the prescribed standards by GPCB/CPCB/MoEF& CC. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port. The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.



## CHAPTER-2

### AMBIENT AIR QUALITY MONITORING

## 2. Introduction

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth's atmosphere. It may cause diseases, allergies or death of humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty. The consequences of industrialization and the demand for improved quality of life has been increased exposure to air pollution (Vallero, 2014). An air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Any gas could qualify as pollution if it reached a high enough concentration to do harm. Theoretically, that means there are dozens of different pollution gases. In practice, about ten different substances cause most concern. Heavy metals represent a class of omnipresent pollutants, with toxic potential, in some cases even at low exposure levels. They concentrate in each tropic level because of their weak mobility, so the concentration in plants is higher than in soil, in herbivore animals higher than in plants, in carnivores' tissues higher than in herbivore, the highest concentration being reached at the end of the tropic chain, at big predacious and human bodies.

Globally, one of the main contributors to emissions of atmospheric pollutants and a significant user of energy is the industrial sector (Conti et al. 2015).

The concentration of air pollutants depends not only on the quantities that are emitted from the polluting sources, but also on the ability of the atmosphere to either absorb or disperse such emissions (USEPA, 2008).

Nowadays, the shipping sector provides low-cost and reliable delivery services in the economic field (Arunachalam et al. 2015). Nevertheless, shipping-related activities have a

considerable impact on air pollution, especially in coastal areas but also globally (Buccolieri et al. 2016). The primary air pollutants are PM, VOCs, NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub>, and CO (Bailey and Solomon 2004). As a consequence, a wide range of options toward “greener” seaports is needed (Bailey and Solomon 2004). Some of these measures are easy to adopt such as the regulation of fuel quality (by using low-sulfur alternative fuels), the speed reduction (Lack et al. 2011), and the use of alternative transportation equipment (Lai et al. 2011).

Clean air is the basic requirement of all living organisms. In recent times, due to population growth, urban sprawl, industrial development, and vehicular boom, the quality of air is deteriorating and being polluted. Pollutants of major public health concerns include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, which pose serious threats to human health and hygiene. In the present study, prime particulate pollutants (PM<sub>10</sub>, PM<sub>2.5</sub>), and gaseous pollutants (SO<sub>2</sub>, and NO<sub>2</sub>) were estimated at seven stations in and around Dahej Port, Gujarat, India (Soni and Jagruti Patel, 2017).

Among particulate pollutants, particulate matter (PM) is a ubiquitous entity, and is especially a grave problem due to its higher suspension rate into the atmosphere, and adverse health effects on plants, animals, humans, and materials in the form of visibility reduction, soiling of buildings, etc. (Horaginamani and Ravichandran, 2010; Chaurasia *et al.*, 2013).

The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

## 2.1 Ambient Air Quality Monitoring

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

**Table: 1. Ambient Air Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Marine Bhavan	AL-1	23° 0' 26.524"N	70° 13' 22.414"E	<b>DPA-Kandla</b>
2.	Oil Jetty	AL-2	23° 1' 45.613"N	70° 13' 11.052"E	
3.	Estate Office	AL-3	23° 1' 11.273"N	70° 12' 48.657"E	
4.	Gopalpuri Hospital	AL-4	23° 4' 53.551"N	70° 8' 7.047"E	
5.	Coal Storage Area	AL-5	22° 59' 31.812"N	70° 13' 9.979"E	
6.	Tuna Port	AL-6	22° 59' 15.291"N	70° 58' 57.018"E	
7.	Signal Building	AL-7	22° 26' 26.750"N	69° 40' 22.127"E	<b>DPA-Vadinar</b>
8.	Admin Building	AL-8	22° 26' 25.223"N	69° 40' 19.358"E	

### ● Air Quality Monitoring Methodology

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> & Benzene and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours for gaseous parameters. The absorbing reagents for SO<sub>2</sub>:- Absorbing Reagent TCM (Potassium Tetrachloromercurate 0.04M): Mercuric Chloride, Potassium Chloride and EDTA used. For NO<sub>2</sub>:- Absorbing Reagent Sodium Hydroxide (NaOH): Sodium Hydroxide and Sodium Arsenite used. For NH<sub>3</sub> need Conc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>. The GFA filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected two consecutive days a week as per CPCB guidelines, from all the eight locations as mentioned in the EMP.

## 2.2 Results

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of September 2022 are given in Tables 2 to 7. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building &Nr. Signal Building) are given in Tables 8 to 9.

The Movement of heavy transport with uncovered coal transportation, raw road around ambient location may be causes fugitive dust emission from dry conditions. Particulate Matter then enters the atmosphere through the action of wind, vehicular movement, or other activities. The dust produces tends to float in air and spread all around the vicinity. Direction and speed of wind affect the dispersion of the dust particulate matter. Humidity of air also has strong effect on the spreading of particulate matter. With increasing humidity, moisture particles eventually grow in size to a point where ‘dry deposition’ occurs, reducing PM<sub>10</sub> concentrations in the atmosphere.

Location 1: Marine Bhavan (AL1)

Table 2 : Results of Air Pollutant Concentration at Marine Bhavan

Table 2 : Results of Air Pollutant Concentration at Marine Bhavan										
	Date	TSPM [µg/m³]	PM <sub>10</sub> [µg/m³]	PM <sub>2.5</sub> [µg/m³]	SO <sub>2</sub> [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL1 – 1	01.09.2022	213	132	78	4.16	5.31	15.24	15.01	2.21	4.01
					5.54		13.16		5.39	
					6.23		16.62		4.42	
AL1 – 2	05.09.2022	254	163	85	2.54	3.63	17.31	15.24	5.94	4.60
					4.71		15.24		3.59	
					3.63		13.16		4.28	
AL1 – 3	08.09.2022	403	181	94	5.44	4.95	22.85	22.62	7.46	6.08
					3.26		19.39		4.14	
					6.16		25.62		6.63	
AL1 – 4	12.09.2022	255	155	88	2.90	3.75	17.31	19.39	4.56	4.83
					4.71		21.47		6.49	
					3.63		19.39		3.45	
AL1 – 5	19.09.2022	317	211	94	6.53	5.32	20.08	18.70	5.66	6.95
					4.35		17.31		8.01	
					5.08		18.70		7.18	
AL1 - 6	22.09.2022	333	222	109	2.54	3.87	13.85	15.47	5.11	4.88
					5.44		16.62		6.22	
					3.63		15.93		3.32	
AL1 - 7	26.09.2022	349	238	110	5.08	5.20	14.54	17.08	6.49	6.35
					4.35		19.39		7.46	
					6.16		17.31		5.11	
AL1 – 8	29.09.2022	296	192	96	3.99	4.71	27.70	25.62	3.59	4.70
					5.80		25.62		6.08	
					4.35		23.55		4.42	
Monthly Average		302	187	94		4.59		18.64		5.30
Standard Deviation		61	36	11		0.73		3.83		1.02

**Table 2 : Results of Air Pollutant Concentration at Marine Bhavan**

	Date	C6H6 [µg/m <sup>3</sup> ]	HC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>	ppm	4.0 mg/m <sup>3</sup>	-
AL1 – 1	01.09.2022	1.154	BDL	1.73	540
AL1 – 2	05.09.2022	1.094	BDL	1.97	893
AL1 – 3	08.09.2022	1.194	BDL	1.51	6836
AL1 – 4	12.09.2022	1.066	BDL	1.61	459
AL1 – 5	19.09.2022	1.223	BDL	1.5	906
AL1 - 6	22.09.2022	1.204	BDL	1.5	632
AL1 - 7	26.09.2022	1.103	BDL	1.35	409
AL1 - 8	29.09.2022	1	BDL	1.26	467
<b>Monthly Average</b>		<b>1.13</b>	-	<b>1.55</b>	<b>1392.75</b>
<b>Standard Deviation</b>		<b>0.08</b>	-	<b>0.22</b>	<b>2207.72</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 302 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 187 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 94 µg/m<sup>3</sup> which is above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.59 µg/ m<sup>3</sup>, 18.64 µg/ m<sup>3</sup> & 5.30 µg/ m<sup>3</sup> respectively; these values were within the permissible limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.13 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.15 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup> prescribed by NAAQS.

Location 2: Oil Jetty (AL2)

Table 3 : Results of Air Pollutant Concentration at Oil Jetty

Table 3 : Results of Air Pollutant Concentration at Oil Jetty										
	Date	TSPM [µg/m³]	PM <sub>10</sub> [µg/m³]	PM <sub>2.5</sub> [µg/m³]	SO <sub>2</sub> [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL2 -1	01.09.2022	143	81	49	4.71	4.47	13.16	12.70	5.39	5.99
					5.44		10.39		7.32	
					3.26		14.54		5.25	
AL2 -2	05.09.2022	158	97	57	3.99	3.99	10.39	10.85	4.14	4.93
					4.71		9.70		5.25	
					3.26		12.47		5.39	
AL2 -3	08.09.2022	170	108	59	2.90	2.90	29.09	22.62	1.38	2.76
					3.26		16.62		3.18	
					2.54		22.16		3.73	
AL2 -4	12.09.2022	141	89	50	3.26	3.87	15.24	14.31	3.32	4.10
					3.99		14.54		4.42	
					4.35		13.16		4.56	
AL2 – 5	19.09.2022	175	109	57	3.99	4.59	15.93	16.62	4.70	3.41
					5.44		22.85		2.35	
					4.35		11.08		3.18	
AL2 – 6	22.09.2022	200	120	67	4.71	4.35	19.39	14.08	2.49	3.68
					3.26		8.31		3.45	
					5.08		14.54		5.11	
AL2 – 7	26.09.2022	221	128	65	2.54	2.05	20.78	18.70	6.22	5.48
					1.45		15.24		4.42	
					2.18		20.08		5.80	
AL2 -8	29.09.2022	155	100	54	2.54	3.02	15.24	19.16	4.14	3.50
					2.18		29.09		2.76	
					4.35		13.16		3.59	
Monthly Average		170	104	57		3.66		16.13		4.23
Standard Deviation		28	16	6		0.90		3.88		1.12



<b>Table 3 : Results of Air Pollutant Concentration at Oil Jetty</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL2 -1</b>	01.09.2022	1.114	BDL	1.73	540
<b>AL2 -2</b>	05.09.2022	1.094	BDL	1.97	893
<b>AL2 -3</b>	08.09.2022	1.166	BDL	1.28	3757
<b>AL2 -4</b>	12.09.2022	1.171	BDL	1.9	1413
<b>AL2 – 5</b>	19.09.2022	1.158	BDL	1.63	972
<b>AL2 – 6</b>	22.09.2022	1.059	BDL	1.86	639
<b>AL2 -7</b>	26.09.2022	1.044	BDL	1.53	2072
<b>AL2 -8</b>	29.09.2022	1.173	BDL	1.18	1054
<b>Monthly Average</b>		<b>1.12</b>	<b>-</b>	<b>1.64</b>	<b>1417.50</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.29</b>	<b>1061.23</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

Oil Jetty Area, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> was mainly by motor vehicle emission produced from various types of vehicles at Oil Jetty Area. The mean TSPM value at Oil Jetty was 170 µg/m<sup>3</sup>. The mean PM<sub>10</sub> value was 104 µg/m<sup>3</sup> which was slightly exceed the permissible limit, PM<sub>2.5</sub> value was 57 µg/m<sup>3</sup> which is within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit prescribed by NAAQS. The mean concentration of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.66 µg/m<sup>3</sup>, 16.13 µg/m<sup>3</sup> and 4.23 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.12 µg/m<sup>3</sup> which was well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.64 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

Location 3: Kandla Colony – Estate Office (AL-3)

Table 4 : Results of Air Pollutant Concentration at Estate Office

	Date	TSPM [µg/m³]	PM <sub>10</sub> [µg/m³]	PM <sub>2.5</sub> [µg/m³]	SO <sub>2</sub> [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL3 – 1	01.09.2022	167	104	54	4.35	4.11	15.93	14.54	5.25	4.51
					2.90		13.16		3.59	
					5.08		14.54		4.70	
AL3 – 2	05.09.2022	268	161	95	6.16	5.07	12.47	12.47	7.04	5.57
					4.35		10.39		5.53	
					4.71		14.54		4.14	
AL3 – 3	08.09.2022	217	131	74	2.90	4.47	20.08	21.01	4.28	4.93
					5.80		23.55		6.77	
					4.71		19.39		3.73	
AL3 – 4	12.09.2022	182	115	63	4.35	5.20	14.54	16.63	4.70	4.19
					7.25		18.04		2.76	
					3.99		17.31		5.11	
AL3 – 5	19.09.2022	205	130	71	2.18	3.99	23.55	21.93	6.49	8.01
					4.35		20.78		9.12	
					5.44		21.47		8.43	
AL3 – 6	22.09.2022	158	97	51	6.53	5.68	17.31	18.93	5.53	5.43
					4.71		20.78		3.73	
					5.80		18.70		7.04	
AL3 – 7	26.09.2022	165	98	55	2.54	3.75	15.93	14.54	2.90	4.42
					5.08		13.16		5.80	
					3.63		14.54		4.56	
AL3 – 8	29.09.2022	174	105	63	2.18	3.75	12.47	13.16	6.35	4.74
					5.08		11.77		3.18	
					3.99		15.24		4.70	
Monthly Average		192	118	66		4.50		16.65		5.23
Standard Deviation		37	22	14		0.73		3.60		1.22

**Table 4 : Results of Air Pollutant Concentration at Estate Office**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
NAAQMS limit					
AL3 -1	01.09.2022	1.131	BDL	1.84	2472
AL3 -2	05.09.2022	1.004	BDL	1.8	7985
AL3 -3	08.09.2022	1.194	BDL	1.51	6836
AL3 -4	12.09.2022	1.063	BDL	1.33	957
AL3 – 5	19.09.2022	1.179	BDL	1.67	1775
AL3 – 6	22.09.2022	1.143	BDL	1.55	690
AL3 – 7	26.09.2022	1.21	BDL	1.37	1335
AL3 – 8	29.09.2022	1.141	BDL	1.25	729
Monthly Average		1.13	-	1.54	2847.38
Standard Deviation		0.07	-	0.22	2893.29

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Kandla Port Colony (Estate Office) was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Kandla port Colony were 192 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 118 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 66 µg/m<sup>3</sup> which is above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.50 µg/m<sup>3</sup>, 16.65 µg/m<sup>3</sup> and 5.23 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.13 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide was 1.54 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

Location 4: Gopalpuri Hospital (AL-4)

Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
	Date	TSPM [µg/m³]	PM <sub>10</sub> [µg/m³]	PM <sub>2.5</sub> [µg/m³]	SO <sub>2</sub> [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL4 -1	01.09.2022	109	66	38	4.35	4.83	12.47	10.85	5.25	4.10
					6.89		9.70		2.76	
					3.26		10.39		4.28	
AL4 -2	05.09.2022	138	88	43	6.53	6.17	15.93	14.31	6.22	5.34
					7.62		13.16		4.70	
					4.35		13.85		5.11	
AL4 -3	08.09.2022	119	72	39	3.63	5.08	8.31	9.47	2.35	2.58
					6.16		10.39		1.93	
					5.44		9.70		3.45	
AL4 -4	12.09.2022	107	66	31	2.54	3.63	14.54	13.62	4.56	3.68
					4.71		12.47		3.59	
					3.63		13.85		2.90	
AL4 – 5	19.09.2022	142	94	45	1.81	2.66	11.08	11.31	5.39	4.14
					3.99		9.70		2.76	
					2.18		13.16		4.28	
AL4 – 6	22.09.2022	142	86	44	5.80	4.59	17.31	18.70	3.59	5.25
					3.63		20.78		6.91	
					4.35		18.01		5.25	
AL4 – 7	26.09.2022	149	95	49	2.90	3.99	12.47	14.08	2.49	3.55
					5.44		15.24		4.83	
					3.63		14.54		3.32	
AL4 – 8	29.09.2022	170	103	64	2.90	4.35	5.54	6.93	6.35	5.15
					5.44		6.93		5.66	
					4.71		8.31		3.45	
Monthly Average		135	84	44		4.41		12.41		4.22
Standard Deviation		22	14	10		1.04		3.58		0.98

<b>Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL4 -1</b>	01.09.2022	1	BDL	1.82	3689
<b>AL4 -2</b>	05.09.2022	1.076	BDL	1.64	7443
<b>AL4 -3</b>	08.09.2022	1.134	BDL	7.06	3193
<b>AL4 -4</b>	12.09.2022	1.066	BDL	1.61	459
<b>AL4 – 5</b>	19.09.2022	1.131	BDL	1.52	885
<b>AL4 – 6</b>	22.09.2022	1.029	BDL	1.58	879
<b>AL4 – 7</b>	26.09.2022	1.01	BDL	1.3	1643
<b>AL4 – 8</b>	29.09.2022	1.159	BDL	1.17	597
<b>Monthly Average</b>		<b>1.08</b>	<b>-</b>	<b>2.21</b>	<b>2348.50</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>1.97</b>	<b>2387.50</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 135 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 84 µg/m<sup>3</sup> and PM<sub>2.5</sub> was 44 µg/m<sup>3</sup> which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.41 µg/m<sup>3</sup>, 12.41 µg/m<sup>3</sup> and 4.22 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.08 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon monoxide concentration was 2.21 mg/m<sup>3</sup> which is well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 5: Coal Storage Area (AL-5)**

**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area										
	Date	TSPM [µg/m³]	PM <sub>10</sub> [µg/m³]	PM <sub>2.5</sub> [µg/m³]	SO <sub>2</sub> [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL6 – 1	01.09.2022	472	347	116	4.71	4.83	23.55	21.24	5.94	4.97
					3.63		20.78		4.01	
					6.16		19.39		4.97	
AL6 – 2	05.09.2022	392	292	95	2.90	4.47	15.93	17.08	8.15	6.77
					4.71		17.31		6.49	
					5.80		18.01		5.66	
AL6 – 3	08.09.2022	482	412	108	7.25	5.44	22.85	23.08	4.56	5.52
					3.99		24.93		7.04	
					5.08		21.47		4.97	
AL6 – 4	12.09.2022	386	288	92	2.54	3.50	19.39	17.31	3.18	4.05
					4.71		15.24		4.83	
					3.26		17.31		4.14	
AL6 – 5	19.09.2022	512	374	116	5.08	5.56	12.47	14.08	5.94	5.71
					7.25		15.24		4.70	
					4.35		14.54		6.49	
AL6 – 6	22.09.2022	552	409	139	6.89	5.68	21.47	21.24	6.22	5.34
					4.71		23.55		4.70	
					5.44		18.70		5.11	
AL6 – 7	26.09.2022	462	350	108	2.54	3.87	14.54	13.39	3.32	4.38
					3.63		12.47		5.25	
					5.44		13.16		4.56	
AL6 – 8	29.09.2022	588	434	144	4.71	4.59	20.78	18.70	6.91	6.58
					5.08		16.62		7.18	
					3.99		18.70		5.66	
Monthly Average		481	363	115		4.74		18.27		5.42
Standard Deviation		70	54	19		0.80		3.48		0.96

**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL5 – 1	01.08.2022	01.09.2022	1.22	BDL	1.82
AL5 – 2	04.08.2022	05.09.2022	1.046	BDL	2.05
AL5 – 3	08.08.2022	08.09.2022	1.109	BDL	1.98
AL5 – 4	12.08.2022	12.09.2022	1.105	BDL	1.48
AL5 – 5	16.08.2022	19.09.2022	1.223	BDL	1.5
AL5 – 6	20.08.2022	22.09.2022	1.07	BDL	1.26
AL5 – 7	23.08.2022	26.09.2022	1.196	BDL	1.15
AL5 – 8	26.08.2022	29.09.2022	1.19	BDL	1.18
Monthly Average		1.15	-	1.55	1796.13
Standard Deviation		0.07	-	0.36	1357.08

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 481 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 363 µg/m<sup>3</sup>, and the PM<sub>2.5</sub> value was 115 µg/m<sup>3</sup> which was above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.74 µg/m<sup>3</sup>, 18.27 µg/m<sup>3</sup> and 5.42 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.15 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.55 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

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**Location 6: Tuna Port (AL-6)**

**Table 7 : Results of Air Pollutant Concentration at Tuna Port**

Table 7 : Results of Air Pollutant Concentration at Tuna Port										
	Date	TSPM [µg/m³]	PM <sub>10</sub> [µg/m³]	PM <sub>2.5</sub> [µg/m³]	SO <sub>2</sub> [µg/m³]		NO <sub>x</sub> [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL5 -1	01.09.2022	85	53	24	3.63	4.35	14.54	13.39	2.21	2.76
					5.08		12.47		2.90	
					4.35		13.16		3.18	
AL5 – 2	05.09.2022	104	67	27	2.18	2.42	10.39	9.00	6.08	5.39
					1.45		7.62		4.56	
					3.63		9.00		5.53	
AL5 – 3	08.09.2022	90	63	25	1.45	2.06	16.62	15.47	2.76	3.59
					2.18		14.54		3.87	
					2.54		15.24		4.14	
AL5 – 4	12.09.2022	89	57	27	4.71	4.32	9.70	11.31	6.22	5.30
					3.16		12.47		4.56	
					5.08		11.77		5.11	
AL5 – 5	19.09.2022	126	85	40	3.99	4.35	16.62	16.16	3.73	5.20
					4.71		14.54		6.91	
					4.35		17.31		4.97	
AL5 – 6	22.09.2022	112	78	31	1.81	1.69	19.39	21.47	8.56	7.64
					2.18		23.55		9.39	
					1.09		21.47		4.97	
AL5 – 7	26.09.2022	121	80	35	3.63	4.96	15.93	17.08	8.98	8.01
					5.44		18.70		7.74	
					5.80		16.62		7.32	
AL5 – 8	29.09.2022	129	88	40	3.26	3.38	9.70	12.01	5.25	5.52
					3.99		13.85		6.35	
					2.90		12.47		4.97	
Monthly Average		107	72	31		3.44		14.49		5.43
Standard Deviation		18	12	7		1.24		3.91		1.78



**Table 7 : Results of Air Pollutant Concentration at Tuna Port**

		<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>		<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>	<b>Date</b>	<b>8 hr</b>	<b>*NMHC</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL6 -1</b>	01.09.2022	1.059	BDL	1.98	3416
<b>AL6 – 2</b>	05.09.2022	1.034	BDL	1.47	8217
<b>AL6 – 3</b>	08.09.2022	1.063	BDL	1.52	2598
<b>AL6 – 4</b>	12.09.2022	1.018	BDL	1.83	421
<b>AL6 – 5</b>	19.09.2022	1.114	BDL	1.31	744
<b>AL6 – 6</b>	22.09.2022	1.138	BDL	1.64	551
<b>AL6 – 7</b>	26.09.2022	1.135	BDL	1.77	1110
<b>AL6 – 8</b>	29.09.2022	1.116	BDL	1.53	952
<b>Monthly Average</b>		<b>1.08</b>		<b>1.63</b>	<b>2251.13</b>
<b>Standard Deviation</b>		<b>0.05</b>		<b>0.22</b>	<b>2634.12</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port was 107 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 72 µg/m<sup>3</sup>, the mean PM<sub>2.5</sub> value was 31 µg/m<sup>3</sup> which is within the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.44 µg/m<sup>3</sup>, 14.49 µg/m<sup>3</sup> and 5.43 µg/m<sup>3</sup> respectively and were all within the permissible limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.08 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.63 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 7: Admin Building (Vadinar) (AL-7)**

**Table 8 : Results of Air Pollutant Concentration at Admin Building**

	Date	TSPM [µg/m <sup>3</sup> ]	PM <sub>10</sub> [µg/m <sup>3</sup> ]	PM <sub>2.5</sub> [µg/m <sup>3</sup> ]	SO <sub>2</sub> [µg/m <sup>3</sup> ]		NOx [µg/m <sup>3</sup> ]		NH <sub>3</sub> [µg/m <sup>3</sup> ]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL7 -1	01.09.2022	159	109	43	3.02	5.14	10.39	16.54	6.45	5.79
					5.44		14.43		4.83	
					2.72		11.54		8.17	
AL7 -2	05.09.2022	168	117	47	3.93	5.24	13.27	18.28	9.44	6.37
					4.84		10.97		7.94	
					3.02		15.00		7.02	
AL7 -3	08.09.2022	164	110	48	4.53	3.75	16.16	24.62	6.79	5.18
					3.32		18.47		7.60	
					2.72		13.27		5.99	
AL7 -4	12.09.2022	150	101	42	5.14	4.33	10.97	15.58	8.52	7.07
					6.65		10.39		7.94	
					3.93		7.50		8.06	
AL7 -5	15.09.202	134	95	34	3.32	4.23	11.54	19.43	6.79	4.34
					3.63		15.00		7.25	
					4.84		9.81		6.10	
AL7 -6	19.09.2022	147	97	43	3.02	4.84	10.97	15.00	9.32	2.76
					2.72		13.85		8.75	
					4.53		9.23		9.67	
AL1 -7	22.09.2022	160	106	50	3.63	4.33	8.66	16.35	5.87	5.22
					5.14		10.97		7.25	
					3.93		7.50		6.33	
AL1-8	26.09.2022	180	118	54	4.23	4.03	12.12	23.85	8.29	3.53
					2.72		14.43		6.91	
					5.44		16.16		5.99	
AL1-9	29.09.2022	134	95	37	3.32	4.73	11.54	19.04	8.63	6.91
					4.84		10.39		7.94	
					6.04		7.50		7.14	
Monthly Average		155	105	44		4.51		18.75		5.24
Standard Deviation		15	9	6		0.50		3.46		1.48

**Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [ $\mu\text{g}/\text{m}^3$ ]	*NMHC	CO [ $\text{mg}/\text{m}^3$ ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 $\mu\text{g}/\text{m}^3$		4.0 $\text{mg}/\text{m}^3$	-
AL7 -1	01.09.2022	1.1	BQL	1.94	387
AL7 -2	05.09.2022	1.06	BQL	1.71	420
AL7 -3	08.09.2022	1.04	1.81	1.81	411
AL7 -4	12.09.2022	1.15	BQL	1.65	529
AL7 -5	15.09.2022	1.15	BQL	1.6	533
AL7 -6	19.09.2022	1.04	BQL	1.95	352
AL7 -7	22.09.2022	1.07	BQL	1.9	384
AL7 -8	26.09.2022	1.15	BQL	1.69	432
AL7 -9	29.09.2022	1.05	BQL	1.36	390
Monthly Average		1.09	-	1.73	426
Standard Deviation		0.05	-	0.19	64

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Admin Building, Vadinar the mean TSPM value was  $155 \mu\text{g}/\text{m}^3$ , the mean PM<sub>10</sub> value was  $105 \mu\text{g}/\text{m}^3$  which was slightly exceed the permissible limit, the mean PM<sub>2.5</sub> value was  $44 \mu\text{g}/\text{m}^3$  which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were  $4.51 \mu\text{g}/\text{m}^3$ ,  $18.75 \mu\text{g}/\text{m}^3$  and  $5.24 \mu\text{g}/\text{m}^3$  respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was  $1.09 \mu\text{g}/\text{m}^3$ , well below the permissible limit of  $5.0 \mu\text{g}/\text{m}^3$ . NMHC's were below the detectable limit and Carbon Monoxide concentration was  $1.73 \text{mg}/\text{m}^3$ , well below the permissible limit of  $4.0 \text{mg}/\text{m}^3$ .

**Location 8: Signal Building (Vadinar) (AL-8)**

**Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar**

Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar										
	Date	TSPM [µg/m³]	PM <sub>10</sub> [µg/m³]	PM <sub>2.5</sub> [µg/m³]	SO <sub>2</sub> [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL8 -1	01.09.2022	137	97	37	3.93	5.64	14.43	14.81	5.29	7.10
					3.32		17.31		7.14	
					1.81		12.70		4.49	
AL8 -2	05.09.2022	153	103	42	2.42	4.10	10.97	27.70	5.76	5.45
					3.02		15.00		4.95	
					3.63		13.27		6.45	
AL8 -3	08.09.2022	146	99	38	4.23	3.88	15.00	16.35	8.29	6.27
					3.32		11.54		6.33	
					4.84		13.85		5.64	
AL8 -4	12.09.2022	142	97	35	2.72	4.63	9.81	17.31	5.06	4.83
					3.93		11.54		6.10	
					5.14		13.27		7.94	
AL8 -5	15.09.202	152	101	45	3.63	3.93	16.16	19.24	4.14	4.11
					5.44		11.54		5.29	
					6.04		9.23		6.56	
AL8 -6	19.09.2022	141	95	39	3.02	4.73	12.12	13.85	8.98	4.18
					2.72		15.58		7.14	
					4.84		17.31		8.17	
AL8 -7	22.09.2022	153	98	49	6.04	4.23	15.00	23.08	6.79	3.91
					5.44		12.70		7.60	
					3.93		10.39		7.02	
AL8-8	26.09.2022	158	101	48	5.14	4.23	9.23	18.28	6.22	5.68
					3.93		11.54		7.14	
					3.02		12.12		8.06	
AL8-9	29.09.2022	165	108	50	4.23	5.44	11.54	21.35	6.79	6.79
					5.14		13.27		8.17	
					6.35		10.97		6.33	
Monthly Average		150	100	43		4.54		19.11		5.37
Standard Deviation		9	4	6		0.64		4.36		1.19

**Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar**

		C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL8 -1	01.09.2022	1.17	BQL	2.13	432
AL8 -2	05.09.2022	1.09	BQL	2.1	412
AL8 -3	08.09.2022	1.06	BQL	1.47	398
AL8 -4	12.09.2022	1.21	BQL	1.64	603
AL8 -5	15.09.2022	1.02	BQL	1.01	569
AL8 -6	19.09.2022	1.19	BQL	1.82	612
AL8 -7	22.09.2022	1.03	BQL	1.01	563
AL8 -8	26.09.2022	1.08	BQL	1.81	578
AL8 -9	29.09.2022	1.17	BQL	2.03	613
<b>Monthly Average</b>		<b>1.11</b>	<b>-</b>	<b>1.67</b>	<b>531</b>
<b>Standard Deviation</b>		<b>0.07</b>	<b>-</b>	<b>0.43</b>	<b>90</b>

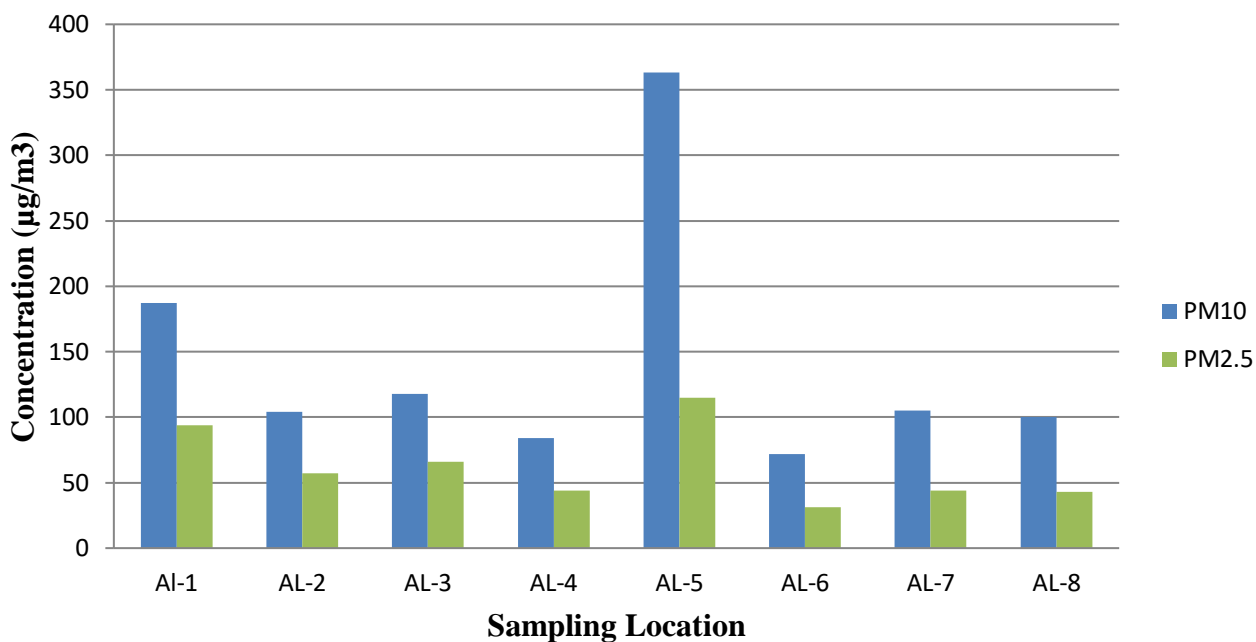
\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

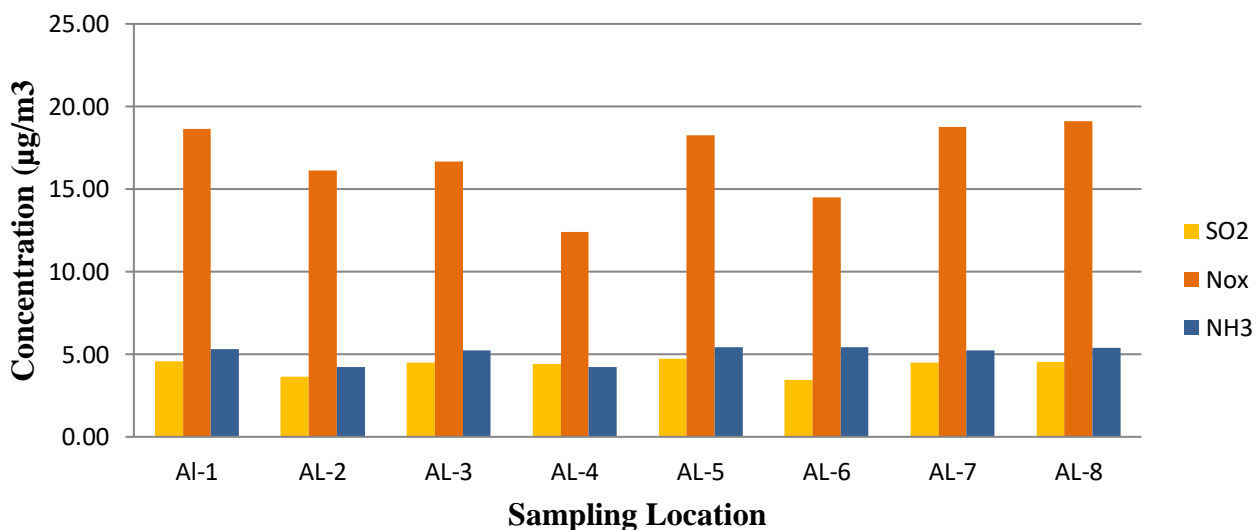
At Signal Building, Vadinar the mean TSPM value was 150 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 100 µg/m<sup>3</sup> which was boundary line of the permissible limit, the mean PM<sub>2.5</sub> value was 43 µg/m<sup>3</sup> which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were 4.55 µg/m<sup>3</sup>, 19.11 µg/m<sup>3</sup> and 5.37 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.11 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.67 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

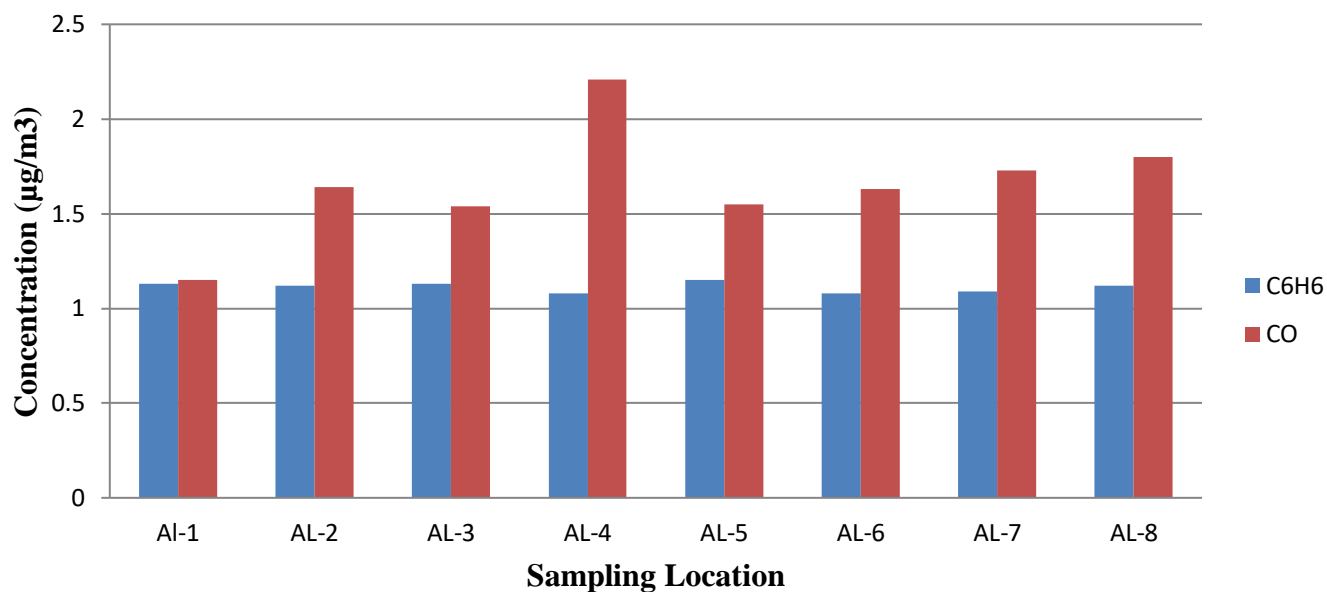
**Fig. No:-1 Average ambient air quality (PM) month of September-2022 at DPA and Vadinar Sampling Station**



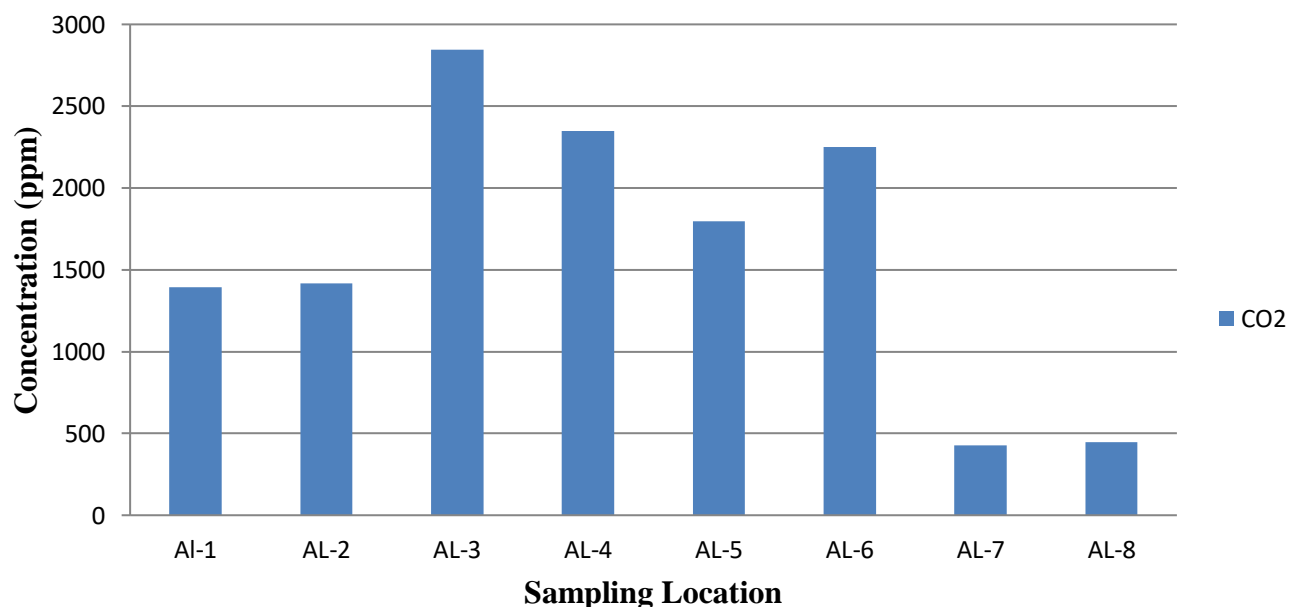
**Fig. No:-2. Average ambient air quality (Gaseous) month of August-2022 at DPA and Vadinar sampling location**



**Fig. No:-3. Average ambient air quality (Gaseous) month of September-2022 at DPA and Vadinar sampling location**



**Fig. No:-4. Average ambient air quality (Gaseous) month of September-2022 at DPA and Vadinar sampling location**



### 2.3 Observations and Conclusion

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Total Suspended Particulate matter as TSPM, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan and Estate Office.

The concentration of PM<sub>10</sub> was slightly exceeded at Oil Jetty while the mean concentration of PM<sub>2.5</sub> was within the limit. At Gopalpuri and Tuna Port location concentration of monitored parameters of ambient air quality were found within the limit.

The mean concentration of PM<sub>10</sub> was slightly exceeded at Admin building Vadinar & at Signal building Vadinar was boundary line (100 µg/m<sup>3</sup>) of permissible limit while the mean concentration at both location of PM<sub>2.5</sub> was found within permissible limit.



## **CHAPTER-3**

### **METEOROLOGICAL OBSERVATIONS**

#### **4.1 Meteorological Data**

Automatic Weather station (ID KAZPHOEN424) have been installed in Seva Sadan-3 at the Deendayal Port which records the data on Temperature (°C), Relative Humidity (%), Wind speed (m/s), Wind Direction (°), Solar radiation ( $\text{w/m}^2$ ) and Rainfall mm.

Meteorological factors play an important role in environmental pollution studies particularly in pollutant transport irrespective of their entry into the environment. The wind speed and direction play a major role in dispersion of environment pollutants. Effects of pollution on receptors animate and inanimate depends on atmospheric condition.

##### **Temperature**

At Deendayal Port, the day time temperature was found range 24.9-34.4°C. The average day time temperature was 29.11°C. The night time temperature was range from 24.6-32.3°C. The mean night time temperature recorded was 27.51 °C.

##### **Solar Radiation**

The mean Solar Radiation in September month was 200.01  $\text{w/m}^2$ . The maximum solar radiation was recorded 942.3  $\text{w/m}^2$  in 28<sup>th</sup> September, 2022 and the minimum solar radiation was recorded 0.93  $\text{w/m}^2$  in 12<sup>th</sup> September, 2022.

##### **Rainfall**

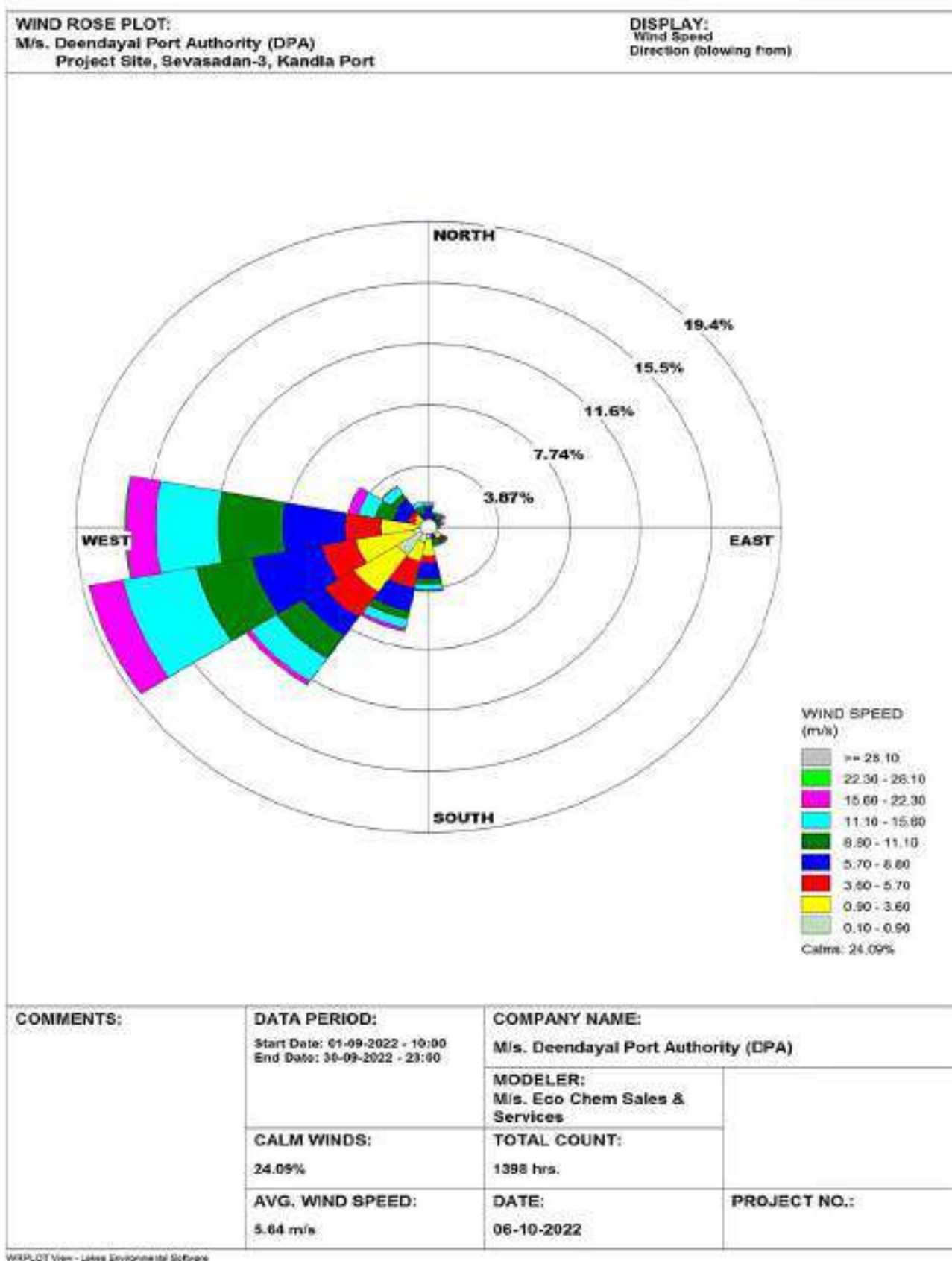
Rain fall of September month with an average rainfall was recorded 56.00 mm.

##### **Relative Humidity**

The mean Relative humidity was 84.81 % for the month of September. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 64.0 %.

##### **Wind Velocity and Wind Direction**

Velocity and direction of wind have a significant role in the dispersion of air borne materials and therefore determines the air quality of the area. The average wind velocity for the entire month of September was 5.64 m/s. Maximum wind velocity was recorded 28.1 m/s. The wind direction was mostly West-South.



## **CHAPTER-4**

### **DRINKING WATER QUALITY MONITORING**

#### 4.0 Drinking Water Quality Monitoring

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

**Table No:-10. Drinking Water Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude
1.	Nirman Building	DL-1	23° 0' 27"N	70° 13' 21"E
2.	P & C Building	DL-2	23° 0' 33"N	70° 13' 20"E
3.	North Gate	DL-3	23° 0' 26.97"N	70° 13' 21.87"E
4.	KPT-Canteen	DL-4	23° 2' 17.2674"N	70° 13' 18.2814"E
5.	West Gate	DL-5	23° 59' 40.48"N	70° 12' 50.96"E
6.	Wharf Area	DL-6	22° 59' 52.2"N	70° 13' 22.95"E
7.	Sevasadan-3	DL-7	23° 0' 22.55"N	70° 13' 15.34"E
8.	Workshop	DL-8	23° 0' 33.74"N	70° 13' 20.05"E
9.	Custom Building	DL-9	23° 1' 8.70"N	70° 12' 52.0"E
10.	Kandla Colony	DL-10	23° 11' 14.9"N	70° 12' 48.4"E
11.	KPT Hospital	DL-11	23° 1' 5.02"N	70° 12' 44.38"E
12.	A.O. Building	DL-12	23° 3' 42.89"N	70° 8' 41.5"E
13.	Gopalpuri School	DL-13	23° 5' 1.03"N	70° 7' 55.42"E
14.	Gopalpuri Guest House	DL-14	23° 4' 43.14"N	70° 7' 51.92"E
15.	E-Type Quarters	DL-15	23° 4' 59.90"N	70° 7' 56.72"E
16.	F-Type Quarters	DL-16	23° 4' 38.45"N	70° 8' 8.63"E
17.	Gopalpuri Hospital	DL-17	23° 4' 54.09"N	70° 8' 7.5"E
18.	Tuna Port	DL-18	23° 58' 23.06"N	70° 5' 35.6"E
19.	Vadinar Jetty	DL-19	22° 25' 51.73"N	69° 41' 36.62"E
20.	Vadinar Colony	DL-20	22° 30' 26.25"N	69° 39' 45.03"E

#### **4.1 Drinking Water Monitoring Methodology**

Samples for physico-chemical analysis were collected in 2 Carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS: 3025 Part-1, analysis was done as per IS: 3025/APHA standard methods and, the analysis results compare with IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate, Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (CFU) .

#### **4.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 11 to Table No. 17

**Table 11: Drinking Water Quality Monitoring Parameters for Nirman Building, P & C Building and Main Gate (North) at Kandla.**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C Building	Main Gate North	Acceptable Limits as per IS 10500 :2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.41	7.51	7.37	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved	mg/l	445	450	449	500	2000
3	Turbidity	NTU	1	0	1	1	5
4	Odor	-	-	-	-	Agreeable	Agreeable
5	Color	-	-	-	-	5	15
6	Conductivity	µs/cm	941	908	892	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	175.39	150.33	145.32	250	1000
9	Ca as Ca	mg/l	38.48	36.07	40.08	75	200
10	Mg as Mg	mg/l	76.30	80.68	86.99	30	100
11	Total Hardness	mg/l	410	422	458	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.01	1.20	0.97	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	38.47	37.54	37.54	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	2.08	1.21	6.04	45	No Relaxation
17	Salinity	‰	0.32	0.27	0.26	NS*	NS*
18	Sodium as Na	mg/l	107.82	107.29	110.44	NS*	NS*
19	Potassium as K	mg/l	3.61	3.55	3.47	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Table 12: Drinking Water Quality Monitoring Parameters for Canteen, West Gate – I & Wharf Area at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per IS	Permissible Limits in the absence of Alternate Source as
1	pH	-	7.28	7.43	7.53	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	470	452	466	500	2000
3	Turbidity	NTU	0	0	1	1	5
4	Odor	-	-	-	-	Agreeable	Agreeable
5	Color	-	-	-	-	5	15
6	Conductivity	µs/cm	936	904	933	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	190.42	155.35	180.40	250	1000
9	Ca as Ca	mg/l	41.68	37.68	42.48	75	200
10	Mg as Mg	mg/l	98.66	84.08	90.88	30	100
11	Total Hardness	mg/l	510	440	480	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.32	1.29	1.21	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	40.43	37.31	41.35	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	37.72	2.55	6.17	45	No Relaxation
17	Salinity	‰	0.34	0.28	0.33	NS*	NS*
18	Sodium as Na	mg/l	113.91	109.93	111.24	NS*	NS*
19	Potassium as K	mg/l	5.02	3.37	5.06	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



**Table 13: Drinking Water Quality Monitoring Parameters for Sewa sadan-3, Workshop I and Custom Building at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.33	7.41	7.37	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	458	454	374	500	2000
3	Turbidity	NTU	1	0	0	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	915	908	747	NS*	NS*
7	Biochemical	mg/l				NS*	NS*
8	Chloride as Cl	mg/l	140.31	185.41	170.38	250	1000
9	Ca as Ca	mg/l	39.28	40.08	36.87	75	200
10	Mg as Mg	mg/l	96.71	71.93	82.13	30	100
11	Total Hardness	mg/l	496	396	430	200	600
12	Iron as Fe	mg/l				0.3	No Relaxation
13	Fluorides as F	mg/l	1.38	1.43	1.07	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	37.43	35.69	37.07	200	400
15	Nitrite as NO <sub>2</sub>	mg/l				NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	3.49	1.28	1.34	45	No Relaxation
17	Salinity	‰	0.25	0.33	0.31	NS*	NS*
18	Sodium as Na	mg/l	108.70	93.00	110.12	NS*	NS*
19	Potassium as K	mg/l	3.45	3.34	3.22	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 14: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla and A.O. Building at Gandhidham.**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 :
1	pH	-	7.28	7.31	7.42	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	454	400	411	500	2000
3	Turbidity	NTU	1	1	1	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	911	800	823	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	195.43	165.37	140.31	250	1000
9	Ca as Ca	mg/l	43.29	44.09	37.68	75	200
10	Mg as Mg	mg/l	86.99	65.61	90.88	30	100
11	Total Hardness	mg/l	466	380	468	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.16	1.29	1.46	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	37.43	39.62	40.54	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.68	4.09	0.34	45	No Relaxation
17	Salinity	‰	0.35	0.30	0.25	NS*	NS*
18	Sodium as Na	mg/l	110.12	102.64	104.59	NS*	NS*
19	Potassium as K	mg/l	3.33	3.46	3.20	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 15: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House) and E - Type Quarter at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.45	7.55	7.42	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	407	420	459	500	2000
3	Turbidity	NTU	0	1	0	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	814	846	908	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	155.35	180.40	135.30	250	1000
9	Ca as Ca	mg/l	38.48	39.28	40.88	75	200
10	Mg as Mg	mg/l	95.26	82.13	67.55	30	100
11	Total Hardness	mg/l	488	436	380	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.33	1.49	1.06	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	40.43	31.53	37.54	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.48	1.28	0.40	45	No Relaxation
17	Salinity	‰	0.28	0.33	0.24	NS*	NS*
18	Sodium as Na	mg/l	100.96	104.36	106.73	NS*	NS*
19	Potassium as K	mg/l	3.27	3.08	3.30	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 16: Drinking Water Quality Monitoring Parameters for F-Type Quarter, Hospital Gopalpuri and Tuna Port.**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.37	7.41	7.38	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	440	404	1473	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-				Agreeable	Agreeable
5	Color	-				5	15
6	Conductivity	µs/cm	880	805	2940	NS*	NS*
7	Biochemical Oxygen Demand	mg/l				NS*	NS*
8	Chloride as Cl	mg/l	130.29	175.39	651.45	250	1000
9	Ca as Ca	mg/l	41.68	42.48	101.80	75	200
10	Mg as Mg	mg/l	76.79	87.48	76.30	30	100
11	Total Hardness	mg/l	420	466	568	200	600
12	Iron as Fe	mg/l				0.3	No Relaxation
13	Fluorides as F	mg/l	1.41	1.31	1.48	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	38.70	39.16	296.00	200	400
15	Nitrite as NO <sub>2</sub>	mg/l				NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.41	1.74	6.71	45	No Relaxation
17	Salinity	‰	0.24	0.32	1.18	NS*	NS*
18	Sodium as Na	mg/l	107.30	102.85	365.00	NS*	NS*
19	Potassium as K	mg/l	3.09	3.11	4.48	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 17: Drinking Water Quality Monitoring Parameters for Vadinar Jetty and Port Colony at Vadinar.**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.5	7.6	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	460	456	500	2000
3	Turbidity	NTU	1.00	1.00	1	5
4	Odor	-			Agreeable	Agreeable
5	Color	-			5	15
6	Conductivity	µs/cm	780	772	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	140.31	110.25	250	1000
9	Ca as Ca	mg/l	420	380	75	200
10	Mg as Mg	mg/l	84.17	72.14	30	100
11	Total Hardness	mg/l	0.25	0.20	200	600
12	Iron as Fe	mg/l	51.03	48.60	0.3	No Relaxation
13	Fluorides as F	mg/l	0.28	0.22	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	63.40	51.20	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.82	0.72	45	No Relaxation
17	Salinity	‰	BQL	BQL	NS*	NS*
18	Sodium as Na	mg/l	55.6	52.2	NS*	NS*
19	Potassium as K	mg/l	2.39	2.11	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **4.3 Results & Discussion**

The colour of all drinking water samples was found Colourless and odour of the samples also agreeable. All parameters were found within the specified limit as per the Drinking water Standard.

#### **pH**

The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. At DPA the pH values for drinking water samples were ranges from 7.28-7.55 and mean value was 7.40 while at Vadinar pH range was 7.5-7.6. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Turbidity**

The selected drinking water sample location turbidity range from 0-1NTU at all location of DPA and Vadinar in month of September. The Turbidity values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Total Dissolved Solids (TDS)**

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc.

TDS values at DPA varied between 374-1473 mg/l. The average TDS value was found 493.63 mg/l. The minimum value for TDS was 374 mg/l at Custom Building and maximum was 1473 mg/l at Tuna Port while at Vadinar TDS ranged from 456-460 mg/l and mean was 458.0 mg/l. The TDS values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of September DPA ranged from 747  $\mu\text{S}/\text{cm}$  at Custom building to 2940  $\mu\text{S}/\text{cm}$  at Tuna Port and mean value was 989.50  $\mu\text{S}/\text{cm}$  while at Vadinar ranged from 772-780  $\mu\text{S}/\text{cm}$  and mean was 776  $\mu\text{S}/\text{cm}$ .

## **BOD**

BOD value in the studied area of DPA and Vadinar was found Below Quantification Limit (2.0 mg/l). IS 10500:2012 does not show any standard values for BOD in drinking water.

## **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. The Chloride value in the studied area of DPA ranged from 130.29 mg/l at F-Type Quarters to 651.45 mg/l at Tuna Port and mean value was 190.15 mg/l while at Vadinar location chloride ranged from 145.32-150.33 and mean was 147.8 mg/l. The Chloride was found within the Permissible limit of the Drinking Water Standard.

## **Calcium**

Calcium is most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases.

Calcium value in the studied area of DPA ranged from 36.07 mg/l at P& C building to 101.80 mg/l at Tuna Port and mean value was 43.46 mg/l while at Vadinar location calcium ranged from 32.87-34.47 mg/l and mean was 33.7 mg/l. The Calcium values were found to be within the Permissible limit of the Drinking Water Standard.

## **Magnesium**

Magnesium value in the studied area of DPA ranged from 65.61 mg/l at DPA Hospital to 98.66 mg/l at DPA-Canteen and mean value was 83.19 mg/l while at Vadinar location magnesium ranged from 73.87-84.08 mg/l and mean was 79.0 mg/l. All the locations had Magnesium within the prescribed limits of 30-100 mg/L.

## **Total Hardness**

Total Hardness value in the studied area of DPA ranged from 380.00 mg/l at DPA Hospital to 568.00 mg/l at Tuna Port and mean value was 450.78 mg/l while at Vadinar location total hardness ranged from 390.00-428.00 mg/l and mean was 409.00 mg/l. The values of total hardness were found within the Permissible limit of the Drinking Water Standard (200-600 mg/L). These results clear, that hardness of water is according to the IS standards and it is not harmful for local inhabitants.

### **Iron**

Iron values in the studied area of DPA & Vadinar were Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards are 0.3 mg/L.

### **Fluoride**

Fluoride value in the studied area of DPA varied between 1.06-1.47 mg/l and mean was 1.26 mg/l. The minimum value was 0.11 mg/ at DPA Hospital and maximum was 2.42 mg/l at Tuna Port while at Vadinar location fluoride ranged from 1.20-1.41 mg/l and mean was 1.31 mg/l. The Fluoride values were well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphate**

Sulphate value in the studied area of DPA varied between 31.53–296.00 mg/l and mean was 52.43 mg/l. The minimum value was 31.53 mg/ at Gopalpuri Guest House and maximum was 296.00 mg/l at Tuna Port while at Vadinar location sulphate ranged from 39.39-42.97 mg/l and mean was 41.2 mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

The all values of Nitrates were well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected at DPA ranged from 0.24 to 1.18 ‰ while at Vadinar sampling location salinity ranged from 0.26-0.27 ‰. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected at DPA ranged from 93.00- 365.00 mg/l and average was 120.94 mg/l while at Vadinar sodium ranged from 52.2- 55.6 mg/l. Potassium salts ranged at DPA ranged from 3.08 to 5.06 mg/l while average was 3.58 mg/l while at Vadinar



sampling location ranged from 2.11-2.39 mg/l and mean was 2.3 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

#### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

#### **Bacteriological Study**

Analysis of the bacteriological parameter (E-coli and total coliform) at all location shows that Bacteria were not detectable. This shows that drinking water samples were safe for human consumption as per tested parameters.

#### **4.4 Conclusions**

These results were compared with permissible limits as prescribed in IS 10500:2012 – Drinking Water Specification. It was seen from the analysis data that during the study period at selected sampling location the water was safe for human consumption as per analyzed parameters at all drinking water monitoring stations.

## **CHAPTER-5**

### **NOISE MONITORING**

## 5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 5.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 5.2 Results

**Table 18: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	6:00 am to 10:00 PM	10:00PM to 6:00 AM
1	Marine Bhavan	74.2	65.1
2	Nirman Building 1	72.3	66.9
3	Tuna Port	58.7	55.9
4	Main Gate North	72.1	67.7
5	West Gate I	69.9	66.6
6	Canteen Area	73.3	65.6
7	Main Road	71.0	66.1
8	ATM Building	72.3	67.2
9	Wharf Area /Jetty Area	71.8	65.2
10	Port & Custom Office	68.1	62.2
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	57.7	50.9
12	Nr. Port Colony, Vadinar	60.5	54.8
13	Nr. Vadinar Jetty	57.1	54.1

### 5.3 Conclusions

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships.

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 58.7 dB(A) to 74.2 dB(A) while at Vadinar port 3 location ranged from 57.1 dB(A) to 60.5 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 55.9 dB to 67.7 dB(A) while at Vadinar port ranged from 50.9 dB (A) to 54.8 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.

## CHAPTER-6

### SOIL MONITORING

## 6.0 Soil Monitoring

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

**Table No.:-19. Soil Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Tuna Port	SL-1	22° 58' 10.18"N	70° 6' 3.7"E	Near main gate of Port
2.	IFFCO Plant	SL-2	23° 26' 8.37"N	70° 13' 4.4"E	10 m away from main gate
3.	Khori creek	SL-3	22° 58' 10.18"N	70° 6' 3.7"E	Sand from creek after tide
4.	Nakti Creek	SL-4	23° 2' 1.10"N	70° 9' 33.6"E	
5.	DPA admin site	SL-5	22° 26' 30.9"N	69° 40' 37.03"E	Vadinar
6.	DPA colony	SL-6	22° 23' 57.09"N	69° 42' 49.42"E	

## 6.1 Methodology

The soil samples were collected in the month of September 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

## 6.2 Results

**Table-20: Chemical Characteristics of Soil in the Study Area for Tuna port, IFFCO, Khori Creek, Nakti Creek, DPA admin site, DPA colony.**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main	Sand from creek after tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	7.70	7.90	8.10	8.10	7.30	7.80
3	Electrical Conductivity	µs/cm	12400.0	2664.0	4,180.00	13,280.0	710.0	648.0
4	Phosphorus	mg/kg	10.1	9.69	12.52	20.50	8.79	7.68
5	Moisture	%	23.3	4.5	18.00	17.10	7.20	10.10
6	Total Organic	%	0.81	0.18	0.64	0.66	0.20	0.49
7	Alkalinity	mg/kg	400.0	600.0	400.0	200.0	300.0	400.0
8	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
9	Sulphate	mg/kg	958.00	326.00	1,420.00	448.00	52.0	50.0
10	Chloride	mg/kg	2313.0	604.0	1,347.00	1,932.00	354.00	531.00
11	Calcium	mg/kg	1,302.00	1,202.00	1,503.00	4,809.00	1,304.00	1,155.00
12	Sodium	mg/kg	1902	868.0	1,060.00	3,108.00	118.14	236.64
13	Potassium	mg/kg	582	478	375.00	510.00	16.54	20.06
14	Copper as Cu	mg/kg	11	278.2	5.00	5.90	50.30	56.00
15	Lead as Pb	mg/kg	3.5	5	2.80	2.70	BDL	BDL
16	Nickel as Ni	mg/kg	17.10	45.30	11.60	17.50	17.20	26.20
17	Zinc as Zn	mg/kg	16.9	111.20	12.50	14.10	14.20	30.70
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BDL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg)

### 6.3 Discussion

- DPA Kandla soil sampling data shows that value of pH ranges from 7.70 at Tuna port to 8.10 at Khori and Nakti Creek while the average value was 7.95. At Vadinar sampling location pH were 7.30 at DPA Admin site and 7.80 at DPA Colony. At all location of all soil samples were neutral to slight basic. Nakti Creek sample showed maximum
- The conductivity of DPA Kandla soil sample ranged from 2664.0  $\mu\text{S}/\text{cm}$  at IFFCO Plant (10 m away from main Gate) to 13280  $\mu\text{S}/\text{cm}$  at Nakti Creek (Sand from creek after tide) and mean was 8131  $\mu\text{S}/\text{cm}$  while Vadinar soil sampling location conductivity were 648.0  $\mu\text{S}/\text{cm}$  at DPA colony and 710  $\mu\text{S}/\text{cm}$  at DPA Admin site.
- Total organic Carbon of DPA Kandla soil sample ranged from 0.18 % at IFFCO Plant to 0.81 % at Tuna Port (Near Main Gate) and mean was 0.50 % while Vadinar soil sample were 0.2% at DPA admin and 0.49 % at DPA Colony.
- The concentration of Phosphorus in the soil samples of DPA Kandla varies from 9.69 mg/kg at IFFCO plant (10 meter away from main gate) and 20.50 mg/kg at Nakti Creek and mean was 13.20 mg/kg while the Vadinar soil sample for Phosphorus were 7.68 mg/kg at DPA Colony and 8.79 mg at DPA Admin Site.
- Chloride in soil sample of DPA ranged from 604 mg/kg at IFFCO Plant to 2313 mg/kg at Tuna Port (Near Main Gate) while Vadinar soil sample were 354 mg/kg at DPA admin and 531mg/kg at DPA Colony.
- The concentration of Potassium in the soil samples of DPA Kandla ranged from 375 mg/kg at Khori creek and 582 mg/kg at Tuna Port and mean was 486.25 mg/kg while the Vadinar soil sample for Potassium were 16.54 mg/kg at DPA Admin Site and 20.06 mg/kg at DPA Colony.
- The concentration of Sodium in the soil samples of DPA Kandla ranged from 868 mg/kg at IFFCO Plant and 3108 mg/kg at Nakti Creek and mean was 1734.50 mg/kg while the Vadinar soil sample for Sodium were 118.14 mg/kg at DPA Admin Site and 236.64 mg/kg at DPA Colony.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) were coastal soil; where as other locations are inland locations and have different chemical properties.

### Heavy Metals in the Soil

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port Authority Kandla and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### 6.4 Conclusion

The soils of Deendayal Port Authority Kandla and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

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## **CHAPTER-7**

### **SEWAGE TREATMENT PLANT MONITORING**

## 7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guidelines of State Pollution Control Board and other statutory bodies.

### 7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

**Table No. 21. Sewage Treatment Plant**

Sr. No.	Location of STP	Types of Treatment	STP Capacity	Treated water Utilization
1.	Gopalpuri Township	MBBR	450 KLD	Plantation and Gardening
2.	Deendayal Port, Kandla	MBBR	600 KLD	Discharge to marine through pipeline, Plantation, Gardening
3.	Vadinar Port Colony	MBBR	1.5 MLD	Plantation and Gardening

## 7.2 Results

**Table 22: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	01.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.36	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	121.8	50.4	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	90	40	100
5	BOD @ 27 °C	mg/l	26.0	12.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	16.0		
7	MLVSS	%	92.0		

**Table 23: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	06.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.45	7.24	6.5 - 8.5
2	Total Suspended Solids	mg/l	49.8	28.7	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	70	28.0	100
5	BOD @ 27 °C	mg/l	20.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	20.0		
7	MLVSS	%	91.0		

**Table 24: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	12.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.51	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	97.4	46.2	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	60	26	100
5	BOD @ 27 °C	mg/l	18.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	25.0		
7	MLVSS	%	86.0		

**Table 25: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	19.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.46	7.33	6.5 - 8.5
2	Total Suspended Solids	mg/l	98.2	46.3	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	110	26	100
5	BOD @ 27 °C	mg/l	30.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	13.0		
7	MLVSS	%	85.0		

**Table 26: Sewage Water Monitoring at Kandla STP (5<sup>th</sup> Week)**

<b>Date of Sampling</b>	26.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.51	7.25	6.5 - 8.5
2	Total Suspended Solids	mg/l	82.8	44.9	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	70	30	100
5	BOD @ 27 °C	mg/l	21.0	10.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	12.0		
7	MLVSS	%	88.0		

**Table 27: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	01.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.52	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	94.6	31.9	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	80	20	100
5	BOD @ 27 °C	mg/l	24.0	6.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	20.0		
7	MLVSS	%	90.0		

**Table 28: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	06.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP	
1	pH	-	7.48	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	109.6	34.4	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	92.0	30.0	100
5	BOD @ 27 °C	mg/l	26.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	23.0		
7	MLVSS	%	88.0		

**Table 29: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	12.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.48	7.23	6.5 - 8.5
2	Total Suspended Solids	mg/l	93	29	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	50	20	100
5	BOD @ 27 °C	mg/l	15.0	6.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	12.0		
7	MLVSS	%	87.0		

**Table 30: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

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<b>Date of Sampling</b>	19.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.54	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	84.2	39.1	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	112	31	100
5	BOD @ 27 °C	mg/l	33.0	10.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	5.0		
7	MLVSS	%	90.0		

**Table 31: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	01.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.56	7.33	6.5 - 8.5
2	Total Suspended Solids	mg/l	86.2	43.4	100
3	Residual Chlorine	mg/	-	<0.5	-
4	COD	mg/l	80.0	50	100
5	BOD @ 27 °C	mg/l	23.0	14.0	30

**Table 32: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

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<b>Date of Sampling</b>	06.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.38	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	77.3	57.5	100
3	Residual Chlorine	mg/l	-	-	-
4	COD	mg/l	90	60	100
5	BOD @ 27 °C	mg/l	26.7	18.2	30

**Table 33: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	12.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.53	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	95	49.8	100
3	Residual Chlorine	mg/l	-	-	-
4	COD	mg/l	61	20.2	100
5	BOD @ 27 °C	mg/l	16.0	6.0	30



**Table 34: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	19.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.48	7.25	6.5 - 8.5
2	Total Suspended Solids	mg/l	94.2	47.1	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	40	30	100
5	BOD @ 27 °C	mg/l	12.2	8.0	30

**Table 35: Sewage Water Monitoring at Vadinar STP (5<sup>th</sup> Week)**

<b>Date of Sampling</b>	26.09.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.41	7.23	6.5 - 8.5
2	Total Suspended Solids	mg/l	96.2	38.5	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	40	20	100
5	BOD @ 27 °C	mg/l	12.0	6.0	30

**Table No. 36. General Standards for discharge of Environmental Pollutant Part-A**

Sr. No.	Parameter	Inland Surface Water	Land Irrigation	Marine Coastal Areas
1.	pH	5.5-9.0	5.5-9.0	5.5-9.0
2.	Total Suspended Solids (mg/l)	100	200	100
3.	Residual Chlorine (mg/l)	1.0	-	1.0
4.	BOD (mg/l)	30	100	100
5.	COD (mg/l)	250	-	250

**Sources:-CPCB****7.3 Results & Discussion**

The STP Sample carried out to evaluate the efficiency and performance of the wastewater treatment plant at Gopalpuri, Kandla and Vadinar STP. The performance of these plants is an essential parameter to monitor because the treated sewage water is discharged for irrigation purposes and discharge into marine. Wastewater samples were collected from different unit operations of the plant i.e, the inlet, aeration tank and the final treated outlet. These samples were analyzed for various physico-chemical characteristics such as pH, TSS, Residual Chlorine, COD, BOD, MLSS and MLVS.

- The final treated outlet observed pH values were within the allowed range at Gopalpuri, DPA Kandla & Vadinar ranged from 7.23 -7.42, 7.21-7.33 & 7.21-7.33 respectively. The wastewater treatment makes it suitable for irrigation. These values are below the allowed limit of the CPCB.
- The final treated outlet observed Total suspended solid values at Gopalpuri, DPA Kandla & Vadinar ranged from 24.60 -39.10 mg/l, 28.70-50.40 mg/l & 38.50-57.50 mg/l respectively. These values are below the allowed limit of the CPCB.
- The final treated outlet observed Residual Chlorine values were <0.5 at Gopalpuri, DPA Kandla & Vadinar. These values are below the allowed limit of the CPCB.
- The final treated outlet observed COD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 20.0 -31.0 mg/l, 26.0-40.0 mg/l & 20.0-60.0 mg/l respectively. These values are below the allowed limit of the CPCB.

- The main focus of wastewater treatment plants is supposed to reduce the BOD in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The observed BOD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 6.0 -10.0 mg/l, 8.0-12.0 mg/l & 6.0-18.17 mg/l respectively. These values are below the allowed limit of the CPCB. .
- The final treated outlet observed BOD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 6.0 -10.0 mg/l, 8.0-12.0 mg/l & 6.0-18.17 mg/l respectively. These values are below the allowed limit of the CPCB for irrigation water and discharge in marine coastal area.

#### **7.4 Conclusions:**

All parameters for STP outlet are within limit prescribed by CPCB. After the final treatment, it is found that the treated water is satisfactory.

## **CHAPTER-8**

### **MARINE WATER MONITORING**

## **8.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of ‘green thinking’. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the “fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”.

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at “integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources.” The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 05<sup>th</sup> & 06<sup>th</sup> September-2022 in harbor regions of DPA & Vadinar during Neap tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 12<sup>th</sup> & 16<sup>th</sup> September-2022 in harbor regions of DPA & Vadinar during Spring tide period first quarter of Lunar Cycle.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbor area and two stations in Nakti creek and one station in Khorī creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation

of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

### Sampling Locations

Offshore monitoring requirement	Number of locations
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khori creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### 8.1 Marine Water Quality and Results

Marine water quality of marine waters of Deendayal Port Harbor waters, Khori & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 37 to 44. During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.

**Table 37: Marine Water Quality Monitoring Parameters for Location Near DPA Colony**

Sr. No.	Parameters	Unit	Kandla Creek Near DPA Colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.54	7.43	7.47	7.51
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	28.5	32.9	33.9	33
5	Turbidity	NTU	48	43	48	43
6	Total Dissolved Solids	mg/l	33482	28640	33482	28640
7	Total Suspended Solids	mg/l	499	692	499	692
8	Total Solids	mg/l	33981	29332	33981	29332
9	DO	mg/l	5.6	5.7	5.6	5.7
10	COD	mg/l	86	80	80	79
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	3.74	0.62	2.58	2.02
13	Phosphate	mg/l	0.04	0.63	0.12	0.14
14	Sulphate	mg/l	3465	3361	3199	2714
15	Nitrate	mg/l	4.69	1.47	2.61	2.82
16	Nitrite	mg/l	0.1	0.08	<0.05	<0.05
17	Calcium	mg/l	721.44	681.36	641.28	681.36
18	Magnesium	mg/l	1312	1555	1360	1215
19	Sodium	mg/l	7485	4308	10100	9770
20	Potassium	mg/l	330.2	346.2	340.1	326.4
21	Iron	mg/l	1.08	BQL	BQL	1.4
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	0.1	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 38: Marine Water Quality Monitoring Parameters for Location Near Passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.61	7.48	7.43	7.38
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	35.8	36.5	32.6	33.5
5	Turbidity	NTU	45	47	45	47
6	Total Dissolved Solids	mg/l	33040	28420	33040	28420
7	Total Suspended Solids	mg/l	378	360	378	360
8	Total Solids	mg/l	33418	28780	33418	28780
9	DO	mg/l	5.5	5.1	5.5	5.1
10	COD	mg/l	78	70	88	84
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.84	1.38	1.18	1.66
13	Phosphate	mg/l	0.06	0.08	0.35	0.17
14	Sulphate	mg/l	2841	3511	2783	2691
15	Nitrate	mg/l	0.8	0.33	9.8	2.75
16	Nitrite	mg/l	0.05	0.03	<0.05	<0.05
17	Calcium	mg/l	601.2	641.28	560	601.2
18	Magnesium	mg/l	1312	1263	1190	1142
19	Sodium	mg/l	6255	7648	8399	7582
20	Potassium	mg/l	309.8	32.7	360.9	319.4
21	Iron	mg/l	BQL	BQL	0.3	0.4
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Nitrite: 0.05mg/l Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).



**Table 39: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.35	7.28	7.41	7.32
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	30.4	33.9	34.4	34.9
5	Turbidity	NTU	46	40	46	40
6	Total Dissolved Solids	mg/l	27740	29210	27740	29210
7	Total Suspended	mg/l	393	484	393	484
8	Total Solids	mg/l	28133	29693	28133	29693
9	DO	mg/l	5.2	5.3	5.2	5.3
10	COD	mg/l	82	86	76	70
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.6	3.24	1.86	1.36
13	Phosphate	mg/l	0.07	0.13	0.33	0.64
14	Sulphate	mg/l	3234	2529	2529	1651
15	Nitrate	mg/l	0.8	3.48	6.04	3.82
16	Nitrite	mg/l	0.02	0.16	<0.05	<0.05
17	Calcium	mg/l	561.12	601.2	561.12	641.28
18	Magnesium	mg/l	1063	1020	1287	1080
19	Sodium	mg/l	4591	4658	8425	5768
20	Potassium	mg/l	32.2	23	364.3	188.1
21	Iron	mg/l	BQL	BQL	0.1	1.2
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 40: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	DPA 4			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.51	7.45	7.28	7.33
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	38.9	35.5	33.9	33.5
5	Turbidity	NTU	42	45	42	45
6	Total Dissolved Solids	mg/l	32820	35470	32820	35470
7	Total Suspended Solids	mg/l	415	452	415	452
8	Total Solids	mg/l	33235	35922	33235	35922
9	DO	mg/l	4.9	4.7	4.9	4.7
10	COD	mg/l	90	88	85	82
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.24	1.1	1.72	2.54
13	Phosphate	mg/l	0.07	0.05	0.46	0.47
14	Sulphate	mg/l	3280	2483	1940	2344
15	Nitrate	mg/l	1.74	2.14	2.81	4.23
16	Nitrite	mg/l	0.04	0.09	<0.05	<0.05
17	Calcium	mg/l	721.44	681.36	681.36	601.2
18	Magnesium	mg/l	1628	1166	1117	1142
19	Sodium	mg/l	5027	6067	6525	7295
20	Potassium	mg/l	31.1	30.4	262.7	318.4
21	Iron	mg/l	BQL	BQL	0.1	1.4
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	0
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	33.9	33.5

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 41: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.63	7.45	7.45	7.53
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	32.5	34.7	33	32.6
5	Turbidity	NTU	46	47	46	47
6	Total Dissolved Solids	mg/l	27050	32110	27050	32110
7	Total Suspended Solids	mg/l	380	430	380	430
8	Total Solids	mg/l	27430	32540	27430	32540
9	DO	mg/l	5	5.1	5	5.1
10	COD	mg/l	92	96	90	88
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.96	0.96	1.44	1.3
13	Phosphate	mg/l	0.08	0.06	0.42	0.12
14	Sulphate	mg/l	3176	2598	2494	2991
15	Nitrate	mg/l	4.16	1.07	2.28	2.21
16	Nitrite	mg/l	0.08	0.06	<0.05	<0.05
17	Calcium	mg/l	641.28	721.44	561.12	521.04
18	Magnesium	mg/l	1215	1312	990	1287
19	Sodium	mg/l	8423	6704	6981	8015
20	Potassium	mg/l	30.2	32	286.7	362
21	Iron	mg/l	BQL	BQL	BQL	0.1
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 42: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.61	Sampling not possible during Low Tide	7.61	Sampling not possible during Low Tide
2	Color	-	Agreeable		Agreeable	
3	Odor	-	Agreeable		Agreeable	
4	Salinity	‰	32.4		34.9	
5	Turbidity	NTU	48		48	
6	Total Dissolved Solids	mg/l	26130		26130	
7	Total Suspended Solids	mg/l	265		265	
8	Total Solids	mg/l	26395		26395	
9	DO	mg/l	5.4		5.4	
10	COD	mg/l	98		92	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	9.4		1.62	
13	Phosphate	mg/l	0.07		0.36	
14	Sulphate	mg/l	3303		3245	
15	Nitrate	mg/l	3.15		4.63	
16	Nitrite	mg/l	0.08		<0.05	
17	Calcium	mg/l	761.52		721.44	
18	Magnesium	mg/l	1312		1312	
19	Sodium	mg/l	5545		9075	
20	Potassium	mg/l	32.5		364.5	
21	Iron	mg/l	BQL		1.1	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		0	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1 mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 43: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.42	7.33	7.58	7.42
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	33	32.1	33	32.1
5	Turbidity	NTU	41	38	41	38
6	Total Dissolved Solids	mg/l	32030	37680	32030	37680
7	Total Suspended Solids	mg/l	395	319	395	319
8	Total Solids	mg/l	32425	37999	32425	37999
9	DO	mg/l	5.1	5.3	5.1	5.3
10	COD	mg/l	96	100	94	98
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.8	0.84	1.8	2
13	Phosphate	mg/l	0.7	2	0.74	0.82
14	Sulphate	mg/l	3017	1401	2256	2780
15	Nitrate	mg/l	1.4	2.02	3.86	4.89
16	Nitrite	mg/l	0.06	0.07	<0.05	<0.05
17	Calcium	mg/l	402	518	601.2	641.28
18	Magnesium	mg/l	1287	1578	1120	1380
19	Sodium	mg/l	7797	4468	6813	6965
20	Potassium	mg/l	326.9	328.4	326.9	328.4
21	Iron	mg/l	0.11	0.05	0.2	0.4
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	0.01	BQL	BQL	BQL
28	Zinc	mg/l	0.49	BQL	0.8	0.1

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 44: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr. Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.52	7.48	7.35	7.28
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	31.7	30.8	31.7	30.8
5	Turbidity	NTU	39	43	39	43
6	Total Dissolved Solids	mg/l	40100	36680	40100	36680
7	Total Suspended Solids	mg/l	490	510	490	510
8	Total Solids	mg/l	40590	37189	40590	37189
9	DO	mg/l	5.2	4.9	5.2	4.9
10	COD	mg/l	92	96	100	98
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.38	0.6	1.62	1.59
13	Phosphate	mg/l	0.23	0.76	0.92	0.9
14	Sulphate	mg/l	841.7	1908	2982	3012
15	Nitrate	mg/l	0.07	0.28	5.02	4.88
16	Nitrite	mg/l	0.03	0.03	<0.05	<0.05
17	Calcium	mg/l	490	430	681.36	561.12
18	Magnesium	mg/l	1297	1368	1192	1115
19	Sodium	mg/l	5883	4304	8589	5653
20	Potassium	mg/l	310.2	307.6	310.2	307.6
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.28	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l)

## **8.2 Results & Discussion for Marine water samples**

Marine water quality of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

### **pH**

During spring tide the pH values was ranged from 7.28-7.63 at DPA Kandla and 7.33-7.52 at Vadinar while during Neap Tide pH values was ranged from 7.28-7.61 at DPA Kandla and 7.28-7.58 at Vadinar.

### **Color and Odor**

All marine samples for Odor and Color were found agreeable at all sampling locations.

### **Turbidity**

During spring tide the Turbidity values was ranged from 40-48 NTU at DPA Kandla and 38-43 NTU at Vadinar while during Neap Tide Turbidity values was ranged from 40-48 NTU at DPA Kandla and 38-43 NTU at Vadinar. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity (Yap et al, 2011). Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler, 2004).

### **Total Dissolved Solids (TDS)**

TDS values in the studied area during Spring Tide varied between 26130- 35470 mg/l at DPA Kandla and 3203- 40100 mg/l at Vadinar while during Neap Tide TDS values was varied 26130-35470 mg/l at DPA Kandla and 32030-40100 mg/l at Near Vadinar.

### **Calcium**

Calcium value in the studied area during Spring Tide varied between 561.12-761.52 mg/l at DPA Kandla and 402.0-518.0 mg/l at Vadinar while during Neap Tide calcium values between 521.0-721.44 mg/l at DPA Kandla and 561.12-681.36 at Vadinar.

### **Magnesium**

Magnesium value in the studied area during Spring Tide varied between 1020-1628 mg/l at DPA Kandla and 1385.1 to 1530.9 mg/l at Vadinar while during Neap Tide magnesium

values between 1042-1360 mg/l at DPA Kandla and 1115 -1380 at Vadinar. Calcium and magnesium both play an important role in antagonizing the toxic effects of various ions and neutralizing the excess acid produced (Narayan R. et. al., 2007)

### **Nitrate**

Nitrate value in the studied area during Spring Tide varied between 0.33-4.69 mg/l at DPA Kandla and 0.07-2.02 mg/l at Vadinar while during Neap Tide Nitrate values between 2.21-9.80 mg/l at DPA Kandla and 3.86-5.02 at Vadinar.

The variations were observed due to variation in phytoplankton excretion, oxidation of ammonia, reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007).

### **Iron**

Iron values in the studied area during Spring Tide was found below quantification limit (BQL) at DPA Kandla only at value observed 1.08 mg/l KPT-1 (DPA Kandla) and at Vadinar value ranged from 0.05-0.11 mg/l while during Neap Tide the iron values was varied 0.01-1.4 mg/l at DPA Kandla and 0.2 to 0.4 mg/l at Vadinar.

### **Sulphates**

Sulphate values in the studied area during Spring Tide ranged from 2483.0-3511.0 mg/l at DPA Kandla and 841.7- 3017.0 mg/l at Vadinar while during Neap Tide the Sulphate values was varied 1651.0 to 3245.0 mg/l at DPA Kandla and 2256.0 to 3012.0 mg/l at Vadinar.

### **Salinity**

Salinity values in the studied area during Spring Tide varied ranged 28.5 to 38.9 ‰ at DPA Kandla and 30.80 to 33.00 ‰ at Vadinar while during Neap Tide the Salinity values was varied 32.6 to 34.9 ‰ at DPA Kandla and 30.8 to 33.0 ‰ at Vadinar.

### **Sodium and Potassium Salts**

During Spring Tide the Sodium values ranged from 4308.0-8423.0 mg/l at DPA Kandla & 4308.0-7797.0 mg/l at Vadinar and Potassium salts ranged from 23.0-346.0 mg/l at DPA Kandla & 307.60-328.40 mg/l at Vadinar while during Neap Tide the sodium values was ranges from 5768.0-10100.0 mg/l at DPA Kandla & 5653.0-8589 mg/l at Vadinar and Potassium salts ranged from 188.1-364.5 mg/l at DPA Kandla & 307.6-328.4 mg/l at Vadinar.



## **DO**

The DO refers to the amount of oxygen dissolved in the water and it is particularly important in limnology (aquatic ecology) (Weiss 1970). The fate and behavior of DO is of critical importance to marine organisms in determining the severity of adverse impacts (Best et al. 2007). The major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best et al. 2007). From the studied samples, DO in marine water during Spring Tide was found in ranges from 4.7-5.7 mg/l at DPA Kandla and 4.90-5.30 mg/l at Vadinar while during Neap Tide 4.7-5.7 mg/l at DPA Kandla and 4.9-5.3 mg/l at Vadinar.

## **BOD**

BOD in marine water at all sampling location in the studied samples were found <2.0 mg/l.

## **Heavy Metals in Marine Water**

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

## **9.3 Conclusion**

In the present study period marine water samples were analyzed and found inline as per Primary Water Quality criteria for class-IV WATERS (For Harbour Waters).

## **CHAPTER-9**

### **MARINE SEDIMENT MONITORING**

## 9.0 Marine Sediments

The deep-sea ocean floor is made up of sediment. This sediment is composed of tiny particles such as fine sand, silt, clay, or animal skeletons that have settled on the ocean bottom. Over long periods of time, some of these particles become compressed and form stratified layers. Scientists that study these layers look at particle size, particle composition, and origin to help them create historical records of the deep ocean floor. This process is called weathering. Weathering can be either mechanical or chemical. Mechanical weathering can occur as ice, wind, or water wears away the rock's surface. Chemical weathering can occur as rocks are dissolved by a chemical such as acid rain. The particles created as a result of weathering are called terrigenous sediments. These particles are transported to the ocean by wind and by rivers and streams. Once the particles enter the ocean, they are dispersed by waves, currents, and tides. The heaviest and largest particles that reach the oceans, such as sand, settle very quickly to the bottom as a result of gravity. Sand is deposited near the coast whereas the smaller silt and clay particles are transported farther distances offshore before they settle to the bottom. Sediments are an important component of aquatic ecosystems because they provide nutrients and habitat for aquatic organisms (Benhamed et al. 2016). However, human activities result in accumulation of toxic substances such as heavy metals in marine sediments. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulation. Metals affect the ecosystem because they are not removed from water by self-purification, but accumulate in sediments and enter the food chain (Astakhov et al. 2015).

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Benthic surface grab samplers look like giant metal jaws. They dig into the bottom and take a bite of the sediment. These samplers are good for collecting softer, sandy or silty sediments that do not contain rocks. A box corer is a cross between a surface sampler and a sediment corer. It is a special device that is used to collect an undisturbed sample of the very top surface layers and the sediment underneath. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

## 10.1 Results

The Sediment Quality results are given in below from table no. 45 & 46.

**Table 45: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.52	0.88	0.96	0.78	0.92	0.45	1.24
3	Organic Carbon	mg/kg	0.30	0.51	0.56	0.45	0.53	0.26	0.72
4	Inorganic Phosphate	mg/kg	98.00	86.00	106.00	88.00	110.00	92.00	110.00
5	Moisture	%	12.50	16.20	15.60	11.62	14.60	18.40	17.30
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	6.90	7.60	8.90	7.00	9.80	10.50	11.60
8	Phosphate	mg/kg	880.00	820.00	682.00	900.00	670.00	505.00	656.00
9	Sulphate	mg/kg	740.00	823.00	562.00	463.00	456.00	823.00	464.00
10	Nitrite	mg/kg	0.12	0.10	0.11	0.12	0.10	0.11	0.12
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	1242.00	1202.00	1202.00	1162.32	1383.00	1422.84	1382.00
13	Magnesium	mg/kg	1677.00	1458.00	1215.00	1725.00	1349.00	1640.00	1409.40
14	Sodium	mg/kg	690.00	702.00	568.00	660.00	720.00	731.00	733.00
15	Potassium	mg/kg	210.00	189.00	166.00	198.00	146.00	388.00	367.00
16	Chromium	mg/kg	BQL	32.60	26.10	36.90	15.90	28.80	34.20
17	Nickel	mg/kg	BQL	16.20	12.90	18.10	7.50	13.20	16.60
18	Copper	mg/kg	BQL	7.20	5.80	10.00	BQL	139.00	22.80
19	Zinc	mg/kg	BQL	18.60	7.70	29.40	5.30	35.10	45.60
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	0.10	0.70
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	4.60	4.00
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

**Table 46 : Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.46	0.93	1.02	0.99	1.10	0.95	0.71
3	Organic Carbon	mg/kg	0.26	0.53	0.59	0.57	0.64	0.55	0.41
4	Inorganic Phosphate	mg/kg	110.00	100.00	82.00	88.00	116.00	78.00	100.00
5	Moisture	%	22.80	12.40	16.00	18.80	20.24	2.50	17.00
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	6.60	8.10	8.62	6.52	8.90	10.20	18.00
8	Phosphate	mg/kg	930.00	868.00	820.00	989.00	720.00	474.00	7.47
9	Sulphate	mg/kg	740.00	823.00	590.00	463.00	496.00	842.00	480.00
10	Nitrite	mg/kg	0.12	0.10	0.11	0.12	0.11	0.11	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	11.02
12	Calcium	mg/kg	1623.00	1663.00	1560.00	1503.00	1420.00	1222.44	1863.00
13	Magnesium	mg/kg	1822.00	1445.00	1880.00	1834.00	890.00	2041.20	935.00
14	Sodium	mg/kg	539.00	708.00	710.00	685.00	620.00	736.00	1353.00
15	Potassium	mg/kg	239.00	342.00	280.00	316.00	240.00	358.00	335.00
16	Chromium	mg/kg	57.30	65.00	22.00	60.20	36.20	35.20	18.20
17	Nickel	mg/kg	27.20	30.30	10.60	21.10	14.50	16.00	8.00
18	Copper	mg/kg	14.30	19.20	BQL	12.40	5.90	10.10	6.90
19	Zinc	mg/kg	47.60	60.80	7.20	35.00	16.50	27.20	BQL
20	Cadmium	mg/kg	0.20	0.80	BQL	0.50	BQL	BQL	BQL
21	Lead	mg/kg	4.70	5.10	BQL	4.90	BQL	3.80	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0 mg/kg, Cd: 1.0 mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg)

## **9.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

## **9.3 Conclusion**

The sediment types are majority Sandy loamy. Also all heavy metals found below Quantification limit wise Al, Pb, Cd, Hg , As and Nitrate for some locations.

## CHAPTER-11

### MARINE ECOLOGICAL MONITORING

## 10.0 INTRODUCTION:

### 10.1 Sampling Stations:

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 16<sup>th</sup> September 2022 in harbour region of DPA at Kandla Creek, and on 17<sup>th</sup> September 2022 in creeks near by the port during Neap tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 26<sup>th</sup> September, 2022 in harbour region of DPA at Kandla Creek and on 27<sup>th</sup> September, 2022 in creeks near by the port during spring tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during Neap tide on 06/09/2022 and Spring tide period on 10/09/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative and quantitative evaluation of phytoplankton, qualitative and quantitative evaluation of zooplankton density and their population.

**TABLE:47 SAMPLING LOCATIONS**

monitoring requirement	Number of locations
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near I <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

#### Sampling methodology adopted:

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample was taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with Nylon bolt cloth of 20µm mesh size. At Nakti Creek Near NH-8A Sampling was not possible during Low Tide.



### **Samples Processing for chlorophyll estimation:**

Samples for chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grinded in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 2017).

### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is a general term for organisms which have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplanktons are free floating organisms that are capable of photosynthesis and zooplanktons are the various free-floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, *plankton* and *nekton* (Lalli and Parsons, 1997). *Plankton* consists of all organisms drifting in the water and is unable to swim against water currents, whereas *Nekton* includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

### **Phytoplankton in the marine environment:**

Phytoplanktons are free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro

flora acts as primary producers as well as the basis of food chain, source of protein, bio-purifier and bio-indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (Bacillariophyceae) and Dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; Diatoms and Dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (Blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

#### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of 'biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into

dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorization of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorized into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

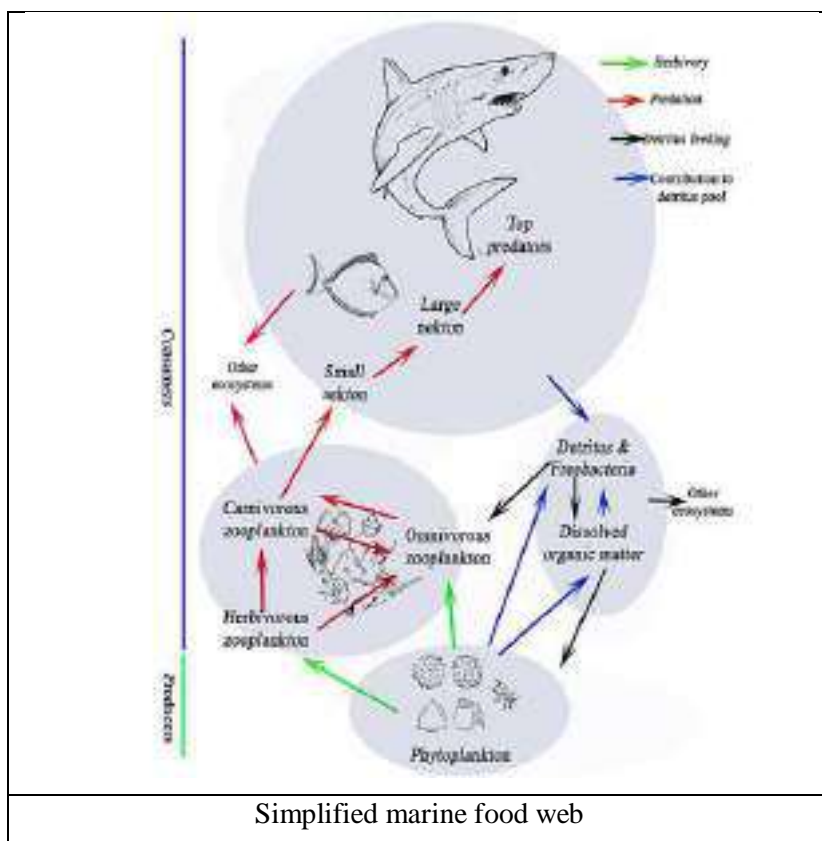
Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely diverse, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominates than others; members of sub class copepods (Phylum Arthropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991 ;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplanktons are efficient grazers of the phytoplankton and are referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they are used as the

indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilometres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton in the month of SEPTEMBER also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

## **10.2 Methodology adopted for Plankton sampling:**

### **Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

### **Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

### **Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of phytoplankton and zooplankton that were encountered

### ***Cell counts by drop count method:***

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22 mm x 60 mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total amount of phytoplankton in the original volume of sample filtered was calculated as units/L and Zooplankton as  $N/m^3$

## **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment–water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42μ in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes

#### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

#### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

#### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

#### **DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A. E. (1988)

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H.R. *etal.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are



a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate specie richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness ( $S$ ) and evenness ( $J$ )

### **Simpson's diversity index**

Simpson's index ( $D$ ) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

The formula for calculating  $D$  is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where  $n_i$  = the total number of organisms of each individual species

$N$  = the total number of organisms of all species

The value of  $D$  ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When  $D$  increases diversity decreases. Simpson's index is therefore usually expressed as  $1-D$  or  $1/D$ . (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment
- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

### **Species richness indices**

The species richness( $S$ ) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic

disturbance. A decline in species richness in may be concomitant with severe or chronic human-induced perturbation .Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness ( $S$ ) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index ( $d$ ), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximized when all types are equally abundant [Rosenzweig, M. L. (1995)]

#### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index ( $H$ ), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index ( $H$ ) reproduces community parameters to a single number by using an equation.

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

$$H' = - \sum_{j=1}^s \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$



### **10.3 RESULTS:**

#### **CHLOROPHYLL-a:**

In the sub surface water chlorophyll-a was varying from 0.323 -0.667 mg/m<sup>3</sup> with an average value 0.508 mg/m<sup>3</sup> in harbour region of DPA in Kandla Creek during sampling done in spring tide period of September 2022. In the nearby creeks chlorophyll-a was varying from 0.237 - 0.764 mg/m<sup>3</sup>. with an average value 0.567 mg/m<sup>3</sup> Pheophytin –a level was below detectable limit- the all the sampling stations during spring tide.

In the sub surface water chlorophyll-a was varying from 0.347- 0.631 mg/m<sup>3</sup> with an average value 0.541mg/m<sup>3</sup>.in harbour region of DPA in Kandla Creek during sampling done in Neap tide period of September 2022. In the nearby creeks chlorophyll-a was varying from 0.496- 0.613 mg/m<sup>3</sup> with an average value 0.545 mg/m<sup>3</sup>.Pheophytin –a level was below detectable limit- at the all the sampling stations.

In the sub surface water chlorophyll-a was varying from 0.448 - 0.630 mg/m<sup>3</sup> in harbour region of DPA OOT in path finder Creek during sampling done in spring tide period of September 2022. In the sub surface water chlorophyll-a was varying from 0.460 - 0.732 mg/m<sup>3</sup> in harbour region of DPA OOT in path finder Creek during sampling done in Neap Tide period of September 2022

**TABLE 48 VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING SPRING TIDE IN SEPTEMBER 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.564	BDL	37.79
		Low tide	0.323	BDL	21.67
2	KPT 2	High tide	0.647	BDL	43.35
		Low tide	0.441	BDL	29.55
3	KPT 3	High tide	0.667	BDL	44.69
		Low tide	0.409	BDL	27.40
CREEKS					
4	KPT-4 Khor-I	High tide	0.748	BDL	50.22
		Low tide	0.440	BDL	29.48
5	KPT-5 Nakti-I	High tide	0.764	BDL	51.19
		Low tide	0.645	BDL	43.22
6	KPT-6 Nakti-II	High tide	-	--	--
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.452	BDL	30.28
8		Low tide	0.630	BDL	42.21
9	SPM	High tide	0.448	BDL	30.02
10	SPM	Low tide	0.530	BDL	35.51

BDL: Below Detectable Limit.

**TABLE 49 VARIATIONS IN CHLOROPHYLL -a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA, NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN SEPTEMBER 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.631	BDL	42.28
		Low tide	0.516	BDL	34.57
2	KPT 2	High tide	0.617	BDL	41.34
		Low tide	0.347	BDL	23.25
3	KPT 3	High tide	0.630	BDL	42.21
		Low tide	0.510	BDL	34.17
CREEKS					
4	KPT-4 Khor-I	High tide	0.548	BDL	36.72
		Low tide	0.526	BDL	35.24
5	KPT-5 Nakti-I	High tide	0.613	BDL	41.07
		Low tide	0.496	BDL	33.23
6	KPT-6 Nakti-II	High tide	-	-	-
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.542	BDL	36.31
8		Low tide	0.460	BDL	30.82
9	SPM	High tide	0.662	BDL	44.35
10	SPM	Low tide	0.732	BDL	49.04

BDL: Below Detectable Limit.

### **PHYTOPLANKTON POPULATION:**

For the evaluation of the Phytoplankton population in DPA harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms, Blue Green Algae algae and Dinoflagellates during spring tide period. Diatoms were represented by 25 genera, Blue Green Algae algae were represented by 3 genera and Dinoflagellates were represented by 3 genera during the sampling conducted in spring tide in September, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 46-312 units/ L during high tide period and 164-213 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue Green Algae algae and Dinoflagellates during Neap tide period. Diatoms were represented by 27 genera, Blue Green Algae algae were represented 4 genera and Dinoflagellates with 3 genera during the sampling conducted in Neap tide in September, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 47-225 units/ L during high tide period and 132-196 units/ L during low tide of Neap Tide.

For the evaluation of the Phytoplankton population in DPA OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; jetty area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue Green Algae algae and Dinoflagellates during spring tide period. Diatoms were represented by 19 genera, Blue Green Algae algae by 2 genera and Dinoflagellates by 5 genera during the sampling conducted in spring tide in September, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area was 95 units/ L during high tide period and 114 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the *SPM area* was varying from 92 units/ L during high tide period and 156 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue Green Algae and Dinoflagellates during Neap tide period. Diatoms were represented by 19 genera and Blue Green Algae algae by 3 genera and Dinoflagellates by 5 genera during the sampling conducted in Neap tide in September, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 105 units/ L during high tide period and 90 units/ L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 87 units/ L during high tide period and 68 units/ L during low tide of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 2.873- 3.94 with an average of 3.302 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.873- 3.233 with an average of 3.084 during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 3.117- 4.431 with an average of 3.852 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 3.072- 4.463 with an average of 3.817 during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 4.392 at OOT jetty area and 3.981 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the path finder creek near OOT jetty was 4.012 and 3.762 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 4.942 at OOT jetty area and 4.702 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the path finder creek near OOT jetty was 4.889 and SPM area was 4.029 during the consecutive low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.868- 0.965 between selected sampling stations with an average value of 0.922 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.850-0.951 between selected sampling stations with an average value of 0.899 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.863– 1.011 between selected sampling stations with an average value of 0.945 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index of phytoplankton communities in the sampling stations was in the range of 0.886- 0.985 between selected sampling stations with an average value of 0.933 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.132 at OOT jetty area and 1.071 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.064 and 0.889 at SPM during the consecutive low tide period of spring tide.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.121 at OOT jetty area and 1.143 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.163 and at SPM area was 1.008 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.779- 0.867 between selected sampling stations with an average of 0.827 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.799- 0.852 between selected sampling stations with an average of 0.820 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during Neap tide also, which was varying from 0.754- 0.881 with an average value of 0.830 between selected sampling stations during high tide period and 0.799- 0.853 varying from with an average value of 0.828 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.908 at OOT jetty area and 0.894 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.878 and 0.802 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.886 at OOT jetty area and 0.901 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.911 and at SPM area was 0.871 during the consecutive low tide period.

Low species diversity suggests a relatively few successful species in this habitat. The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment. Any change in the environment would probably have quite serious effects.

**Table 50 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% Of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	266	23/31	74.19	3.94	0.9655	0.8335
	2	271	18/31	58.06	3.035	0.9079	0.8265
	3	312	19/31	61.29	3.134	0.8683	0.7787
	4	247	19/31	61.29	3.267	0.913	0.8179
	5	273	21/31	67.74	3.565	0.946	0.8389
	6	46	12/31	38.71	2.873	0.9315	0.8667
LOW TIDE	1	185	16/31	51.61	2.873	0.8496	0.7989
	2	205	18/31	58.06	3.194	0.8789	0.8064
	3	192	18/31	58.06	3.233	0.924	0.8256
	4	164	17/31	54.84	3.137	0.9512	0.8519
	5	213	17/31	54.84	2.984	0.8931	0.8181

**Table 51 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING NEAP TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	225	25/34	73.53	4.431	1.002	0.8524
	2	201	23/34	67.65	4.148	1.011	0.8571
	3	180	19/34	55.88	3.466	0.8852	0.8044
	4	216	23/34	67.65	4.093	0.8626	0.754
	5	179	21/34	61.76	3.856	0.9338	0.8298
	6	47	13/34	38.24	3.117	0.9729	0.8807
LOW TIDE	1	196	23/34	67.65	4.168	0.9087	0.7995
	2	132	16/34	47.06	3.072	0.9348	0.8489
	3	165	20/34	58.82	3.721	0.8862	0.8
	4	173	24/34	70.59	4.463	0.985	0.8382
	5	179	20/34	58.82	3.663	0.9498	0.8535

**Table 52 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN SEPTEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	34-307	25/31	80.64
			BLUE GREEN ALGAE ALGAE	3-12	3/31	9.68
			DINOFLAGELLATES	0-3	3/31	9.68
			TOTAL PHYTO PLANKTON	<b>46-312</b>	<b>31</b>	
LOW TIDE	Sub surface	5	DIATOMS	162-209	25/31	80.64
			BLUE GREEN ALGAE ALGAE	1-5	3/31	9.68
			DINOFLAGELLATES	1-3	3/31	9.68
			TOTAL PHYTO PLANKTON	<b>164-213</b>	<b>31</b>	



**TABLE 53 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN SEPTEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	44-210	27/34	79.42
			BLUE GREEN ALGAE ALGAE	3-11	4/34	11.76
			DINOFLAGELLATES	0-4	3/34	8.82
			TOTAL PHYTO PLANKTON	<b>47-225</b>	<b>34</b>	
LOW TIDE	Sub surface	5	DIATOMS	120-185	27/34	79.42
			BLUE GREEN ALGAE ALGAE	5-22	4/34	11.76
			DINOFLAGELLATES	1-6	3/34	8.82
			TOTAL PHYTO PLANKTON	<b>132-196</b>	<b>34</b>	

**TABLE # 8 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	95	21/26	80.77	4.392	1.132	0.908
	SPM	92	19/26	73.08	3.981	1.071	0.894
LOW TIDE	Jetty	114	20/26	76.92	4.012	1.064	0.878
	SPM	156	20/26	76.92	3.762	0.889	0.802

**TABLE 54 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	105	24/27	88.89	4.942	1.121	0.886
	SPM	87	22/27	81.48	4.702	1.143	0.901
LOW TIDE	Jetty	90	23/27	85.19	4.889	1.163	0.911
	SPM	68	18/27	66.67	4.029	1.008	0.871

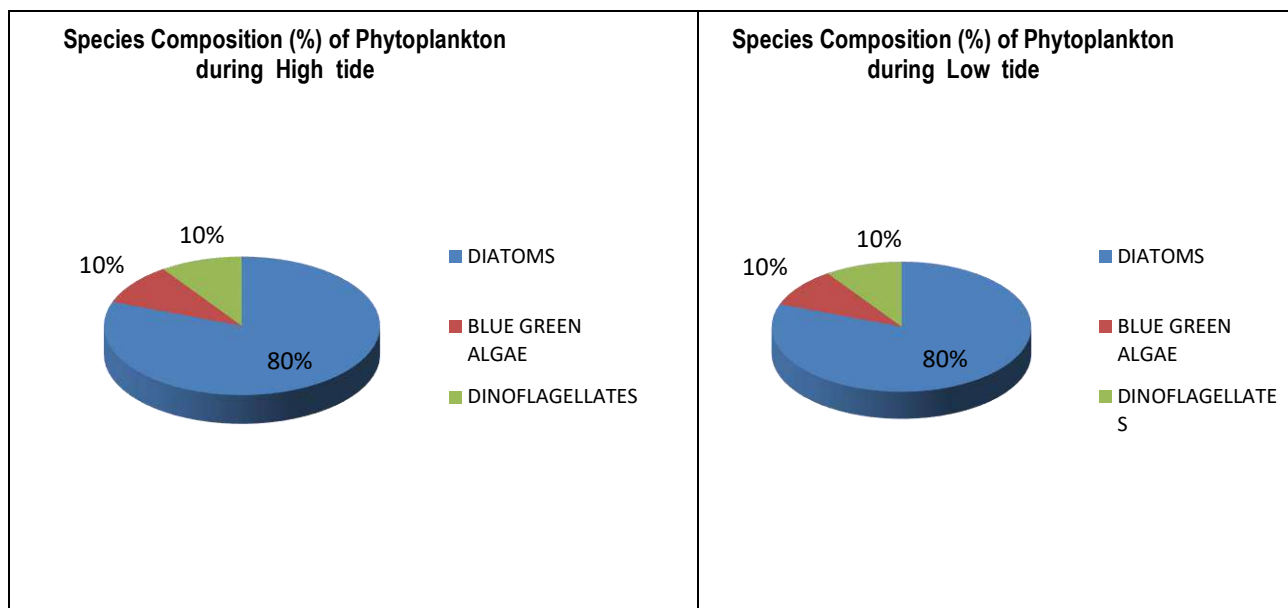
**TABLE 55 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPAOOT AT PATH FINDER CREEK, VADINAR & NEAR BY SPM, DURING SPRING TIDE IN SEPTEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	DIATOMS	79-80	19/26	73.08
			BLUE GREEN ALGAE ALGAE	2-6	2/26	7.69
			DINOFLAGELLATES	9-11	5/26	19.23
			TOTAL PHYTO PLANKTON	<b>92-95</b>	<b>26</b>	
LOW TIDE	Sub surface	2	DIATOMS	102-147	19/26	73.08
			BLUE GREEN ALGAE ALGAE	2-5	2/26	7.69
			DINOFLAGELLATES	7	5/26	19.23
			TOTAL PHYTO PLANKTON	<b>114-156</b>	<b>26</b>	

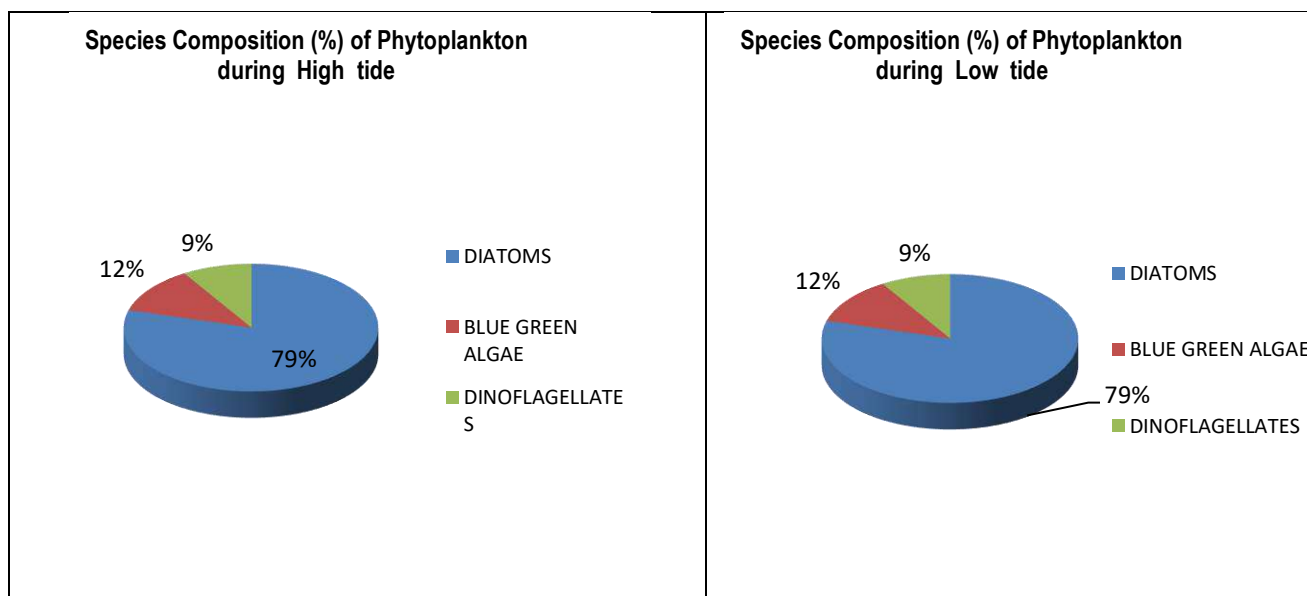
**Table 56 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPAOOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN SEPTEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	DIATOMS	70-93	19/27	70.37
			BLUE GREEN ALGAE ALGAE	6-8	3/27	11.11
			DINOFLAGELLATES	6-9	5/27	18.52
			TOTAL PHYTO PLANKTON	<b>87-105</b>	<b>27</b>	
LOW TIDE	Sub surface	2	DIATOMS	59-74	19/27	70.37
			BLUE GREEN ALGAE ALGAE	4-12	3/27	11.11
			DINOFLAGELLATES	4-5	5/27	18.52
			TOTAL PHYTO PLANKTON	<b>68-90</b>	<b>27</b>	

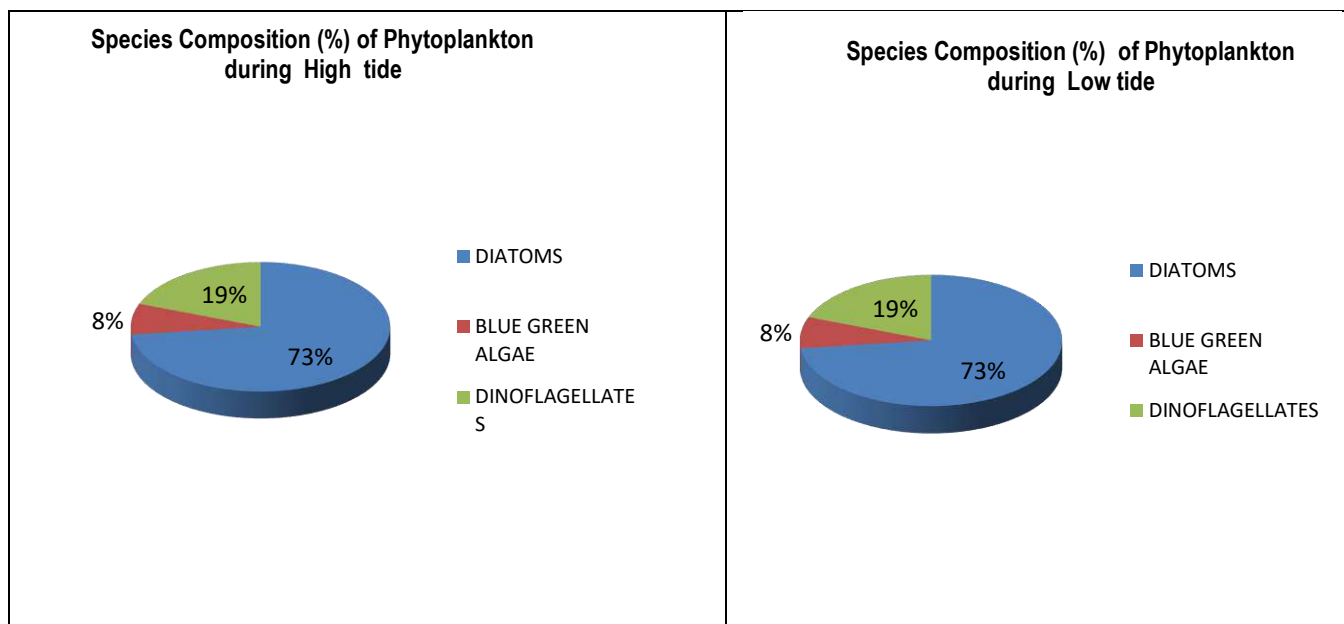
**Species Composition (%) of Phytoplankton during High tide and Low tide period during spring tide in Kandala creek and nearby creeks**



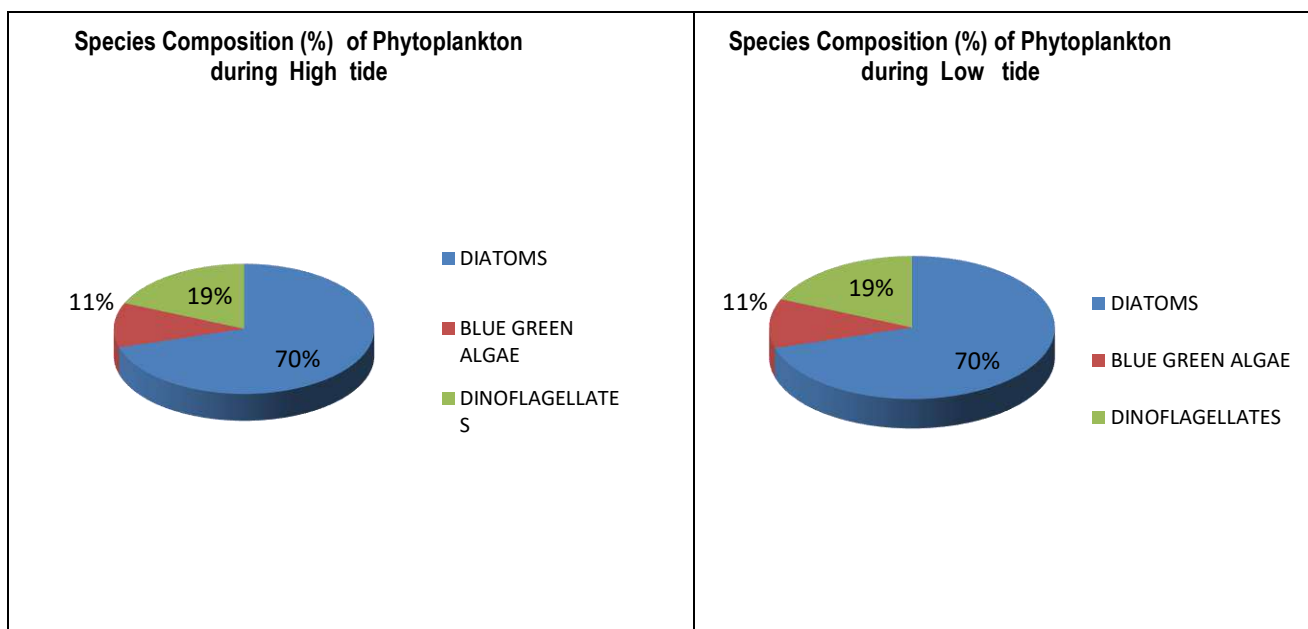
**Species Composition (%) of Phytoplankton during High tide and Low tide period during Neap tide in Kandala creek and nearby creeks**



**Species Composition (%) of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



**Species Composition (%) of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar**



### **ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPA harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khorī creek) during high tide period and low tide period of spring tide and Neap tide in September, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly seven groups; Tintinids, Copepods, Rotifers, Arrow worms, Urochordata, Ciliates, Nematodes and 6 larval forms. The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly eight groups; Tintinids, Copepods, Rotifers, Mysids, Urochordata, Arrow worms, Ciliates, Nematode and 7 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $34-85 \times 10^3 \text{ N/ m}^3$  during high tide and  $35-54 \times 10^3 \text{ N/ m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $43-145 \times 10^3 \text{ N/ m}^3$  during high tide and  $95-118 \times 10^3 \text{ N/ m}^3$  during low tide of Neap Tide period.

For the evaluation of the Zooplankton population in DPA OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM).

During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly five groups Tintinids, Copepods, Arrow worms, Urochordata, Mysids and 5 larval forms.

The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly Seven groups, Tintinids, Copepods, Arrow worms, Mysids, Urochordata, Medusa, Nematode and 8 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT Jetty area of path finder creek was  $102 \times 10^3 \text{ N/ m}^3$  during high tide and  $106 \times 10^3 \text{ N/ m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA SPM area of path finder creek was  $60 \times 10^3 \text{ N/ m}^3$  during high tide and  $124 \times 10^3 \text{ N/ m}^3$  during low tide of spring Tide period.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT jetty area in path finder creek was recorded  $150 \times 10^3 \text{ N/ m}^3$  during high tide and  $147 \times 10^3 \text{ N/ m}^3$  during consecutive low tide period of Neap tide. Zooplankton of the sampling stations at sub surface layer in the DPA SPM area

in path finder creek was recorded  $108 \times 10^3$  N/  $m^3$  during high tide and  $117 \times 10^3$  N/  $m^3$  during consecutive low tide period of Neap Tide.

#### **Species Richness Indices and Diversity Indices:**

##### **Margalef's diversity index (Species Richness)**

Margalef's diversity index (Species Richness) of Zooplankton communities in the stations Kandla creek region and nearby creeks were varying from 1.701- 3.95 with an average of 2.924 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) of Zooplankton communities varying from 1.688- 3.834 with an average of 2.582 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations were varying from 2.393- 4.996 with an average of 3.85 during the sampling conducted in high tide and varying from 3.272 - 4.942 with an average of 3.903 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 4.324 and 4.503 respectively. Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.419 and 3.527 respectively.

Margalef's diversity index (Species Richness) of Zooplankton communities near Jetty at Path finder creek were varying from 5.189 and 3.607 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity indexes (Species Richness) of Zooplankton communities near SPM at Path finder creek were varying from 4.272- 3.15 respectively during the consecutive High tide and low tide period.

##### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.624-1.049 between selected sampling stations with an average value of 0.884 during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.584- 0.977 between selected sampling stations with an average value of 0.762 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.893-1.103 between selected sampling stations with an average value of 0.99' during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was

in the range 0.939- 1.138 of between selected sampling stations with an average value of 1.020 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.073-1.05 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.897-0.863 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 1.023-0.996 respectively during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 1.064-0.898 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.709-0.885 between selected sampling stations with an average of 0.835 during high tide period and was varying from 0.672 - 0.859 with an average value of 0.761 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of Neap tide except few, which was varying from 0.781- 0.898 between selected sampling stations with an average of 0.849 during high tide period and was varying from 0.840--0.901 with an average value of 0.867 between selected sampling stations during consecutive low tide .This species diversity suggests a relatively few successful species in this habitat during September ,2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.876 and 0.868 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.818 and 0.789 respectively.

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Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.851- 0.867 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.889 and 0.843 respectively.



**TABLE 57 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB  
SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND  
NEAR BY CREEKS DURING SPRING TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	74	18/27	66.67	3.95	1.049	0.8852
	2	59	13/27	48.15	2.943	0.8943	0.8533
	3	85	17/27	62.96	3.601	0.9974	0.8731
	4	61	14/27	51.85	3.162	0.9681	0.8765
	5	39	9/27	33.33	2.184	0.7723	0.8097
	6	34	7/27	25.93	1.701	0.6237	0.7094
LOW TIDE	1	50	12/27	44.44	2.812	0.7838	0.7657
	2	50	16/27	59.26	3.834	0.9769	0.8588
	3	35	7/27	25.93	1.688	0.5843	0.6723
	4	54	11/27	40.74	2.507	0.7574	0.7428
	5	48	9/27	33.33	2.067	0.7083	0.7668

**TABLE 58 ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB  
SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND  
NEAR BY CREEKS DURING NEAP TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In $No \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	122	25/32	78.13	4.996	1.079	0.8675
	2	132	18/32	56.25	3.482	0.9421	0.8241
	3	145	21/32	65.63	4.019	1.033	0.8575
	4	145	20/32	62.50	3.818	0.8926	0.781
	5	95	21/32	65.63	4.392	1.103	0.8983
	6	43	10/32	31.25	2.393	0.8945	0.8682
LOW TIDE	1	105	24/32	75.00	4.942	1.138	0.9013
	2	95	16/32	50.00	3.294	0.9387	0.8396
	3	98	16/32	50.00	3.272	0.9756	0.8586
	4	118	22/32	68.75	4.402	1.067	0.8812
	5	112	18/32	56.25	3.603	0.9797	0.8554

**Table 59 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN SEPTEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	1-8	5/27	18.53
			Copepods	3-39	11/27	40.75
			Rotifers	0-16	1/27	3.70
			Arrow worms	0-2	1/27	3.70
			Urochordata	0-2	1/27	3.70
			Ciliates	0-2	1/27	3.70
			Larval forms	10-35	6/27	22.22
			Nematode	0-1	1/27	3.70
			TOTAL ZOOPLANKTON N/ M <sup>3</sup>	<b>34-85</b>	<b>27</b>	
LOW TIDE	Sub surface	5	Tintinids	0-5	5/27	18.53
			Copepods	11-28	11/27	40.75
			Rotifers	0	1/27	3.70
			Arrow worms	0-2	1/27	3.70
			Urochordata	0-1	1/27	3.70
			Ciliates	0-1	1/27	3.70
			Larval forms	14-32	6/27	22.22
			Nematode	0-1	1/27	3.70
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>35-54</b>	<b>27</b>	

**TABLE 60 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN SEPTEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	0-11	7/32	21.86
			Copepods	14-55	12/32	37.50
			Rotifers	0-10	1/32	3.13
			Arrow worms	0-2	1/32	3.13
			Mysids	0-2	1/32	3.13
			Urochordata	0-2	1/32	3.13
			Ciliates	1-4	1/32	3.13
			Larval forms	17-90	7/32	21.86
			Nematode	0-1	1/32	3.13
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>43-145</b>	<b>32</b>	
			Tintinids	7-12	7/32	21.86

LOW TIDE	Sub surface	5	Copepods	26-50	12/32	37.50
			Rotifers	0	1/32	3.13
			Arrow worms	0-2	1/32	3.13
			Mysids	0-2	1/32	3.13
			Urochordata	0-2	1/32	3.13
			Ciliates	1-5	1/32	3.13
			Larval forms	45-56	7/32	21.86
			Nematode	0-4	1/32	3.13
			TOTAL ZOOPLANKTON N/M³	95-118	32	

**Table 61 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In $\times 10^3 \text{ N / m}^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	102	21/26	80.77	4.324	1.073	0.876
	SPM	60	15/26	57.69	3.419	0.897	0.818
LOW TIDE	Jetty	106	22/26	84.62	4.503	1.05	0.868
	SPM	124	18/26	69.23	3.527	0.863	0.789

**TABLE 62 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN SEPTEMBER 2022**

Tide	Sampling Station	Abundance In $\text{N} \times 10^3 / \text{m}^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	150	27/32	84.38	5.189	1.023	0.851
	SPM	108	21/32	65.63	4.272	1.064	0.889
LOW TIDE	Jetty	147	19/32	59.38	3.607	0.996	0.867
	SPM	117	16/32	50.00	3.15	0.898	0.843

**Table 63 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AND PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN SEPTEMBER 2022**

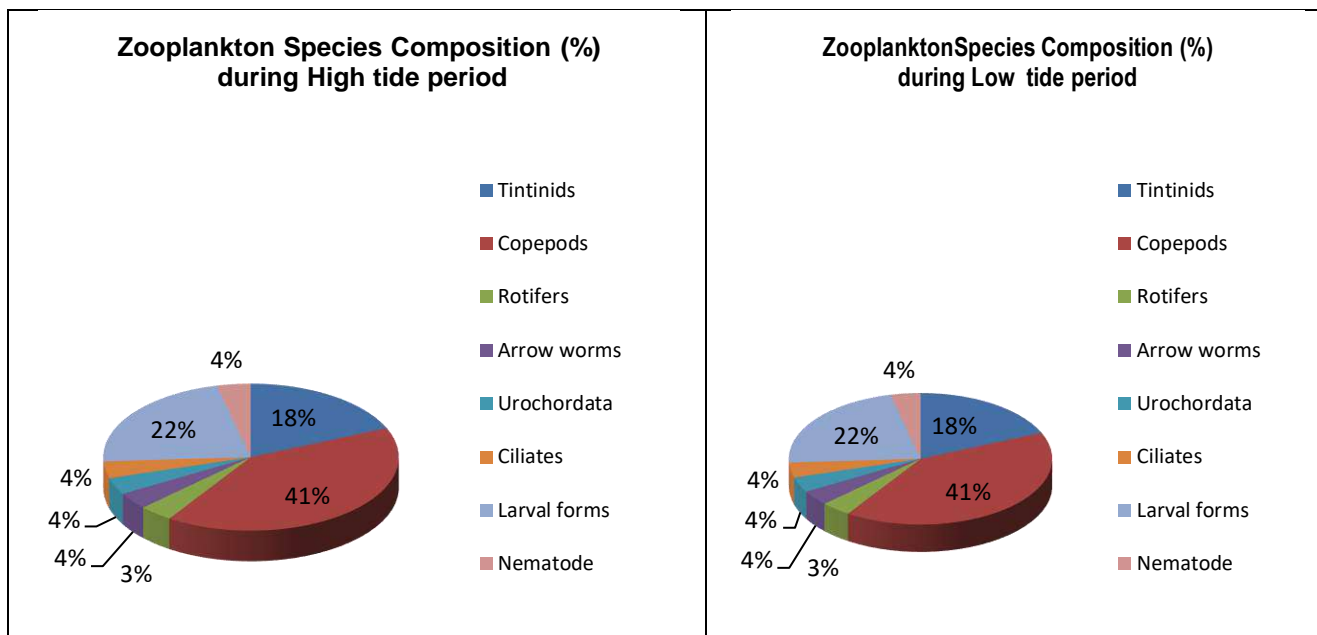
Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / \text{m}^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	12-28	8/26	30.77
			Copepods	23-34	10/26	38.46
			Arrow worms	1-2	1/26	3.85
			Mysids	1-2	1/26	3.85
			Urochordata	1	1/26	3.85
			Larval forms	22-35	5/26	19.22
			TOTAL ZOOPLANKTON NO/L	<b>60-102</b>	<b>26</b>	
LOW TIDE	Sub surface	2	Tintinids	32-37	8/26	30.77
			Copepods	32-35	10/26	38.46
			Arrow worms	0-1	1/26	3.85
			Mysids	0-1	1/26	3.85
			Urochordata	0-2	1/26	3.85
			Larval forms	37-53	5/26	19.22
			TOTAL ZOOPLANKTON NO/L	<b>106-124</b>	<b>26</b>	

**TABLE 64 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN SEPTEMBER 2022**

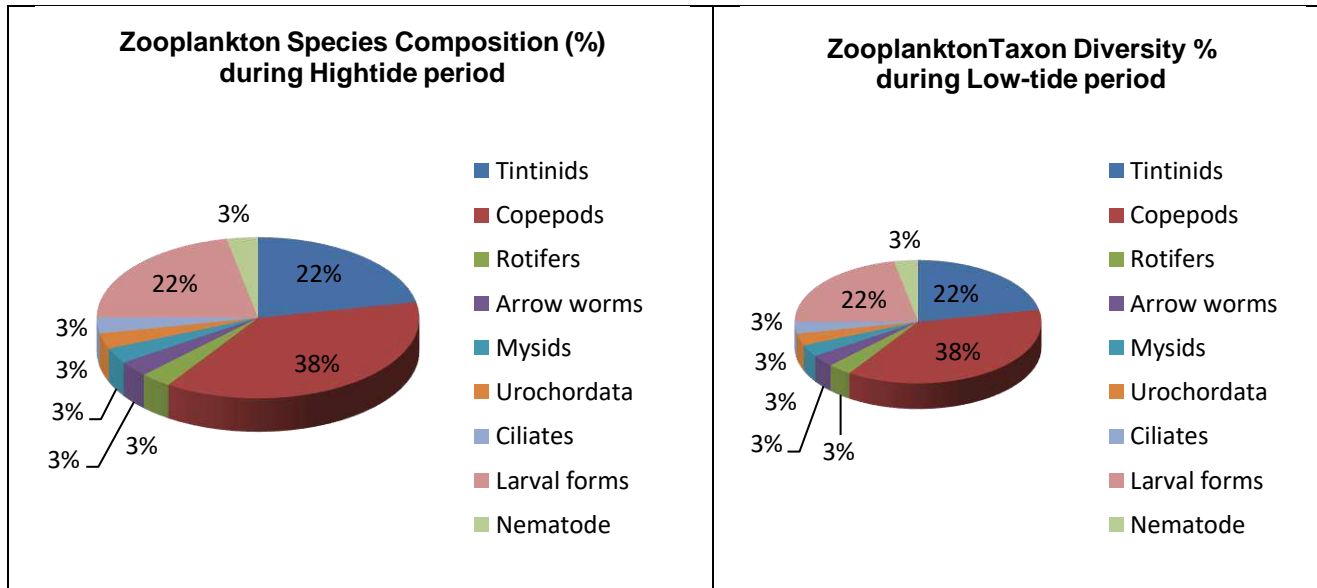
Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / \text{m}^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	27-30	6/32	18.73
			Copepods	53-61	13/32	40.62
			Arrow worms	1	1/32	3.13
			Mysids	0-2	1/32	3.13
			Urochordata	0	1/32	3.13
			Medusa	0-1	1/32	3.13
			Larval forms	25-55	8/32	25.00
			Nematode	1	1/32	3.13
			TOTAL ZOOPLANKTON	<b>108-150</b>	<b>32</b>	
LOW TIDE	Sub surface	2	Tintinids	27-37	6/32	18.73
			Copepods	55-61	13/32	40.62
			Arrow worms	0	1/32	3.13
			Mysids	0	1/32	3.13
			Urochordata	0-2	1/32	3.13
			Medusa	0	1/32	3.13
			Larval forms	35-47	8/32	25.00
			Nematode	0	1/32	3.13
			TOTAL ZOOPLANKTON	<b>117-147</b>	<b>32</b>	

DCPL/DPA/21-22/29– September-2022

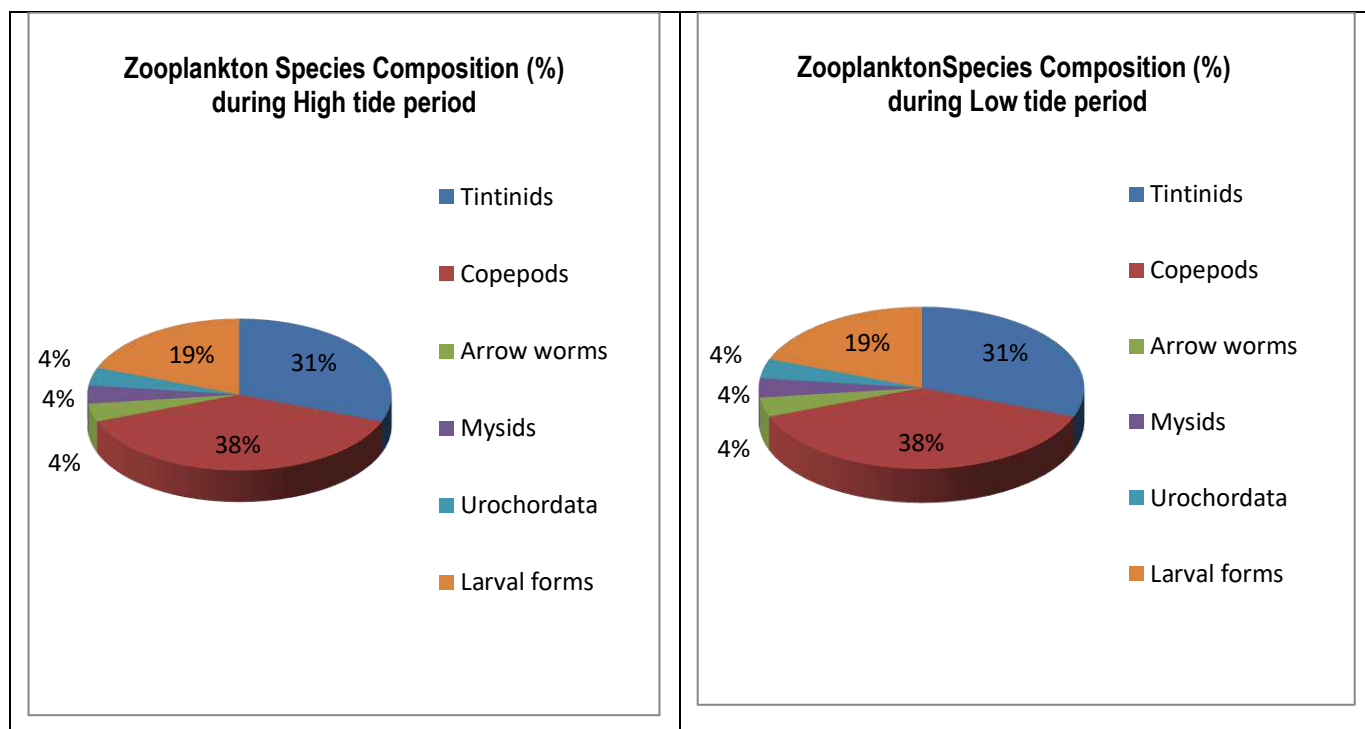
**Species Composition (%) of Zooplankton during High tide and Low tide period of Spring tide  
In Kandla Creek and nearby Creeks**



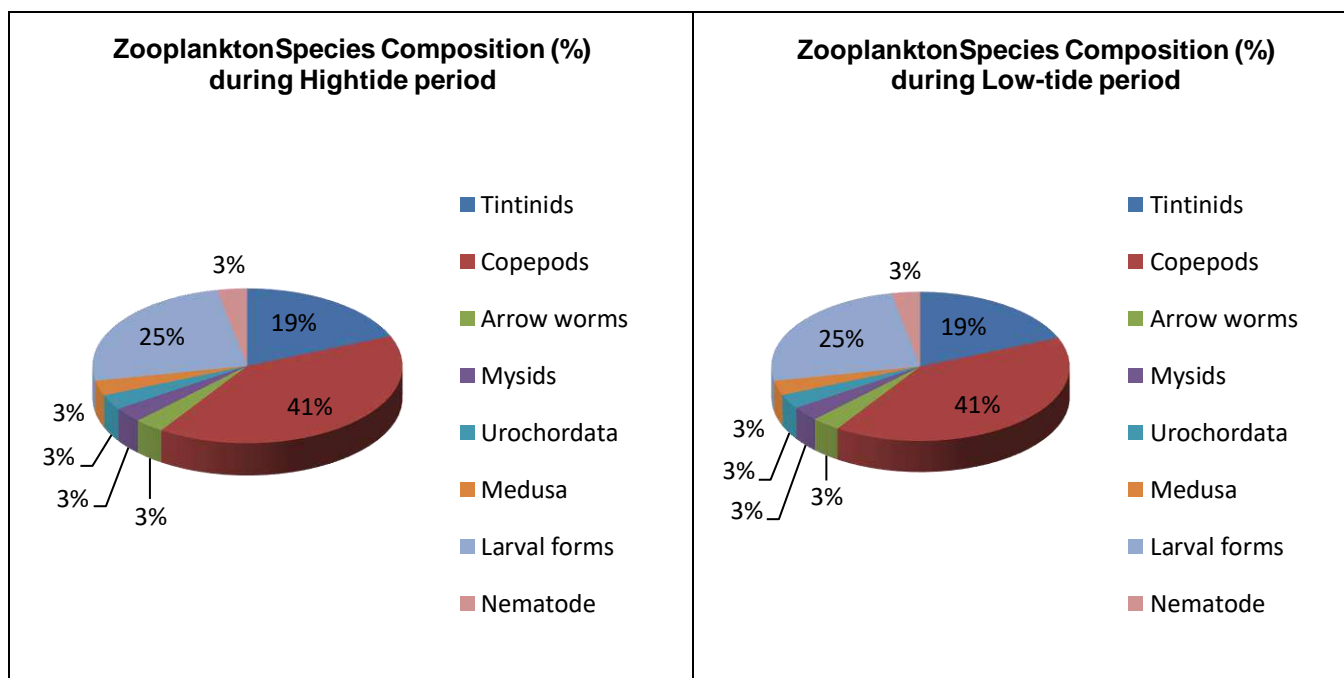
**Species Composition (%) of Zooplankton during High tide and Low tide period of Neap tide In  
Kandla Creek and nearby Creeks**



**Species Composition (%) of Zooplankton during High tide and Low tide period of Spring tide  
In Path Finder Creek and near Jetty**



**Species Composition (%) of Zooplankton during High tide and Low tide period of Neap tide In  
Path Finder Creek near jetty and nearby SPM**



**TABLE 65 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING  
LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS  
DURING NEAP TIDE OF SEPTEMBER 2022**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Very sparse
			<i>Lyngbya sp.</i>	B2	Very sparse
			<i>Oscillatoria sp.</i>	B3	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B4	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D1	Dominant
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D3	Scattered
	Hemiaulales	Bellerocheaceae	<i>Bellerochea sp.</i>	D4	Very sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Very sparse
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp.</i>	D6	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D7	Abundant
	Melosirales	Melosiraceae	<i>Melosira sp.</i>	D8	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D9	Very sparse
	Thalassiosirales	Skeletonemataceae	<i>Skeletonema sp.</i>	D10	Very sparse
		Lauderiaceae	<i>Lauderia sp.</i>	D11	Very sparse
		Thalassiosiraceae	<i>Planktoniella sp.</i>	D12	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D13	Scattered
			<i>Triceratium sp.</i>	D14	Sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D15	Very sparse
			<i>Nitzschia sp.</i>	D16	Very sparse
			<i>Pseudo-nitzschia sp.</i>	D17	Very sparse
	Naviculales	Naviculaceae	<i>Navicula sp.</i>	D18	Very sparse
		Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D19	Very sparse
		Pinnulariaceae	<i>Pinnularia sp.</i>	D20	Very sparse
	Surirellales	Surirellaceae	<i>Campylodiscus sp.</i>	D21	Very sparse
			<i>Surirella sp.</i>	D22	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp.</i>	D23	Scattered
			<i>Fragilaria sp.</i>	D24	Very sparse
			<i>Synedra sp.</i>	D25	Sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D26	Very sparse
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Thalassiothrix sp.</i>	D27	Scattered
			<i>Protoperidinium sp.</i>	DF1	Very sparse
	Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF2	Very sparse
			<i>Ceratium tripos</i>	DF3	Very sparse

**TABLE 66 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF SEPTEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Arthrospira sp.</i>	B1	Sparse
			<i>Oscillatoria sp.</i>	B2	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B3	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp.	D2	Scattered
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus</i> sp.	D3	Scattered
	Hemiaulales	Bellerocheaceae	<i>Bellerochea</i> sp	D4	Very sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Sparse
			<i>Eucampia</i> sp	D6	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Dactyliosolen</i> sp.	D7	Very sparse
			<i>Rhizosolenia</i> sp.	D8	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum</i> sp	D9	Dominant
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp	D10	Very sparse
		Lauderiaceae	<i>Lauderia</i> sp	D11	Very sparse
		Skeletonemataceae	<i>Skeletonema</i> sp	D12	Scattered
	Triceratiales	Triceratiaceae	<i>Odontella</i> sp.	D13	Scattered
			<i>Triceratium</i> sp.	D14	Very sparse
<i>Bacillaria</i> sp.			D15	Very sparse	
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Nitzschia</i> sp	D16	Very sparse
			<i>Pseudo-nitzschia</i> sp.	D17	Sparse
			Naviculales	Naviculaceae	<i>Navicula</i> sp.
		<u>Pleurosigmataceae</u>	<i>Pleurosigma</i> sp.	D19	Very sparse
	Surirellales	Surirellaceae	<i>Surirella</i> sp.	D20	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp	D21	Abundant
			<i>Fragilaria</i> sp	D22	Sparse
			<i>Synedra</i> sp	D23	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema</i> sp.	D24	Sparse
			<i>Thalassiothrix</i> sp.	D25	Scattered
Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF1	Very sparse
	Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF2	Very sparse
			<i>Ceratium tripos</i>	DF3	Very sparse



**TABLE 67 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING  
LOCATIONS IN OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT  
VADINARDURING NEAP TIDE OF SEPTEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Chroococcales	Chroococcaceae	<i>Merismopedia sp.</i>	B1	Very sparse
	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B2	Very sparse
	Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B3	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp	D1	Very sparse
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp	D2	Scattered
			<i>Coscinodiscus sp.</i>	D3	Scattered
			<i>Palmeria sp.</i>	D4	Very sparse
	Hemiaulales	Bellerocheaceae	<i>Bellerochea</i> sp	D5	Sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D7	Scattered
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D8	Sparse
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp	D9	Very sparse
			<i>Odontella sp</i>	D10	Very sparse
			<i>Triceratium</i> sp	D11	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D12	Sparse
			<i>Cylindrotheca sp</i>	D13	Very sparse
			<i>Nitzschia sp</i>	D14	Sparse
			<i>Pseudo-nitzschia</i> sp	D15	Very sparse
	Naviculales	Pinnulariaceae	<i>Pinnularia sp</i>	D16	Very sparse
			<i>Pleurosigmataceae</i>	<i>Pleurosigma</i> sp	D17
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Synedra sp.</i>	D18	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D19	Very sparse
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF2	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
			<i>Ceratium fusus</i>	DF4	Very sparse
			<i>Ceratium tripos</i>	DF5	Very sparse

**TABLE 68 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND SPRING TIDE OF SEPTEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
	Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B2	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D1	Very sparse
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D3	Dominant
	Hemiaulales	Bellerocheaceae	<i>Bellerochea sp.</i>	D4	Scattered
		Hemiaulaceae	<i>Cerataulina sp.</i>	D5	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D6	Abundant
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D7	Sparse
	Thalassiosirales	Lauderiaceae	<i>Lauderia sp.</i>	D8	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D9	Very sparse
			<i>Triceratium sp.</i>	D10	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D11	Sparse
			<i>Nitzschia sp.</i>	D12	Very sparse
			<i>Pseudo-nitzschia sp.</i>	D13	Very sparse
	Naviculales	<i>Pleurosigmataceae</i>	<i>Pleurosigma sp.</i>	D14	Very sparse
		<i>Pinnulariaceae</i>	<i>Pinnularia sp.</i>	D15	Very sparse
Fragilariophyceae	Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D16	Very sparse
	Fragilariales	Fragilariaceae	<i>Synedra sp.</i>	D17	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D18	Very sparse
			<i>Thalassiothrix sp.</i>	D19	Sparse
Dinophyceae	Peridiniales	Protopteridiniaceae	<i>Protopteridinium sp.</i>	DF1	Very sparse
	Dinophysales	Dinophysaceae	<i>Dinophysis sp.</i>	DF2	Very sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF3	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF4	Sparse
			<i>Ceratium tripos</i>	DF5	Sparse

**TABLE 69 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING  
LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY  
CREEKS DURING NEAP TIDE OF SEPTEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
		Codonellidae	<i>Tintinnopsis acuminata</i>	T2	Very sparse
			<i>Tintinnopsis dadayi</i>	T3	Sparse
			<i>Tintinnopsis failakkaensis</i>	T4	Very sparse
			<i>Tintinnopsis gracilis</i>	T5	Very sparse
			<i>Tintinnopsis radix</i>	T6	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T7	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
		Eucalanidae	<i>Subeucalanus sp.</i>	C6	Very sparse
		Temoridae	<i>Temora sp.</i>	C7	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C8	Abundant
	Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C9	Scattered
		Euterpinae	<i>Euterpina sp.</i>	C10	Sparse
	Poecilostomatoida	Corycaeidae	<i>Corycaeus sp.</i>	C11	Very sparse
		Oncaeidae	<i>Oncaea sp.</i>	C12	Very sparse
Rotifera Subclass: Eurotatoria	Superorder: Monogononta Order: Ploimida	Brachionidae	<i>Brachionus plicatilis</i>	R1	Sparse
Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Malacostraca	Mysida, Decapoda	Solenoceridae	<i>Solenocera sp.</i>	M1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
			Cyphonautes larvae	L4	Sparse
			Ophiopluteus larvae	L5	Very sparse
Polychaeta			Trochophore larvae	L6	Abundant
Pelecypoda			Veliger larvae of bivalves	L7	Very sparse
			Unidentified nematodes	N1	Sparse

**TABLE 70 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF SEPTEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Very sparse
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T5	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
		Eucalanidae	<i>Subeucalanus sp.</i>	C6	Very sparse
		Temoridae	<i>Temora sp.</i>	C7	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C8	Scattered
	Harpacticoida	Canthocamptidae	<i>Canthocamptus sp.</i>	C9	Very sparse
		Ectinosomatidae	<i>Microsetella sp.</i>	C10	Sparse
		Euterpinae	<i>Euterpina sp.</i>	C11	Very sparse
Rotifera Subclass: Eurotatoria	Superorder: Monogononta Order:Ploimida	Brachionidae	<i>Brachionus plicatilis</i>	R1	Scattered
Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Abundant
Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
			Cyphonautes larvae	L4	Very sparse
Polychaeta			Trochophore larvae	L5	Scattered
Pelecypoda			Veliger larvae of bivalves	L6	Very sparse
			Unidentified nematodes	N1	Very sparse

**TABLE 71 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NAEP TIDE OF SEPTEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus sp.</i>	T1	Dominant
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Sparse
		Dictyocystidae	<i>Luminella sp.</i>	T5	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T6	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Abundant
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
		Eucalanidae	<i>Subeucalanus sp.</i>	C5	Very sparse
		Temoridae	<i>Temora sp.</i>	C6	Very sparse
	Cyclopoida	Tortanidae	<i>Tortanus sp.</i>	C7	Very sparse
		Oithonidae	<i>Oithona sp.</i>	C8	Abundant
	Harpacticoida	Clytemnestridae	<i>Clytemnestra sp.</i>	C9	Very sparse
		Euterpinae	<i>Euterpina sp.</i>	C10	Scattered
		Ectinosomatidae	<i>Microsetella sp.</i>	C11	Very sparse
	Poecilostomatoida	Corycaidae	<i>Corycaeus sp.</i>	C12	Very sparse
		Oncaeidae	<i>Oncaea sp.</i>	C13	Sparse
Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse
Hydrozoa			Unidentified medusa	ME1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L6	Very sparse
Polychaeta			Trochophore larvae	L7	Very sparse
Pelecypoda			Veliger larvae of bivalves	L8	Very sparse
			Unidentified nematodes	N1	Very sparse

**TABLE 72 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPAOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF SEPTEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Abundant
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis mortensenii</i>	T4	Very sparse
			<i>Tintinnopsis radix</i>	T5	Scattered
			<i>Tintinnopsis tocanensis</i>	T6	Very sparse
		Dictyocystidae	<i>Luminella sp.</i>	T7	Very sparse
		Tintinnidae	<i>Eutintinnus sp.</i>	T8	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C5	Scattered
	Harpacticoida	Clytemnestridae	<i>Clytemnestra sp.</i>	C6	Very sparse
		Euterpinae	<i>Euterpina sp.</i>	C7	Sparse
		Ectinosomatidae	<i>Microsetella sp.</i>	C8	Sparse
	Poecilostomatoida	Corycaidae	<i>Corycaeus sp.</i>	C9	Very sparse
		Oncaeidae	<i>Oncaea sp.</i>	C10	Very sparse
Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L3	Very sparse
Polychaeta			Trochophore larvae	L4	Very sparse
Pelecypoda			Veliger larvae of bivalves	L5	Very sparse

**BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPA harbour region and nearby creek. The meio-benthic organisms during spring tide and Neap tide were represented by Polychaetes *Heteromastus* sp. and *Notomastus*. Population of benthic fauna was varying from 10-60- $N/m^2$  during spring tide and 20-40  $N/m^2$  during Neap tide. The benthic communities at path finder Creek were represented by Polychaetes *Tharyx* sp., *Paraonis* sp. and *Dasybranchus* sp. Their population was varying as 30  $N/m^2$  at OOT jetty premises and 40  $N/m^2$  near the SPM area during spring tide and 70  $N/m^2$  at OOT jetty premises and 40  $N/m^2$  near the SPM area during Neap tide period.

**Table 73 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING SPRING TIDE IN SEPTEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family : CAPITELLIDAE <i>Heteromastus</i> sp.	10	20	40	10	20	NS
Family : Capitellidae <i>Notomastus</i> sp.	0	10	20	0	0	NS
Total Polychaetes N/M <sup>2</sup>	10	30	60	10	20	NS
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	10	30	60	10	20	NS

NS : No sample

**Table 74 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING NEAP TIDE IN SEPTEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	KPT-1	KPT-2	KPT-3	KPT-4	KPT-5	KPT-6
Family : CAPITELLIDAE <i>Heteromastus</i> sp.	30	20	NS	20	NS	NS
Family : Capitellidae <i>Notomastus</i> sp.	0	0	NS	0	NS	NS
Total Polychaetes N/M <sup>2</sup>	30	20	NS	20	NS	NS
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	30	20	NS	20	NS	NS

NS: No sample

**Table 75 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA, VADINAR DURING SPRING TIDE IN SEPTEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family : Cirratulidae <i>Tharyx sp.</i>	10	0
Family : Capitellidae <i>Dasybranchus sp.</i>	20	40
Total Polychaetes N/M <sup>2</sup>	30	40
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	30	40

**Table 76 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA, VADINAR DURING NEAP TIDE IN SEPTEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family : Cirratulidae <i>Tharyx sp.</i>	20	20
FAMILY: PARAONIDAE <i>Paraonis sp.</i>	10	0
Family : Capitellidae <i>Dasybranchus sp.</i>	40	20
Total Polychaetes N/M <sup>2</sup>	70	40
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	70	40



## **CHAPTER-11**

### **CONCLUSIVE SUMMARY & REMEDIAL MEASURES**

## 11.0 Conclusive Summary and Remedial measures Suggested

- The AAQ monitoring of six locations at Deendayal Port Kandla indicates that the mean  $PM_{10}$  and  $PM_{2.5}$  values for three locations viz. Marine Bhavan, Estate Office and Coal storage area were found higher than the permissible limit (standards  $100 \mu\text{g}/\text{m}^3$ ,  $60 \mu\text{g}/\text{m}^3$ ). The higher concentration of Particulate matter at Marine Bhavan may be due to vehicles emissions during loading-unloading of food grains and timbers; at Estate office due to construction work, vehicles emission produced from trucks, heavy duty vehicles that pass through the road outside Kandla port and Oil jetty area; while at Coal Storage area lifting of coal from grab yard and other coal handling processes. Moreover, the transportation of coal produces pollution from heavy vehicles. At Oil Jetty location, concentration of  $PM_{10}$  varied from  $81\text{--}128 \mu\text{g}/\text{m}^3$  and mean value was observed  $104 \mu\text{g}/\text{m}^3$  which was slightly exceed the prescribed standard limit, concentration of  $PM_{2.5}$  was ranged from  $49\text{--}67 \mu\text{g}/\text{m}^3$  and mean was found  $57 \mu\text{g}/\text{m}^3$  which was within the prescribed limit. At Gopalpuri and Tuna port  $PM_{10}$  and  $PM_{2.5}$  were found within permissible limit prescribed by NAAQS.
- The AAQ monitoring signal building concentration of  $PM_{10}$  exceed the permissible limit and  $PM_{2.5}$  was found within limit while at admin building had  $PM_{10}$  concentration was exceed the permissible limit and  $PM_{2.5}$  shown slight increased.
- At Vadinar, the average concentration of  $PM_{10}$  was found  $105 \mu\text{g}/\text{m}^3$  slightly exceed at Vadinar Colony and  $100 \mu\text{g}/\text{m}^3$  at Signal Building which was boundary line of standard limit (Standard Limit  $100 \mu\text{g}/\text{m}^3$ ). The average concentration of  $PM_{2.5}$  at Admin building was  $44 \mu\text{g}/\text{m}^3$  and Signal building was  $43 \mu\text{g}/\text{m}^3$  which was within standard limit ( $60 \mu\text{g}/\text{m}^3$ ).
- Further, precautionary measures and management strategies to minimize the effect of particulate as well as gaseous pollutants have also been suggested for achieving its ambient levels in and around Kandla Port and Vadinar Port, Gujarat, India.
- Drinking water at all the twenty locations was found potable and it was found within in line of BIS standards (IS 10500-2012).
- Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. All sampling location were within the permissible limit day time 75 dB(A) and night time 70 dB (A) for the industrial area.

- The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) and Vadinar were in line with the standards set by the Central Pollution Control Board.
- It was suggested to monitor the STP performance on regular basis to avoid flow of contamination / Polluted water into the sea.
- Good species diversity suggests a relatively successful species in this habitat. A greater number of successful species and a more stable ecosystem. More ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole.
- The results obtained from the study for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.
- The mean day time temperature at Deendayal Port was 29.11 °C. The day-time maximum temperature was 34.4°C and minimum was 24.9 °C. The mean night time temperature recorded was 27.51 °C. The mean Solar Radiation in September month was 199.87 w/m<sup>2</sup>. The maximum solar radiation was recorded 942.3 w/m<sup>2</sup> in 28<sup>th</sup> September, 2022 and the minimum solar radiation was recorded 0.93 w/m<sup>2</sup> in 12<sup>th</sup> September, 2022. The mean Relative humidity was 84.81 % for the month of September. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 64.0 %. The average wind velocity for the entire month of September was 5.64 m/s. Maximum wind velocity was recorded 28.1 m/s. The wind direction was mostly West-South.

#### **Reasons for higher Values of PM<sub>10</sub>**

- The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.
- Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

#### **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of September, 2022 were beyond the permissible limit at 3 locations (Coal Storage, Marine Bhavan and Estate office) except Gopalpuri and Tuna Port. At Oil Jetty location the concentration of PM<sub>10</sub> was slightly exceeding from the standard limit. Given below are the remedial measures suggest to minimize the Air pollution.

**DCPL/DPA/21-22/29–September-2022**

- During September, 2022 overall ambient air quality of the DPA was within CPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, Marine Bhavan, Estate Office. To improve air quality the port was using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

### **Solution towards the Green port:**

Today, it is increasingly recognized that air pollution hurts human health. Consequently, efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits.

The guidelines can be considered a basis for governments for the implementation of a strategic plan focused on the reduction of multi pollutant emission, as well as of the overall air pollution related risk.

- The plantation should be all along the periphery of the port and inside and outside the port along with the road. Trees having high dust trapping efficiency (*Azadirachta indica*, *Cassia fistula*, *Delonix regia*, *Ficus religiosa*, *Pterocarpus marsupium*) are to be grown alongside the roads.
- The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.
- The vehicles should be covered during transportation and the vehicle carrying the coal should not be overloaded by raising the height of carriage.
- The water sprinklers should be use during transportation of loaded heavy vehicles on raw road.
- It should be ensure that regular sweeping of coal internal, main road and space a free circulation.
- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle- Mask advised in sensitive areas.
- Department for use maintenance should have a routine checkup noise level by replacing bearings, tights of all loose parts that can vibrate.

- Speed control is also an effective way to mitigate noise pollution, the lowest sound emission arise from vehicles moving smoothly.
- Use of renewable energy like solar energy should be optimal and ensure to work continuously.
- Keep neat and clean public transport and all basic items at public interaction places as much as possible.
- Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.
- Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.
- Initiate Natural Gas (CNG) as fuel by all buses and trucks.

### **Green Ports Initiative**

- Deendayal Port is committed to sustainable development and adequate measures are being taken to maintain the Environmental well-being of the Port and its surrounding environs. Weighing in the environmental perspective for sustained growth, the Ministry of Shipping had started “Project Green Ports” which will help in making the Major Ports across India cleaner and greener. “Project Green Ports” will have two verticals - one is “Green Ports Initiatives” related to environmental issues and second is “Swachh Bharat Abhiyaan”.
- The Green Port Initiatives include twelve initiatives such as preparation and monitoring plan, acquiring equipments required for monitoring environmental pollution, acquiring dust suppression system, setting up of waste water treatment plants/ garbage disposal plant, setting up Green Cover area, projects for energy generation from renewable energy sources, completion of shortfalls of Oil Spill Response (OSR) facilities (Tier-I), prohibition of disposal of almost all kind of garbage at sea, improving the quality of harbour wastes etc.
- Deendayal port has also appointed GEMI as an Advisor for “Making Deendayal Port a Green Port - Intended Sustainable Development under the Green Port Initiatives.
- Deendayal Port has also signed MOU with Gujarat Forest Department in September 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Trust. The plantation is being carried out by the Social Forestry division of Kachchh.

## **CHAPTER-12**

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## ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY



**REPORT** : **DCPL/DPA/21-22/30**

**Mont** : **October 01**

**Issue** : **00**

**Revision** :

**Prepare** : **DETOX CORPORATION PVT. LTD.,**

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## EXECUTIVE SUMMARY

## **ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTAL MONITORING REPORT- OCTOBER, 2022**

### **1. EXECUTIVE SUMMARY**

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to understand status of various parameters in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### **A) Ambient Air**

The monitoring of Ambient Air quality at 6-locations at Deendayal Port Authority Kandla and 2- location at Vadinar Port on 24 hourly basis for TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> and NMHC in twice a week 24 hourly at uniform intervals (as per NAAQS) at Gopalpuri, Tuna Port, Marine Bhavan Building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and Vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The Maximum TSPM values in month of October 2022 were found 983 µg/m<sup>3</sup> at Coal Storage area on 23.10.2022 and minimum 71 µg/m<sup>3</sup> at Tuna Port on 03.10. 2022. The Maximum PM<sub>10</sub> values were 713µg/m<sup>3</sup> at Coal Storage area on 23.10.2022 and minimum was 42 µg/m<sup>3</sup> at Tuna Port on 03.10. 2022. The maximum PM<sub>2.5</sub> values were found 267 µg/m<sup>3</sup> at Coal Storage area on 23.10.2022 and minimum was 23 µg/m<sup>3</sup> at Tuna Port on 03.10. 2022. The PM<sub>10</sub> and PM<sub>2.5</sub> values were found for four locations (Marine Bhavan Building, Oil Jetty, Coal Storage Area and Estate Office Building) to exceed the permissible limit.

At Tuna Port location the mean concentration of PM<sub>10</sub> was found slightly exceed the permissible limit, the mean concentration of PM<sub>2.5</sub> was 60 µg/m<sup>3</sup> within the permissible limit. At Gopalpuri sampling location all parameters of ambient air quality were found within the limit.

The AAQ monitoring for Vadinar at Admin building mean value of PM<sub>10</sub> and PM<sub>2.5</sub> were slightly exceed while at signal building the concentration of PM<sub>10</sub> and PM<sub>2.5</sub> was within the limit.

The overall values of October for Gaseous SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> concentration were within the permissible limit at all location and NMHC were found BQL (Below Quantification Limit).



## **B) Weather**

The mean day time temperature at Deendayal Port was 29.87 °C. The day-time maximum temperature was 35.1°C and minimum was 23.2 °C. The mean night time temperature recorded was 27.91 °C. The night-time maximum temperature was 32.5°C and minimum was 23.4 °C. The mean Solar Radiation in October month was 185.99 w/m<sup>2</sup>. The maximum solar radiation was recorded 856.7 w/m<sup>2</sup> in 1<sup>st</sup> October, 2022 and the minimum solar radiation was recorded 1.106 w/m<sup>2</sup> in 29<sup>th</sup> October, 2022. The mean Relative humidity was 74.90 % for the month of October. Maximum Relative humidity was recorded 98.0 % and minimum Relative humidity was recorded 30.0 %. The average wind velocity for the entire month of October was 1.22 m/s. Maximum wind velocity was recorded 6.50 m/s. The wind direction was mostly West-South.

## **C) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:**

The results obtained from the study for the month of October 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

## **D) Drinking Water Quality**

The drinking water being supplied to Deendayal Port was safe for drinking purpose. At all drinking water monitoring stations around port area were in line with the standard limit as per the drinking water specifications given in IS 10500:2012 as per tested parameters only.

The average results for 20 locations were as: pH were found Min 7.28 and maximum 7.6, TDS were found min 374.0 mg/l and Max found 1473.0 mg/l, Chloride were found Min 130.29 mg/l and Max 651.45 mg/l, Total Hardness were found Min 380.0 mg/l and Max 568.0 mg/l and Calcium were found Min 36.07 mg/l and Max 101.80 mg/l, color were colorless and odor were odorless. In all water samples BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count (E-coli & Coliform) is absent in all drinking water samples.

### **E) Monitoring Performance of Sewage Treatment Plant**

It was seen that the performance of STP at Deendayal Township Gopalpuri, DPA STP Plant Kandla and Vadinar STP plant was satisfactory by overall. The treatment plant was well maintained during [October 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. At Gopalpuri STP, the pollutant removal efficiency for TSS, BOD and COD was ranged from 58-62%, 50% and 48-51% respectively. At Kandla STP, removal efficiency for TSS, BOD and COD was ranged from 49-62%, 63-68% and 63-72% respectively & at Vadinar STP removal efficiency for TSS, BOD and COD was ranged from 58-61%, 40-73% and 33-75% respectively. At all STP location treated waste water the pH were ranged from 7.21-7.45, Total Suspended Solids were found 41.8-59.9 mg/l, Residual Chlorine were below Detection Limit (< 0.5), COD were found 20-60 mg/l and 3day BOD @ 27 °C were found 6.0-18.0 mg/l.

### **F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 63.8 dB(A) to 72.8 dB(A) while at Vadinar port 3 location ranged from 57.2 dB(A) to 58.4 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 53.9 dB to 64.7 dB(A) while at Vadinar port ranged from 53.6 dB (A) to 57.5 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.



# **CHAPTER-1**

## **INTRODUCTION**

### **DEENDAYAL PORT AUTHORITY**

## **1.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 Kms. From the mouth of Gulf of Kachchh. Latitude: 23° 01" N Longitude: 70° 13"E. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rise to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15 consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 127.10 million metric tons of cargo during the FY 2021-22, as against 117.566 million metric tons in FY 2020-21. Showing a growth of 8.11 %. Incidentally, DPA is the only major Indian port of handle more than 127 MMT cargo throughout and it has also registered the highest cargo throughput in its history. While the port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in Sept. 2021. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural up-gradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32 MMTPA Essar Oil Refinery in Jamnagar District. Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the prescribed standards by GPCB/CPCB/MoEF& CC. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port. The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.

## CHAPTER-2

### AMBIENT AIR QUALITY MONITORING

## **2. Introduction**

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth's atmosphere. It may cause diseases, allergies or death of humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty. The consequences of industrialization and the demand for improved quality of life has been increased exposure to air pollution (Vallero, 2014). An air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Any gas could qualify as pollution if it reached a high enough concentration to do harm. Theoretically, that means there are dozens of different pollution gases. In practice, about ten different substances cause most concern. Heavy metals represent a class of omnipresent pollutants, with toxic potential, in some cases even at low exposure levels. They concentrate in each tropic level because of their weak mobility, so the concentration in plants is higher than in soil, in herbivore animals higher than in plants, in carnivores' tissues higher than in herbivore, the highest concentration being reached at the end of the tropic chain, at big predacious and human bodies. Globally, one of the main contributors to emissions of atmospheric pollutants and a significant user of energy is the industrial sector (Conti et al. 2015).

The concentration of air pollutants depends not only on the quantities that are emitted from the polluting sources, but also on the ability of the atmosphere to either absorb or disperse such emissions (USEPA, 2008).

Nowadays, the shipping sector provides low-cost and reliable delivery services in the economic field (Arunachalam et al. 2015). Nevertheless, shipping-related activities have a considerable impact on air pollution, especially in coastal areas but also globally (Buccolieri et al. 2016). The primary air pollutants are PM, VOCs, NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub>, and CO (Bailey and Solomon 2004). As a consequence, a wide range of options toward “greener” seaports is needed (Bailey and Solomon 2004). Some of these measures are easy to adopt such as the regulation of fuel quality (by using low-sulfur alternative fuels), the speed reduction (Lack et al. 2011), and the use of alternative transportation equipment (Lai et al. 2011).

Clean air is the basic requirement of all living organisms. In recent times, due to population growth, urban sprawl, industrial development, and vehicular boom, the quality of air is deteriorating and being polluted. Pollutants of major public health concerns include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, which pose serious threats to human health and hygiene. In the present study, prime particulate pollutants (PM<sub>10</sub>, PM<sub>2.5</sub>), and gaseous pollutants (SO<sub>2</sub>, and NO<sub>2</sub>) were estimated at seven stations in and around Dahej Port, Gujarat, India (Soni and Jagruti Patel, 2017).

Among particulate pollutants, particulate matter (PM) is a ubiquitous entity, and is especially a grave problem due to its higher suspension rate into the atmosphere, and adverse health effects on plants, animals, humans, and materials in the form of visibility reduction, soiling of buildings, etc. (Horaginamani and Ravichandran, 2010; Chaurasia *et al.*, 2013).

The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

## 2.1 Ambient Air Quality Monitoring

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

**Table: 1. Ambient Air Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Marine Bhavan	AL-1	23° 0' 26.524"N	70° 13' 22.414"E	<b>DPA-Kandla</b>
2.	Oil Jetty	AL-2	23° 1' 45.613"N	70° 13' 11.052"E	
3.	Estate Office	AL-3	23° 1' 11.273"N	70° 12' 48.657"E	
4.	Gopalpuri Hospital	AL-4	23° 4' 53.551"N	70° 8' 7.047"E	
5.	Coal Storage Area	AL-5	22° 59' 31.812"N	70° 13' 9.979"E	
6.	Tuna Port	AL-6	22° 59' 15.291"N	70° 58' 57.018"E	
7.	Signal Building	AL-7	22° 26' 26.750"N	69° 40' 22.127"E	<b>DPA-Vadinar</b>
8.	Admin Building	AL-8	22° 26' 25.223"N	69° 40' 19.358"E	

### ● Air Quality Monitoring Methodology

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> & Benzene and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours for gaseous parameters. The absorbing reagents for SO<sub>2</sub>:- Absorbing Reagent TCM (Potassium Tetrachloromercurate 0.04M): Mercuric Chloride, Potassium Chloride and EDTA used. For NO<sub>2</sub>:- Absorbing Reagent Sodium Hydroxide (NaOH): Sodium Hydroxide and Sodium Arsenite used. For NH<sub>3</sub> need Conc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>. The GFA filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected two consecutive days a week as per CPCB guidelines, from all the eight locations as mentioned in the EMP.



## 2.2 Results

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of October 2022 are given in Tables 2 to 7. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 8 to 9.

The Movement of heavy transport with uncovered coal transportation, raw road around ambient location may be causes fugitive dust emission from dry conditions. Particulate Matter then enters the atmosphere through the action of wind, vehicular movement, or other activities. The dust produces tends to float in air and spread all around the vicinity. Direction and speed of wind affect the dispersion of the dust particulate matter. Humidity of air also has strong effect on the spreading of particulate matter. With increasing humidity, moisture particles eventually grow in size to a point where 'dry deposition' occurs, reducing PM<sub>10</sub> concentrations in the atmosphere.

**Location 1: Marine Bhavan (AL1)**

**Table 2 : Results of Air Pollutant Concentration at Marine Bhavan**

Table 2 : Results of Air Pollutant Concentration at Marine Bhavan										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL1 – 1	03.10.2022	350	226	112	3.32	3.53	5.77	11.93	4.14	5.68
					2.72		17.89		7.25	
					4.53		12.12		5.64	
AL1 – 2	06.10.2022	372	235	127	4.53	4.33	14.43	14.81	4.83	5.60
					5.74		12.12		7.02	
					2.72		17.89		4.95	
AL1 – 3	11.10.2022	397	257	135	4.61	5.09	30.59	23.85	5.87	4.11
					6.05		24.24		2.88	
					4.61		16.74		3.57	
AL1 – 4	14.10.2022	496	339	153	2.72	6.55	20.20	13.66	4.72	4.45
					7.55		8.66		5.87	
					9.37		12.12		2.76	
AL1 – 5	17.10.2022	543	362	175	4.23	4.73	24.24	19.62	3.91	4.37
					6.95		16.74		4.72	
					3.02		17.89		4.49	
AL1 - 6	20.10.2022	580	378	192	9.37	5.64	17.89	14.43	4.37	4.22
					2.72		15.58		4.95	
					4.84		9.81		3.34	
AL1 - 7	23.10.2022	600	393	202	6.35	4.53	14.43	18.66	7.02	5.33
					4.53		23.66		4.95	
					2.72		17.89		4.03	
AL1 – 8	28.10.2022	459	326	125	3.93	4.43	29.43	25.20	4.72	3.41
					6.65		20.20		3.80	
					2.72		25.97		1.73	
Monthly Average		475	315	153		4.85		17.77		4.65
Standard Deviation		96	66	33		0.92		4.89		0.81

**Table 2 : Results of Air Pollutant Concentration at Marine Bhavan**

	Date	C6H6 [µg/m <sup>3</sup> ]	HC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>	ppm	4.0 mg/m <sup>3</sup>	-
AL1 – 1	03.10.2022	1.22	BQL	1.46	1010
AL1 – 2	06.10.2022	1.14	BQL	1.46	912
AL1 – 3	11.10.2022	1.08	BQL	1.16	1042
AL1 – 4	14.10.2022	1.05	BQL	1.17	1392
AL1 – 5	17.10.2022	1.1	BQL	1.2	888
AL1 - 6	20.10.2022	1.16	BQL	1.26	650
AL1 - 7	23.10.2022	1.15	BQL	1.13	454
AL1 - 8	28.10.2022	1.17	BQL	1.43	364
<b>Monthly Average</b>		<b>1.13</b>	<b>-</b>	<b>1.28</b>	<b>839</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.14</b>	<b>337</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 475 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 315 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 153 µg/m<sup>3</sup> which is above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.85 µg/ m<sup>3</sup>, 17.77 µg/ m<sup>3</sup> & 4.65 µg/ m<sup>3</sup> respectively; these values were within the permissible limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.13 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.28 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup> prescribed by NAAQS.

**Location 2: Oil Jetty (AL2)**

**Table 3 : Results of Air Pollutant Concentration at Oil Jetty**

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL2 -1	03.10.2022	137	92	40	4.23	3.53	10.39	14.43	4.95	5.64
					2.72		15.00		7.02	
					3.63		17.89		4.95	
AL2 -2	06.10.2022	140	89	41	3.32	3.63	8.66	9.43	2.19	4.45
					4.53		7.50		5.29	
					3.02		12.12		5.87	
AL2 -3	11.10.2022	207	131	70	4.61	3.84	36.36	24.82	2.88	15.58
					2.59		24.24		39.14	
					4.32		13.85		4.72	
AL2 -4	14.10.2022	234	142	69	9.07	6.35	13.85	19.04	1.61	2.38
					6.35		24.82		4.14	
					3.63		18.47		1.38	
AL2 – 5	17.10.2022	137	91	40	4.84	5.34	10.97	14.43	4.03	3.15
					8.76		20.20		3.34	
					2.42		12.12		2.07	
AL2 – 6	20.10.2022	671	461	209	6.35	6.45	17.89	14.62	4.03	4.91
					7.25		10.97		4.83	
					5.74		15.00		5.87	
AL2 – 7	23.10.2022	209	135	64	2.12	4.13	24.24	19.62	4.95	4.68
					3.93		16.74		5.87	
					6.35		17.89		3.22	
AL2 -8	28.10.2022	207	130	62	2.12	4.33	17.89	18.28	2.76	4.49
					6.35		23.66		4.83	
					4.53		13.27		5.87	
Monthly Average		243	159	74		4.70		16.83		5.66
Standard Deviation		177	124	56		1.19		4.63		4.14

Table 3 : Results of Air Pollutant Concentration at Oil Jetty					
	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL2 -1	03.10.2022	1.09	BQL	1.31	849
AL2 -2	06.10.2022	1.12	BQL	1.19	870
AL2 -3	11.10.2022	1.07	BQL	1.43	1280
AL2 -4	14.10.2022	1.07	BQL	1.47	1032
AL2 -5	17.10.2022	1.12	BQL	1.32	862
AL2 -6	20.10.2022	1.11	BQL	1.19	555
AL2 -7	23.10.2022	1.15	BQL	1.13	454
AL2 -8	28.10.2022	1.17	BQL	1.43	364
Monthly Average		1.11	-	1.31	783
Standard Deviation		0.04	-	0.13	308

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

Oil Jetty Area, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> was mainly by motor vehicle emission produced from various types of vehicles at Oil Jetty Area. The mean TSPM value at Oil Jetty was 243 µg/m<sup>3</sup>. The mean PM<sub>10</sub> value was 159 µg/m<sup>3</sup> and mean PM<sub>2.5</sub> value was 74 µg/m<sup>3</sup> which was above the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit prescribed by NAAQS. The mean concentration of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.70 µg/m<sup>3</sup>, 16.83 µg/m<sup>3</sup> and 5.66 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.11 µg/m<sup>3</sup> which was well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.31 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 3: Kandla Colony – Estate Office (AL-3)**

Table 4 : Results of Air Pollutant Concentration at Estate Office										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL3 – 1	03.10.2022	160	100	50	1.81	2.72	13.85	10.97	4.83	6.29
					4.84		10.39		6.68	
					1.51		8.66		7.37	
AL3 – 2	06.10.2022	247	154	78	3.32	3.42	13.27	11.16	4.83	3.91
					4.53		8.08		3.57	
					2.42		12.12		3.34	
AL3 – 3	11.10.2022	362	237	118	4.32	5.09	23.66	16.35	3.91	3.07
					6.05		14.43		1.73	
					4.90		10.97		3.57	
AL3 – 4	14.10.2022	413	271	133	4.53	6.85	20.78	12.70	0.46	2.65
					6.35		12.12		4.83	
					9.67		5.19		2.65	
AL3 – 5	17.10.2022	535	421	112	2.72	4.23	24.24	24.43	4.83	3.80
					3.63		29.43		4.14	
					6.35		19.62		2.42	
AL3 – 6	20.10.2022	314	216	95	6.35	4.43	20.20	19.62	4.83	3.68
					2.12		12.12		3.57	
					4.84		26.55		2.65	
AL3 – 7	23.10.2022	436	318	117	3.63	5.34	23.66	16.16	5.18	4.18
					7.55		13.85		4.14	
					4.84		10.97		3.22	
AL3 – 8	28.10.2022	451	332	114	4.53	4.53	12.70	15.00	4.83	3.57
					6.35		17.89		3.22	
					2.72		14.43		2.65	
Monthly Average		365	256	102		4.58		15.80		3.89
Standard Deviation		121	103	27		1.25		4.55		1.08

**Table 4 : Results of Air Pollutant Concentration at Estate Office**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
<b>NAAQMS limit</b>					
<b>AL3 -1</b>	03.10.2022	1.09	BQL	1.36	785
<b>AL3 -2</b>	06.10.2022	1.21	BQL	1.21	573
<b>AL3 -3</b>	11.10.2022	1.01	BQL	1.08	795
<b>AL3 -4</b>	14.10.2022	1.19	BQL	1.34	1037
<b>AL3 – 5</b>	17.10.2022	1.22	BQL	1.22	742
<b>AL3 – 6</b>	20.10.2022	1.1	BQL	1.31	555
<b>AL3 – 7</b>	23.10.2022	1.15	BQL	1.13	454
<b>AL3 – 8</b>	28.10.2022	1.17	BQL	1.43	364
<b>Monthly Average</b>		<b>1.14</b>	<b>-</b>	<b>1.26</b>	<b>663</b>
<b>Standard Deviation</b>		<b>0.07</b>	<b>-</b>	<b>0.12</b>	<b>218</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Kandla Port Colony (Estate Office) was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Kandla port Colony were 265 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 256 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 102 µg/m<sup>3</sup> which was above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.58 µg/m<sup>3</sup>, 15.80 µg/m<sup>3</sup> and 3.89 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.14 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide was 1.26 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 4: Gopalpuri Hospital (AL-4)**

**Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital**

Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL4 -1	03.10.2022	138	93	41	2.72	2.22	5.19	6.73	3.80	2.92
					2.12		8.66		2.76	
					1.81		6.35		2.19	
AL4 -2	06.10.2022	118	73	32	2.42	2.92	6.93	9.23	2.88	3.45
					3.63		8.66		3.57	
					2.72		12.12		3.91	
AL4 -3	11.10.2022	136	87	39	2.59	2.21	12.12	11.93	2.42	1.73
					1.15		15.00		1.73	
					2.88		8.66		1.04	
AL4 -4	14.10.2022	171	104	56	2.42	2.32	8.08	12.89	2.42	2.42
					3.02		12.70		1.27	
					1.51		17.89		3.57	
AL4 – 5	17.10.2022	140	95	44	1.51	2.72	10.39	14.04	3.57	3.84
					3.02		12.12		4.83	
					3.63		19.62		3.11	
AL4 – 6	20.10.2022	118	64	38	2.72	2.52	15.00	14.62	3.80	3.80
					3.32		10.97		2.88	
					1.51		17.89		4.72	
AL4 – 7	23.10.2022	218	130	75	1.51	4.23	4.62	12.89	2.42	3.88
					6.35		20.20		5.18	
					4.84		13.85		4.03	
AL4 – 8	28.10.2022	123	73	49	2.72	4.53	17.89	11.54	2.88	3.72
					4.53		10.39		3.57	
					6.35		6.35		4.72	
Monthly Average		145	90	47		2.96		11.73		3.22
Standard Deviation		34	21	14		0.92		2.61		0.79



<b>Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL4 -1</b>	03.10.2022	1.19	BQL	1.18	641
<b>AL4 -2</b>	06.10.2022	1.10	BQL	1.37	637
<b>AL4 -3</b>	11.10.2022	1.20	BQL	1.24	859
<b>AL4 -4</b>	14.10.2022	1.21	BQL	1.47	1061
<b>AL4 – 5</b>	17.10.2022	1.16	BQL	1.45	899
<b>AL4 – 6</b>	20.10.2022	1.20	BQL	1.46	545
<b>AL4 – 7</b>	23.10.2022	1.15	BQL	1.13	454
<b>AL4 – 8</b>	28.10.2022	1.17	BQL	1.43	364
<b>Monthly Average</b>		<b>1.17</b>	<b>-</b>	<b>1.34</b>	<b>683</b>
<b>Standard Deviation</b>		<b>0.04</b>	<b>-</b>	<b>0.14</b>	<b>238</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 145 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 90 µg/m<sup>3</sup> and PM<sub>2.5</sub> was 47 µg/m<sup>3</sup> which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 2.96 µg/m<sup>3</sup>, 11.73 µg/m<sup>3</sup> and 3.22 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.17 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon monoxide concentration was 1.34 mg/m<sup>3</sup> which is well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 5: Coal Storage Area (AL-5)**

**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL6 – 1	03.10.2022	495	319	158	2.12	3.22	13.85	16.93	5.18	6.33
					3.32		20.20		7.25	
					4.23		16.74		6.56	
AL6 – 2	06.10.2022	567	383	173	5.44	3.93	20.20	19.62	7.83	7.60
					3.63		23.66		6.79	
					2.72		15.00		8.17	
AL6 – 3	11.10.2022	587	412	180	10.09	6.73	26.55	26.93	5.18	5.45
					6.05		13.27		7.48	
					4.04		40.97		3.68	
AL6 – 4	14.10.2022	663	441	210	7.25	4.43	19.04	19.43	5.53	4.87
					3.32		15.00		2.99	
					2.72		24.24		6.10	
AL6 – 5	17.10.2022	671	451	217	7.86	7.45	21.35	16.35	6.68	5.03
					9.37		16.74		4.83	
					5.14		10.97		3.57	
AL6 – 6	20.10.2022	940	682	252	8.16	7.76	13.27	18.47	5.87	4.57
					5.74		17.89		5.18	
					9.37		24.24		2.65	
AL6 – 7	23.10.2022	983	713	267	7.55	5.54	15.00	19.62	7.02	5.87
					3.63		20.20		4.72	
					5.44		23.66		5.87	
AL6 – 8	28.10.2022	845	610	231	4.53	4.94	13.27	19.43	6.56	5.18
					6.95		25.97		4.83	
					3.32		19.04		4.14	
Monthly Average		719	501	211		5.50		19.60		5.61
Standard Deviation		182	147	39		1.67		3.22		0.98

**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL5 – 1	03.10.2022	1.16	BQL	1.41	881
AL5 – 2	06.10.2022	1.09	BQL	1.61	888
AL5 – 3	11.10.2022	1.16	BQL	0.95	819
AL5 – 4	14.10.2022	1.17	BQL	1.64	1026
AL5 – 5	17.10.2022	1.14	BQL	1.42	878
AL5 – 6	20.10.2022	1.18	BQL	1.48	630
AL5 – 7	23.10.2022	1.15	BQL	1.13	454
AL5 – 8	28.10.2022	1.17	BQL	1.43	364
Monthly Average		1.15	-	1.38	743
Standard Deviation		0.03	-	0.23	234

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 719 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 501 µg/m<sup>3</sup>, and the PM<sub>2.5</sub> value was 211 µg/m<sup>3</sup> which was above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 5.50 µg/m<sup>3</sup>, 19.60 µg/m<sup>3</sup> and 5.61 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.15 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.38 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 6: Tuna Port (AL-6)**

**Table 7 : Results of Air Pollutant Concentration at Tuna Port**

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL5 -1	03.10.2022	71	42	23	0.60	2.32	4.62	5.19	3.91	2.65
					3.63		7.50		2.42	
					2.72		3.46		1.61	
AL5 – 2	06.10.2022	173	109	50	1.81	1.31	6.93	6.54	2.99	3.38
					1.21		7.50		3.91	
					0.91		5.19		3.22	
AL5 – 3	11.10.2022	186	122	56	3.46	2.40	7.50	8.46	2.65	2.49
					1.15		13.27		1.61	
					2.59		4.62		3.22	
AL5 – 4	14.10.2022	328	206	115	0.91	1.81	10.97	14.81	1.73	1.80
					2.42		13.85		2.65	
					2.12		19.62		1.04	
AL5 – 5	17.10.2022	252	186	58	2.42	3.32	12.12	8.85	5.29	3.72
					4.84		9.23		3.68	
					2.72		5.19		2.19	
AL5 – 6	20.10.2022	184	119	52	3.93	3.42	27.70	24.62	4.03	10.79
					2.72		29.43		15.57	
					3.63		16.74		12.76	
AL5 – 7	23.10.2022	209	131	78	2.42	2.82	12.12	8.46	4.72	3.84
					3.32		8.08		4.03	
					2.72		5.19		2.76	
AL5 – 8	28.10.2022	169	108	50	4.53	4.63	17.89	13.08	3.22	4.22
					6.95		13.27		3.57	
					2.42		8.08		5.87	
Monthly Average		196	128	60		2.76		11.25		4.11
Standard Deviation		74	50	27		1.04		6.27		2.81

**Table 7 : Results of Air Pollutant Concentration at Tuna Port**

		<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>		<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>	<b>Date</b>	<b>8 hr</b>	<b>*NMHC</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL6 -1</b>	03.10.2022	1.1	BQL	1.28	1145
<b>AL6 – 2</b>	06.10.2022	1.16	BQL	1.23	736
<b>AL6 – 3</b>	11.10.2022	1.17	BQL	1.65	1081
<b>AL6 – 4</b>	14.10.2022	1.1	BQL	1.20	1059
<b>AL6 – 5</b>	17.10.2022	1.14	BQL	1.29	900
<b>AL6 – 6</b>	20.10.2022	1.18	BQL	1.42	647
<b>AL6 – 7</b>	23.10.2022	1.15	BQL	1.13	454
<b>AL6 – 8</b>	28.10.2022	1.17	BQL	1.43	364
<b>Monthly Average</b>		<b>1.15</b>	<b>-</b>	<b>1.33</b>	<b>798</b>
<b>Standard Deviation</b>		<b>0.03</b>	<b>-</b>	<b>0.17</b>	<b>296</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port was 196 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 128 µg/m<sup>3</sup> which was slightly exceed the permissible limit , the mean PM<sub>2.5</sub> value was 60 µg/m<sup>3</sup> which was within the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 5.50 µg/m<sup>3</sup>, 19.60 µg/m<sup>3</sup> and 5.61µg/m<sup>3</sup> respectively and were all within the permissible limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.15 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.33 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 7: Admin Building (Vadinar) (AL-7)**

**Table 8 : Results of Air Pollutant Concentration at Admin Building**

Table 8 : Results of Air Pollutant Concentration at Admin Building										
	Date	TSPM [µg/m <sup>3</sup> ]	PM <sub>10</sub> [µg/m <sup>3</sup> ]	PM <sub>2.5</sub> [µg/m <sup>3</sup> ]	SO <sub>2</sub> [µg/m <sup>3</sup> ]		NO <sub>x</sub> [µg/m <sup>3</sup> ]		NH <sub>3</sub> [µg/m <sup>3</sup> ]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL7 -1	03.10.2022	179	113	60	2.20	2.64	9.53	14.82	3.83	5.02
					3.08		15.24		5.87	
					2.64		19.69		5.36	
AL7 -2	06.10.2022	171	108	57	3.08	4.25	22.23	13.13	6.64	6.13
					5.28		11.43		7.91	
					4.40		5.72		3.83	
AL7 -3	10.10.2022	156	103	51	4.40	3.37	10.80	19.69	5.36	6.55
					2.64		28.58		7.91	
					3.08		19.69		6.38	
AL7 -4	13.10.2022	106	76	29	5.71	4.25	26.04	20.33	6.13	4.85
					4.40		19.69		3.06	
					2.64		15.24		5.36	
AL7 -5	17.10.2022	208	123	82	3.08	4.98	15.24	17.15	5.36	4.17
					5.28		19.69		4.34	
					6.59		16.51		2.81	
AL7 -6	20.10.2022	205	122	79	1.76	2.64	10.80	7.83	3.57	5.62
					1.32		6.99		7.91	
					4.84		5.72		5.36	
AL1 -7	25.10.2022	216	132	83	6.59	5.13	13.34	13.55	4.34	6.98
					4.84		10.80		8.68	
					3.96		16.51		7.91	
AL1-8	28.10.2022	240	144	91	4.40	3.52	5.72	9.74	6.38	4.08
					3.52		13.34		3.57	
					2.64		10.16		2.30	
Monthly Average		185	115	67		3.8		14.5		5.4
Standard Deviation		42	21	21		1		4		1

**Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL7 -1	03.10.2022	1.02	BQL	1.14	474
AL7 -2	06.10.2022	1.11	BQL	1.57	465
AL7 -3	10.10.2022	1.01	BQL	1.17	473
AL7 -4	13.10.2022	1.08	BQL	1.17	373
AL7 -5	17.10.2022	1.06	BQL	1.03	473
AL7 -6	20.10.2022	1.11	BQL	1.07	481
AL7 -7	25.10.2022	1.14	BQL	1.51	486
AL7 -8	28.10.2022	1.01	BQL	1.2	501
AL7 -9	29.10.2022	1.18	BQL	1.52	512
Monthly Average		1.08	-	1.26	471
Standard Deviation		0.06	-	0.21	40

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Admin Building, Vadinar the mean TSPM value was 185 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 115 µg/m<sup>3</sup> and the mean PM<sub>2.5</sub> value was 67 µg/m<sup>3</sup> which was slightly exceed the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were 3.8 µg/m<sup>3</sup>, 14.5 µg/m<sup>3</sup> and 5.4 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.08 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.26 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 8: Signal Building (Vadinar) (AL-8)**

**Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar.**

Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar.										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL8 -1	03.10.2022	146	97	45	4.40	2.64	15.24	13.34	2.81	3.83
					1.32		13.34		3.32	
					2.20		11.43		5.36	
AL8 -2	06.10.2022	125	82	40	2.20	2.20	14.61	17.36	6.13	4.17
					1.32		22.87		3.32	
					3.08		14.61		3.06	
AL8 -3	10.10.2022	130	90	34	3.96	3.66	13.34	16.09	3.83	5.02
					4.84		24.14		3.32	
					2.20		10.80		7.91	
AL8 -4	13.10.2022	94	62	30	3.08	3.52	11.43	13.55	8.68	7.23
					4.84		20.33		5.36	
					2.64		8.89		7.66	
AL8 -5	17.10.2022	140	94	43	3.08	2.64	10.80	10.37	5.87	6.47
					2.64		6.99		7.91	
					2.20		13.34		5.62	
AL8 -6	20.10.2022	163	100	61	5.71	3.96	13.34	11.01	6.38	6.55
					2.20		10.16		7.91	
					3.96		9.53		5.36	
AL8 -7	25.10.2022	192	115	74	2.64	3.96	8.26	9.53	7.15	7.32
					5.28		13.34		4.34	
					3.96		6.99		10.47	
AL8-8	28.10.2022	205	125	77	4.84	4.69	12.07	14.82	3.32	3.83
					5.28		17.78		2.81	
					3.96		14.61		5.36	
Monthly Average		150	96	50		3.4		13.3		5.6
Standard Deviation		36	19	18		1		3		2



**Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar**

		C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL8 -1	03.10.2022	1.06	BQL	1.5	467
AL8 -2	06.10.2022	1.05	BQL	1.46	501
AL8 -3	10.10.2022	1.14	1.81	1.31	489
AL8 -4	13.10.2022	1.16	BQL	1.38	439
AL8 -5	17.10.2022	1.17	BQL	1.29	231
AL8 -6	20.10.2022	1.10	BQL	1.31	244
AL8 -7	25.10.2022	1.00	BQL	1.34	227
AL8 -8	28.10.2022	1.05	BQL	1.37	261
AL8 -9	29.10.2022	1.02	BQL	1.29	234
<b>Monthly Average</b>		<b>1.08</b>	<b>-</b>	<b>1.36</b>	<b>344</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.08</b>	<b>125</b>

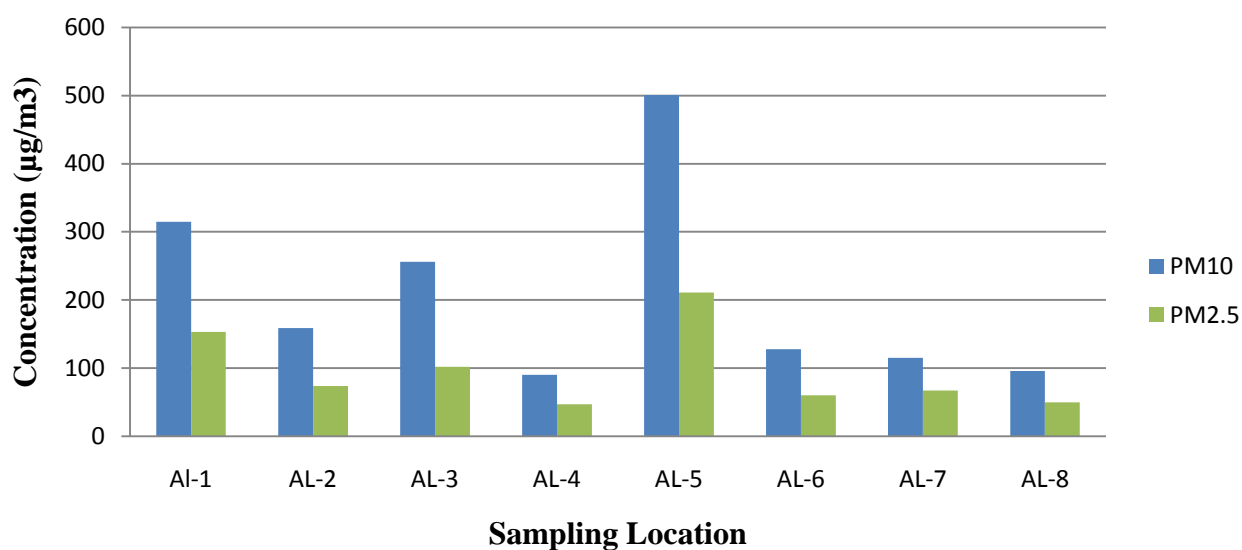
\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

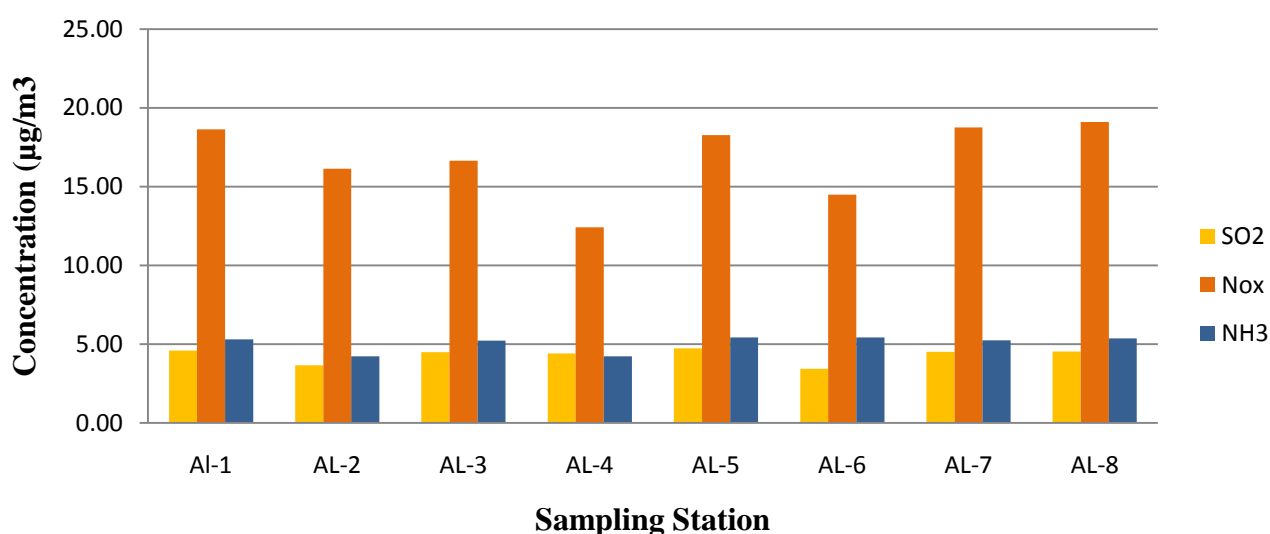
At Signal Building, Vadinar the mean TSPM value was 150 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 96 µg/m<sup>3</sup> which was boundary line of the permissible limit, the mean PM<sub>2.5</sub> value was 50 µg/m<sup>3</sup> which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were 3.4 µg/m<sup>3</sup>, 13.3 µg/m<sup>3</sup> and 5.6 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.08 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.36 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

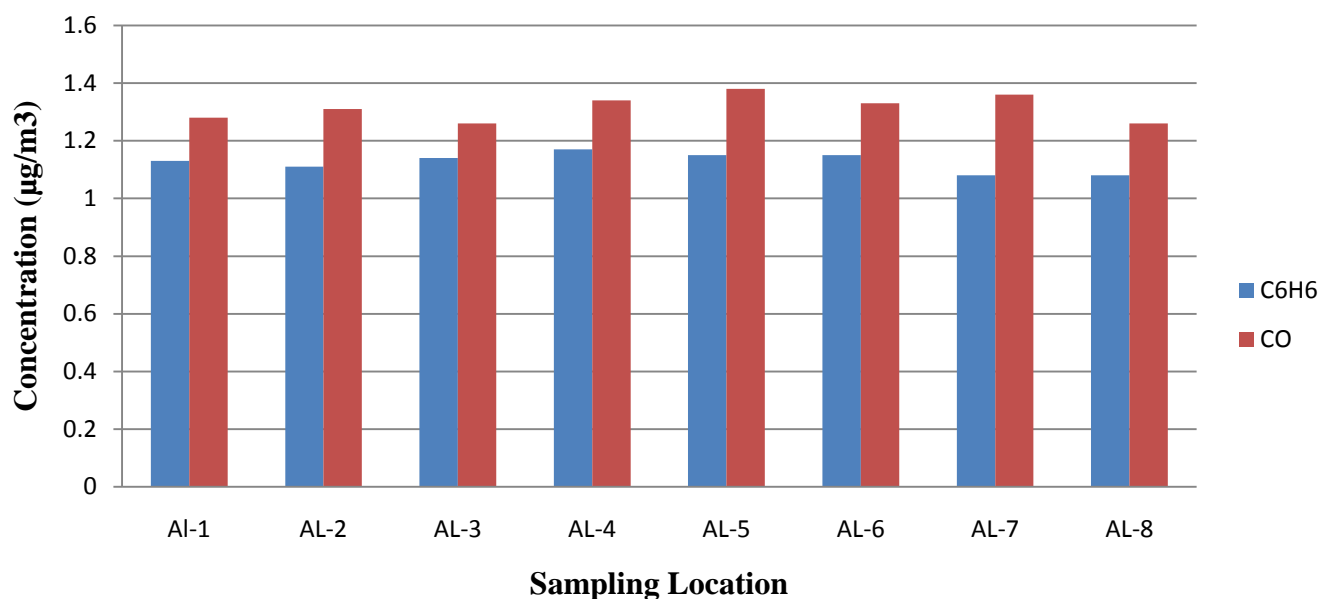
**Fig. No:-1 Average ambient air quality (PM) month of October-2022 at DPA and Vadinar Sampling Station**



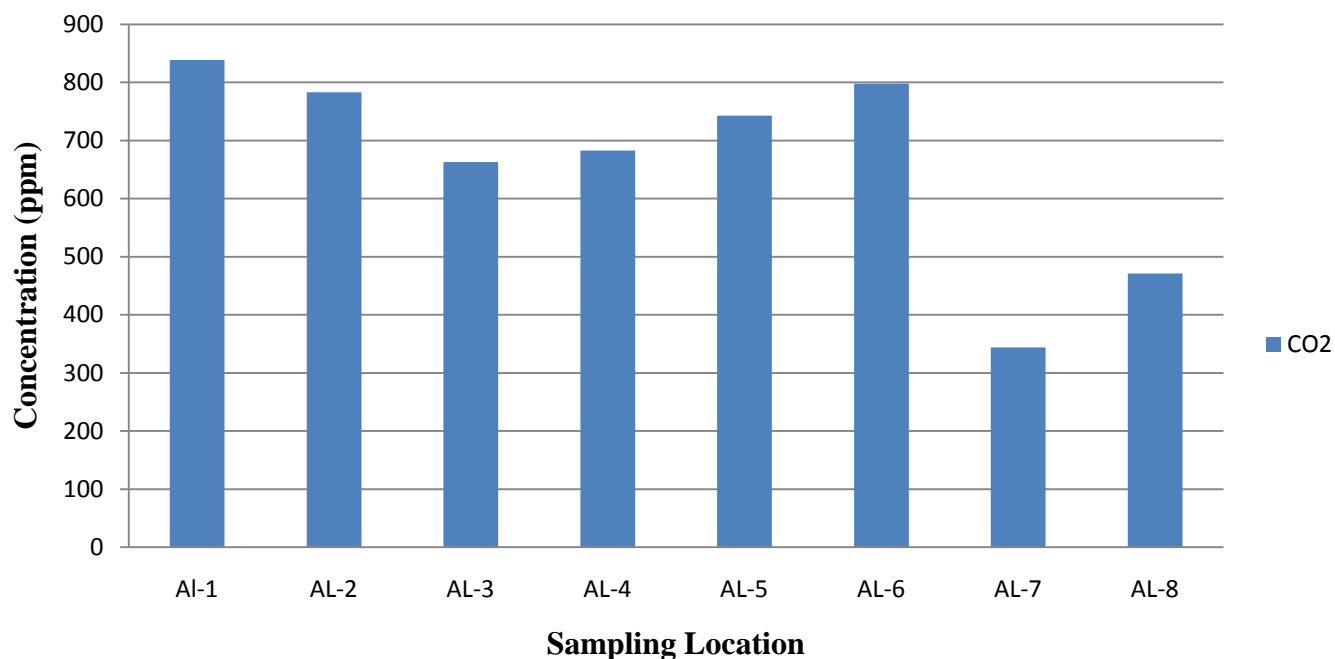
**Fig. No:-2. Average ambient air quality (Gaseous) month of October-2022 at DPA and Vadinar sampling location**



**Fig. No:-3. Average ambient air quality (Gaseous) month of October-2022 at DPA and Vadinar sampling location**



**Fig. No:-4. Average ambient air quality (Gaseous) month of October-2022 at DPA and Vadinar sampling location**



### 2.3 Observations and Conclusion

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Total Suspended Particulate matter as TSPM, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations like Near Coal storage area, Marine Bhavan and Estate Office and Oil Jetty.

The concentration of PM<sub>10</sub> slightly exceeded at Tuna Port while the mean concentration of PM<sub>2.5</sub> was 60 µg/m<sup>3</sup> which was within the limit. At Gopalpuri location concentration of monitored parameters of ambient air quality were found within the limit.

The mean concentration of PM<sub>10</sub> and PM<sub>2.5</sub> were slightly exceeded at Admin building Vadinar & at Signal building Vadinar were within the permissible limit.

## CHAPTER-3

### METEOROLOGICAL OBSERVATIONS

#### **4.1 Meteorological Data**

Automatic Weather station (ID KAZPHOEN424) have been installed in Seva Sadan-3 at the Deendayal Port which records the data on Temperature ( $^{\circ}\text{C}$ ), Relative Humidity (%), Wind speed (m/s), Wind Direction ( $^{\circ}$ ), Solar radiation ( $\text{w/m}^2$ ) and Rainfall mm.

Meteorological factors play an important role in environmental pollution studies particularly in pollutant transport irrespective of their entry into the environment. The wind speed and direction play a major role in dispersion of environment pollutants. Effects of pollution on receptors animate and inanimate depends on atmospheric condition.

##### **Temperature**

At Deendayal Port, the day time temperature was found range  $23.2\text{--}35.1^{\circ}\text{C}$ . The average day time temperature was  $29.87^{\circ}\text{C}$ . The night time temperature was range from  $23.4\text{--}32.5^{\circ}\text{C}$ . The mean night time temperature recorded was  $27.91^{\circ}\text{C}$ .

##### **Solar Radiation**

The mean Solar Radiation in October month was  $185.99 \text{ w/m}^2$ . The maximum solar radiation was recorded  $856.7 \text{ w/m}^2$  in 1<sup>st</sup> October, 2022 and the minimum solar radiation was recorded  $1.106 \text{ w/m}^2$  in 29<sup>th</sup> October, 2022.

##### **Rainfall**

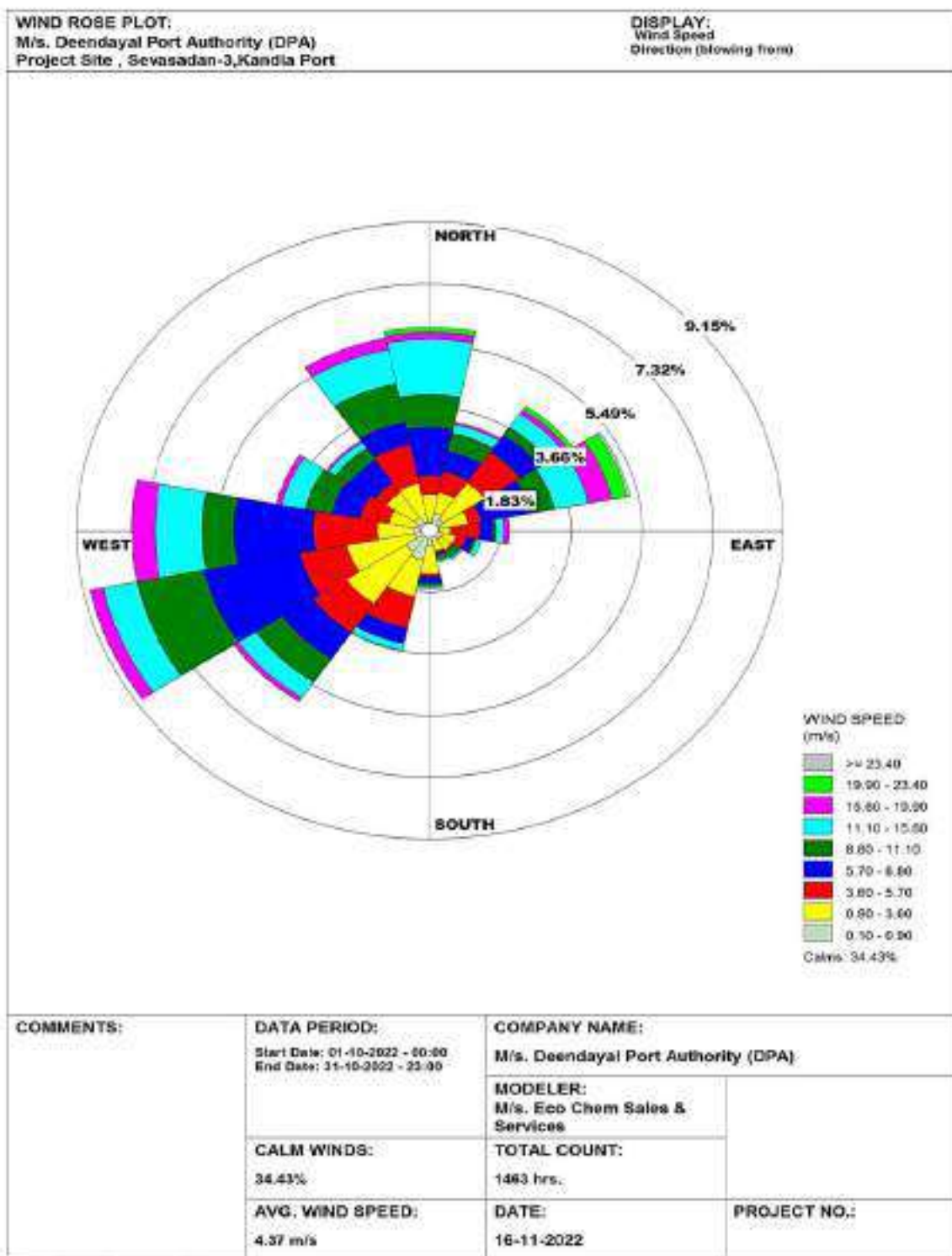
Rain fall of October month was recorded 0.00 mm.

##### **Relative Humidity**

The mean Relative humidity was 74.90 % for the month of October. Maximum Relative humidity was recorded 98.0 % and minimum Relative humidity was recorded 30.0 %.

##### **Wind Velocity and Wind Direction**

Velocity and direction of wind have a significant role in the dispersion of air borne materials and therefore determines the air quality of the area. The average wind velocity for the entire month of October was 1.22 m/s. Maximum wind velocity was recorded 6.50 m/s. The wind direction was mostly West-South.



## CHAPTER-4

### DRINKING WATER QUALITY MONITORING



#### 4.0 Drinking Water Quality Monitoring

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

**Table No:-10. Drinking Water Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude
1.	Nirman Building	DL-1	23° 0' 27"N	70° 13' 21"E
2.	P & C Building	DL-2	23° 0' 33"N	70° 13' 20"E
3.	North Gate	DL-3	23° 0' 26.97"N	70° 13' 21.87"E
4.	KPT-Canteen	DL-4	23° 2' 17.2674"N	70° 13' 18.2814"E
5.	West Gate	DL-5	23° 59' 40.48"N	70° 12' 50.96"E
6.	Wharf Area	DL-6	22° 59' 52.2"N	70° 13' 22.95"E
7.	Sevasadan-3	DL-7	23° 0' 22.55"N	70° 13' 15.34"E
8.	Workshop	DL-8	23° 0' 33.74"N	70° 13' 20.05"E
9.	Custom Building	DL-9	23° 1' 8.70"N	70° 12' 52.0"E
10.	Kandla Colony	DL-10	23° 11' 14.9"N	70° 12' 48.4"E
11.	KPT Hospital	DL-11	23° 1' 5.02"N	70° 12' 44.38"E
12.	A.O. Building	DL-12	23° 3' 42.89"N	70° 8' 41.5"E
13.	Gopalpuri School	DL-13	23° 5' 1.03"N	70° 7' 55.42"E
14.	Gopalpuri Guest House	DL-14	23° 4' 43.14"N	70° 7' 51.92"E
15.	E-Type Quarters	DL-15	23° 4' 59.90"N	70° 7' 56.72"E
16.	F-Type Quarters	DL-16	23° 4' 38.45"N	70° 8' 8.63"E
17.	Gopalpuri Hospital	DL-17	23° 4' 54.09"N	70° 8' 7.5"E
18.	Tuna Port	DL-18	23° 58' 23.06"N	70° 5' 35.6"E
19.	Vadinar Jetty	DL-19	22° 25' 51.73"N	69° 41' 36.62"E
20.	Vadinar Colony	DL-20	22° 30' 26.25"N	69° 39' 45.03"E

#### **4.1 Drinking Water Monitoring Methodology**

Samples for physico-chemical analysis were collected in 2 Carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS: 3025 Part-1, analysis was done as per IS: 3025/APHA standard methods and, the analysis results compare with IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate, Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (CFU) .

#### **4.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 11 to Table No. 17

**Table 11: Drinking Water Quality Monitoring Parameters for Nirman Building, P & C Building and Main Gate (North) at Kandla.**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C Building	Main Gate North	Acceptable Limits as per IS 10500 :2012 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.35	7.45	7.36	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	730	770	740	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1279	1341	1298	NS*	NS*
7	Biochemical Oxygen	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	375.84	395.88	390.87	250	1000
9	Ca as Ca	mg/l	36.87	36.07	34.47	75	200
10	Mg as Mg	mg/l	57.83	63.18	61.72	30	100
11	Total Hardness	mg/l	330	350	340	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.32	1.28	1.37	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	36.01	32.83	34.95	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.16	1.23	4.21	45	No Relaxation
17	Salinity	‰	0.68	0.72	0.71	NS*	NS*
18	Sodium as Na	mg/l	93.00	103.10	94.50	NS*	NS*
19	Potassium as K	mg/l	3.04	4.50	3.00	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/10 Oml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Table 12: Drinking Water Quality Monitoring Parameters for Canteen, West Gate – I & Wharf Area at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per IS 10500 :	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.51	7.33	7.51	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	780	750	780	500	2000
3	Turbidity	NTU	1	1	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1352	1316	1349	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	380.85	365.81	360.80	250	1000
9	Ca as Ca	mg/l	35.27	36.07	37.68	75	200
10	Mg as Mg	mg/l	68.53	63.18	57.35	30	100
11	Total Hardness	mg/l	370	350	330	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.25	1.27	1.22	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	39.19	34.95	40.25	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	3.27	2.18	5.22	45	No Relaxation
17	Salinity	‰	0.69	0.66	0.65	NS*	NS*
18	Sodium as Na	mg/l	104.80	103.80	104.30	NS*	NS*
19	Potassium as K	mg/l	4.86	4.76	3.90	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 13: Drinking Water Quality Monitoring Parameters for Sewa sadan-3, Workshop I and Custom Building at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.53	7.42	7.32	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	760	770	710	500	2000
3	Turbidity	NTU	0	0	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1324	1352	1242	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	355.79	370.82	320.71	250	1000
9	Ca as Ca	mg/l	38.48	36.07	36.87	75	200
10	Mg as Mg	mg/l	59.29	65.61	57.83	30	100
11	Total Hardness	mg/l	340	360	330	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.25	1.41	1.24	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	36.01	29.66	34.95096	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL		NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	2.98	4.21	3.63	45	No Relaxation
17	Salinity	‰	0.64	0.67	0.58	NS*	NS*
18	Sodium as Na	mg/l	102.80	103.70	73.50	NS*	NS*
19	Potassium as K	mg/l	3.03	3.53	2.75	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 14: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla and A.O. Building at Gandhidham.**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 :
1	pH	-	7.41	7.28	7.25	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	730	660	700	500	2000
3	Turbidity	NTU	1	1	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1282	1159	1240	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	330.74	310.69	385.86	250	1000
9	Ca as Ca	mg/l	34.47	36.07	38.48	75	200
10	Mg as Mg	mg/l	56.86	53.46	54.43	30	100
11	Total Hardness	mg/l	320	310	320	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.18	1.12	1.41	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	36.01008	39.18744	41.30568	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	2.32	3.12	1.02	45	No Relaxation
17	Salinity	‰	0.60	0.56	0.70	NS*	NS*
18	Sodium as Na	mg/l	101.30	113.40	101.90	NS*	NS*
19	Potassium as K	mg/l	3.81	3.13	2.45	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 15: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House) and E - Type Quarter at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.23	7.21	7.31	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	670	720	740	500	2000
3	Turbidity	NTU	0	0	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1164	1268	1308	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	320.71	330.74	340.76	250	1000
9	Ca as Ca	mg/l	39.28	40.08	41.68	75	200
10	Mg as Mg	mg/l	61.24	55.89	57.35	30	100
11	Total Hardness	mg/l	350	330	340	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.37	1.47	1.29	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	42.3648	36.01008	34.95096	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.31	2.18	1.09	45	No Relaxation
17	Salinity	‰	0.58	0.60	0.62	NS*	NS*
18	Sodium as Na	mg/l	108.20	109.50	104.40	NS*	NS*
19	Potassium as K	mg/l	2.52	3.86	2.96	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 16: Drinking Water Quality Monitoring Parameters for F-Type Quarter, Hospital Gopalpuri and Tuna Port.**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.29	7.33	7.55	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	730	700	980	500	2000
3	Turbidity	NTU	1	0	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1270	1240	1706	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	325.72	335.75	405.90	250	1000
9	Ca as Ca	mg/l	40.88	39.28	63.33	75	200
10	Mg as Mg	mg/l	55.40	63.67	49.09	30	100
11	Total Hardness	mg/l	330	360	360	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.10	1.39	1.42	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	40.24656	42.3648	187.46424	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.31	1.52	5.22	45	No Relaxation
17	Salinity	‰	0.59	0.61	0.73	NS*	NS*
18	Sodium as Na	mg/l	108.40	104.50	105.90	NS*	NS*
19	Potassium as K	mg/l	3.58	3.35	3.85	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



**Table 17: Drinking Water Quality Monitoring Parameters for Vadinar Jetty and Port Colony at Vadinar.**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.36	7.28	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	300	280	500	2000
3	Turbidity	NTU	1.00	1.00	1	5
4	Odor	-	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	5	15
6	Conductivity	µs/cm	559	280	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	145.32	135.30	250	1000
9	Ca as Ca	mg/l	36.07	36.87	75	200
10	Mg as Mg	mg/l	36.45	40.82	30	100
11	Total Hardness	mg/l	240	260	200	600
12	Iron as Fe	mg/l	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	1.15	1.09	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	4.13	3.71	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	1.38	1.60	45	No Relaxation
17	Salinity	‰	0.26	0.24	NS*	NS*
18	Sodium as Na	mg/l	108.5	110.8	NS*	NS*
19	Potassium as K	mg/l	2.35	2.89	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **4.3 Results & Discussion**

The colour of all drinking water samples was found Colourless and odour of the samples also agreeable. All parameters were found within the specified limit as per the Drinking water Standard.

#### **pH**

The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. At DPA Site the pH values for drinking water samples ranged from 7.21-7.55 and mean value was 7.36 while at Vadinar pH ranged from 7.28-7.36 and mean value was 7.32. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Turbidity**

The selected drinking water sample location turbidity range from 0-1NTU at all location of DPA and Vadinar in month of October. The Turbidity values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Total Dissolved Solids (TDS)**

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc.

TDS values at DPA varied between 660-980 mg/l. The average TDS value was found 745.0 mg/l. The minimum value for TDS was 660 mg/l at Hospital Gopalpuri and maximum was 980 mg/l at Tuna Port while at Vadinar TDS ranged from 280-300 mg/l and mean was 290.0 mg/l. The TDS values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of October DPA ranged from 1159.0  $\mu\text{S}/\text{cm}$  at Hospital Gopalpuri to 1706.0  $\mu\text{S}/\text{cm}$  at Tuna Port and mean value was 1305.0  $\mu\text{S}/\text{cm}$  while at Vadinar ranged from 280-559  $\mu\text{S}/\text{cm}$  and mean was 419.5  $\mu\text{S}/\text{cm}$ .

## **BOD**

BOD value in the studied area of DPA and Vadinar was found Below Quantification Limit (<2.0 mg/l). IS 10500:2012 does not show any standard values for BOD in drinking water.

## **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. The Chloride value in the studied area of DPA ranged from 310.69-405.90 mg/l. The mean value was 355.79 mg/l. The minimum chloride was 310.69 mg/l at Hospital Gopalpuri and maximum was 405.90 mg/l at Tuna Port while at Vadinar location chloride ranged from 135.30-145.32 mg/l and mean was 140.31 mg/l. The Chloride was found within the Permissible limit of the Drinking Water Standard.

## **Calcium**

Calcium is most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases.

The Calcium value in the studied area of DPA ranged from 34.47-63.33 mg/l. The mean value was 38.97 mg/l. The minimum calcium was 34.47 mg/l at Port Colony and maximum was 63.33 mg/l at Tuna Port while at Vadinar location Calcium ranged from 36.07-36.87 and mean was 36.47 mg/l. All the locations had calcium within the prescribed limits of 75-200 mg/L.

## **Magnesium**

The magnesium value in the studied area of DPA ranged from 49.09-68.53 mg/l. The mean value was 59.0 mg/l. The minimum magnesium was 49.09 mg/l at Tuna Port and maximum was 68.53 mg/l at Canteen while at Vadinar location magnesium ranged from 36.45-40.82 and mean was 38.64 mg/l. All the locations had magnesium within the prescribed limits of 30-100 mg/L.

## **Total Hardness**

Total Hardness value in the studied area of DPA ranged from 310.0 mg/l at DPA Hospital to 370.0 mg/l at Canteen and mean value was 340.0 mg/l while at Vadinar location total hardness ranged from 240.0-260.00 mg/l and mean was 250.0 mg/l. The values of total

hardness were found within the Permissible limit of the Drinking Water Standard (200-600 mg/L). These results clear, that hardness of water is according to the IS standards and it is not harmful for local inhabitants.

### **Iron**

Iron values in the studied area of DPA & Vadinar were Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards are 0.3 mg/L.

### **Fluoride**

Fluoride value in the studied area of DPA varied between 1.10-1.42 mg/l and mean was 1.28 mg/l. The minimum value was 1.10 mg/ at F-Type Quarter and maximum was 1.42 mg/l at Tuna Port while at Vadinar location fluoride ranged from 1.09-1.15 mg/l and mean was 1.11 mg/l. The Fluoride values were well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphate**

Sulphate value in the studied area of DPA varied between 29.66–187.46 mg/l and mean was 45.48 mg/l. The minimum value was 29.66 mg/ at Workshop and maximum was 187.46 mg/l at Tuna Port while at Vadinar location sulphate ranged from 3.71-4.13 mg/l and mean was 3.92 mg/l. All the sampling points showed sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

The all values of Nitrates were well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected at DPA ranged from 0.56 ‰ at Hospital Gopalpuri to 0.73 ‰ at Tuna Port and average salinity was 0.64 ‰ while at Vadinar sampling location salinity ranged from 0.24-0.26 ‰. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected at DPA ranged from 73.50 - 113.40 mg/l and average was 102.28 mg/l while at Vadinar sodium ranged from 108.50- 110.8 mg/l. Potassium salts ranged at DPA ranged from 2.45 to 4.86 mg/l while average was 3.49 mg/l while at Vadinar sampling location ranged from 2.35-2.89 mg/l and mean was 2.62 mg/l. There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter (E-coli and total coliform) at all location shows that Bacteria were not detectable. This shows that drinking water samples were safe for human consumption as per tested parameters.

## **4.4 Conclusions**

These results were compared with permissible limits as prescribed in IS 10500:2012 – Drinking Water Specification. It was seen from the analysis data that during the study period at selected sampling location the water was safe for human consumption as per analyzed parameters at all drinking water monitoring stations.

## **CHAPTER-5**

### **NOISE MONITORING**

## 5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 5.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 5.2 Results

**Table 18: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	6:00 am to 10:00 PM	10:00PM to 6:00 AM
1	Marine Bhavan	72.8	64.4
2	Nirman Building 1	69.7	63.3
3	Tuna Port	71.2	55.4
4	Main Gate North	71.0	61.5
5	West Gate I	71.7	58.5
6	Canteen Area	68.3	59.2
7	Main Road	70.3	64.0
8	ATM Building	71.8	62.9
9	Wharf Area /Jetty Area	72.6	64.7
10	Port & Custom Office	63.8	53.9
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	57.2	53.6
12	Nr. Port Colony, Vadinar	58.4	56.9
13	Nr. Vadinar Jetty	58.0	57.5

### 5.3 Conclusions

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships.

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 63.8 dB(A) to 72.8 dB(A) while at Vadinar port 3 location ranged from 57.2 dB(A) to 58.4 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 53.9 dB to 64.7 dB(A) while at Vadinar port ranged from 53.6 dB (A) to 57.5 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.



## **CHAPTER-6**

### **SOIL MONITORING**

## 6.0 Soil Monitoring

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

**Table No.:-19. Soil Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Tuna Port	SL-1	22° 58' 10.18"N	70° 6' 3.7"E	Near main gate of Port
2.	IFFCO Plant	SL-2	23° 26' 8.37"N	70° 13' 4.4"E	10 m away from main gate
3.	Khori creek	SL-3	22° 58' 10.18"N	70° 6' 3.7"E	Sand from creek after tide
4.	Nakti Creek	SL-4	23° 2' 1.10"N	70° 9' 33.6"E	
5.	DPA admin site	SL-5	22° 26' 30.9"N	69° 40' 37.03"E	Vadinar
6.	DPA colony	SL-6	22° 23' 57.09"N	69° 42' 49.42"E	

## 6.1 Methodology

The soil samples were collected in the month of October 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

## 6.2 Results

**Table-20: Chemical Characteristics of Soil in the Study Area for Tuna port, IFFCO, Khori Creek, Nakti Creek, DPA admin site, DPA colony.**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main	Sand from creek after tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	8.60	8.20	7.90	7.80	6.50	7.10
3	Electrical Conductivity	µs/cm	10240.0	14400.0	9,180.00	17,290.0	910.0	522.0
4	Phosphorus	mg/kg	11.2	10.62	12.50	18.20	6.00	4.80
5	Moisture	%	16.76	17.5	2.02	17.70	7.20	10.10
6	Total Organic	%	1.56	0.1	0.30	0.39	0.11	0.79
7	Alkalinity	mg/kg	200.0	800.0	700.0	500.0	500.0	800.0
8	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
9	Sulphate	mg/kg	215.00	282.00	189.90	210.80	52.0	50.0
10	Chloride	mg/kg	1878.0	2660.0	1,347.00	1,790.00	106.00	124.00
11	Calcium	mg/kg	2,124.00	2,424.00	2,004.00	2,264.00	1,062.00	1,609.00
12	Sodium	mg/kg	501	516.0	320.00	493.00	144.00	307.20
13	Potassium	mg/kg	468	444	293.70	370.00	26.66	29.28
14	Copper as Cu	mg/kg	25.9	20.1	15.40	16.90	54.10	31.60
15	Lead as Pb	mg/kg	7	8	5.20	25.50	BDL	BDL
16	Nickel as Ni	mg/kg	24.90	23.40	24.40	23.90	19.90	15.80
17	Zinc as Zn	mg/kg	43.5	67.50	39.70	50.00	25.70	31.80
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BDL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg)

### 6.3 Discussion

- DPA Kandla soil sampling data shows that value of pH ranges from 7.80 at Nakti Creek to 8.60 at Tuna Port while the average value was 8.13. At Vadinar sampling location pH were 6.50 at DPA Admin site and 7.10 at DPA Colony.
- The conductivity of DPA Kandla soil sample ranged from 9180.0  $\mu\text{S}/\text{cm}$  at Khori Creek (Sand from creek after tide) to 17290  $\mu\text{S}/\text{cm}$  at Nakti Creek (Sand from creek after tide) and mean was 12777.50  $\mu\text{S}/\text{cm}$  while Vadinar soil sampling location conductivity were 910  $\mu\text{S}/\text{cm}$  at DPA Admin Site and 522  $\mu\text{S}/\text{cm}$  at DPA Colony site.
- Total organic Carbon of DPA Kandla soil sample ranged from 0.1 % at IFFCO Plant to 1.56 % at Tuna Port (Near Main Gate) and mean was 0.59 % while Vadinar soil sample were 0.11% at DPA admin and 0.79 % at DPA Colony.
- The concentration of Phosphorus in the soil samples of DPA Kandla varies from 11.2 mg/kg at Tuna Port (Near Main Gate) and 18.20 mg/kg at Nakti Creek (Sand from creek after tide) and mean was 13.13 mg/kg while the Vadinar soil sample for Phosphorus were 4.80 mg/kg at DPA Colony and 6.00 mg at DPA Admin Site.
- Chloride in soil sample of DPA ranged from 1347.00 mg/kg at Khori Creek (Sand from creek after tide) to 2660 mg/kg at IFFCO Plant while Vadinar soil sample were 106 mg/kg at DPA admin and 124 mg/kg at DPA Colony.
- The Concentration of Potassium in the soil samples of DPA Kandla ranged from 293.70 mg/kg at Khori creek and 468 mg/kg at Tuna Port and mean was 393.93 mg/kg while the Vadinar soil sample for Potassium were 26.66 mg/kg at DPA Admin Site and 29.28 mg/kg at DPA Colony.
- The concentration of Sodium in the soil samples of DPA Kandla ranged from 320.0 mg/kg at Khori creek and 516.0 mg/kg at IFFCO Plant and mean was 457.50 mg/kg while the Vadinar soil sample for Sodium were 144.00 mg/kg at DPA Admin Site and 307.20 mg/kg at DPA Colony.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) were coastal soil; where as other locations are inland locations and have different chemical properties.

### Heavy Metals in the Soil

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port Authority Kandla and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### 6.4 Conclusion

The soils of Deendayal Port Authority Kandla and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

## **CHAPTER-7**

### **SEWAGE TREATMENT PLANT MONITORING**

## 7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guidelines of State Pollution Control Board and other statutory bodies.

### 7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

**Table No. 21. Sewage Treatment Plant**

Sr. No.	Location of STP	Types of Treatment	STP Capacity	Treated water Utilization
1.	Gopalpuri Township	MBBR	450 KLD	Plantation and Gardening
2.	Deendayal Port, Kandla	MBBR	600 KLD	Discharge to marine through pipeline, Plantation, Gardening
3.	Vadinar Port Colony	MBBR	1.5 MLD	Plantation and Gardening

## 7.2 Results

**Table 22: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	01.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.58	7.35	6.5 - 8.5
2	Total Suspended Solids	mg/l	117.8	59.9	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	110	40.0	100
5	BOD @ 27 °C	mg/l	34.0	11.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l		12.0	
7	MLVSS	%		88.0	

**Table 23: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	10.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.45	7.25	6.5 - 8.5
2	Total Suspended Solids	mg/l	105.4	50.9	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	92	32.0	100
5	BOD @ 27 °C	mg/l	28.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l		12.0	
7	MLVSS	%		88.0	

**Table 24: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	17.10.2022
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Sr. No.	Parameters	Unit	Results		CPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.48	7.27	6.5 - 8.5
2	Total Suspended Solids	mg/l	97.6	37.5	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	90	30	100
5	BOD @ 27 °C	mg/l	29.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	20.0		
7	MLVSS	%	98.0		

**Table 25: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	28.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.53	7.35	6.5 - 8.5
2	Total Suspended Solids	mg/l	95.8	38.1	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	80	26	100
5	BOD @ 27 °C	mg/l	22.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	33.0		
7	MLVSS	%	99.0		



**Table 26: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	17.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.54	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	100	41.8	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	82	40	100
5	BOD @ 27 °C	mg/l	22.0	11.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	8.0		
7	MLVSS	%	98.0		

**Table 27: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	28.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.48	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	110.2	42.1	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	78	40	100
5	BOD @ 27 °C	mg/l	24.0	12.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	30.0		
7	MLVSS	%	99.0		

**Table 28: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	01.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.35	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	97.5	37.1	100
3	Residual Chlorine	mg/		<0.5	-
4	COD	mg/l	60.0	40	100
5	BOD @ 27 °C	mg/l	21.0	12.0	30

**Table 29: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	10.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.45	7.33	6.5 - 8.5
2	Total Suspended Solids	mg/l	88.1	36.6	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	80	20	100
5	BOD @ 27 °C	mg/l	23.0	6.0	30

**Table 30: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	17.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.54	7.32	6.5 - 8.5
2	Total Suspended Solids	mg/l	100	41.8	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	90	60	100
5	BOD @ 27 °C	mg/l	30.0	18.0	30

**Table 31: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	28.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.54	7.36	6.5 - 8.5
2	Total Suspended Solids	mg/l	88.1	39.5	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	70	30	100
5	BOD @ 27 °C	mg/l	20.0	8.0	30

**Table No. 32. General Standards for discharge of Environmental Pollutant Part-A**

Sr. No.	Parameter	Inland Surface Water	Land Irrigation	Marine Coastal Areas
1.	pH	5.5-9.0	5.5-9.0	5.5-9.0
2.	Total Suspended Solids (mg/l)	100	200	100
3.	Residual Chlorine (mg/l)	1.0	-	1.0
4.	BOD (mg/l)	30	100	100
5.	COD (mg/l)	250	-	250

**Sources:-CPCB****7.3 Results & Discussion**

The STP Sample carried out to evaluate the efficiency and performance of the wastewater treatment plant at Gopalpuri, Kandla and Vadinar STP. The performance of these plants is an essential parameter to monitor because the treated sewage water is discharged for irrigation purposes and discharge into marine. Wastewater samples were collected from different unit operations of the plant i.e, the inlet, aeration tank and the final treated outlet. These samples were analyzed for various physico-chemical characteristics such as pH, TSS, Residual Chlorine, COD, BOD, MLSS and MLVS. The sampling of Gopalpuri STP was not done as per STP monitoring plan 1<sup>st</sup> Week dated 01.10.2022 and 2<sup>nd</sup> Week Dated 10.10.2022 as it was under construction.

- The final treated outlet observed pH values were within the allowed range at STP Gopalpuri, STP Kandla & STP Vadinar ranged from 7.28 -7.32, 7.23-7.35 & 7.21-7.36 respectively. The wastewater treatment makes it suitable for irrigation. These values are below the allowed limit of the GPCB.
- The final treated outlet observed Total suspended solid values at Gopalpuri, DPA Kandla & Vadinar ranged from 41.80-42.10 mg/l, 37.50-59.90 mg/l & 36.60-41.80 mg/l respectively. These values are below the allowed limit of the GPCB.
- The final treated outlet observed Residual Chlorine values were <0.5 at Gopalpuri, DPA Kandla & Vadinar. These values are below the allowed limit of the CPCB.

- The final treated outlet observed COD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 40.0-40.0 mg/l, 26.0-40.0 mg/l & 20.0-60.0 mg/l respectively. These values are below the allowed limit of the CPCB.
- The main focus of wastewater treatment plants is supposed to reduce the BOD in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The final treated outlet observed BOD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 11.0-12.0 mg/l, 8.0-11.0 mg/l & 6.0-18.0 mg/l respectively. These values are below the allowed limit of the CPCB. .

#### **7.4 Conclusions:**

All parameters for STP outlet are within limit prescribed by CPCB. After the final treatment, it is found that the treated water is satisfactory.

## **CHAPTER-8**

### **MARINE WATER MONITORING**

## **8.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of ‘green thinking’. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the “fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”.

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at “integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources.” The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 05<sup>th</sup> & 06<sup>th</sup> October-2022 in harbor regions of DPA & Vadinar during Neap tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 12<sup>th</sup> & 16<sup>th</sup> October-2022 in harbor regions of DPA & Vadinar during Spring tide period first quarter of Lunar Cycle.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbor area and two stations in Nakti creek and one station in Khori creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation

of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

### Sampling Locations

Offshore monitoring requirement	Number of locations
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khorī creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### 8.1 Marine Water Quality and Results

Marine water quality of marine waters of Deendayal Port Harbor waters, Khorī & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 33 to 40. During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.



**Table 33: Marine Water Quality Monitoring Parameters for Location Near DPA Colony**

Sr. No.	Parameters	Unit	Kandla Creek Near DPA Colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.44	7.38	7.51	7.42
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	31.9	32.0	35.3	34.9
5	Turbidity	NTU	49	43	52	48
6	Total Dissolved Solids	mg/l	31916	30489	30236.0	31682.0
7	Total Suspended Solids	mg/l	568	537	532.9	629.5
8	Total Solids	mg/l	32484	31026	30768.9	32311.5
9	DO	mg/l	5.9	5.8	5.6	5.4
10	COD	mg/l	94.0	82.0	90.0	89.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.46	1.36	1.76	1.89
13	Phosphate	mg/l	0.30	0.30	0.21	0.20
14	Sulphate	mg/l	3262	3362	3019	2713
15	Nitrate	mg/l	4.28	1.52	2.60	2.83
16	Nitrite	mg/l	BQL	BQL	0.018	0.015
17	Calcium	mg/l	641.28	721.44	601.2	681.36
18	Magnesium	mg/l	1676.7	1676.7	1628.1	1603.8
19	Sodium	mg/l	7269.0	7901.0	7380.0	8302.0
20	Potassium	mg/l	310.9	336.1	330.0	346.0
21	Iron	mg/l	2.24	BQL	BQL	0.1
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	0.1	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 34: Marine Water Quality Monitoring Parameters for Location Near Passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.53	7.45	7.38	7.45
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	32.8	31.9	33.9	33.5
5	Turbidity	NTU	46	41	47	43
6	Total Dissolved Solids	mg/l	35931	34021	36225.0	32423.0
7	Total Suspended Solids	mg/l	591	491	664.5	601.3
8	Total Solids	mg/l	36522	34512	36889.5	33024.3
9	DO	mg/l	5.6	5.3	5.5	5.7
10	COD	mg/l	96.0	106.0	92.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.45	1.67	1.37	1.86
13	Phosphate	mg/l	0.60	0.18	0.11	0.24
14	Sulphate	mg/l	2940	2628	2782	2690
15	Nitrate	mg/l	1.02	0.51	2.89	2.81
16	Nitrite	mg/l	BQL	BQL	0.021	0.019
17	Calcium	mg/l	601.20	641.28	761.52	721.44
18	Magnesium	mg/l	1773.9	1701	1603.8	1676.7
19	Sodium	mg/l	7771.0	7544.0	8076.0	7645.0
20	Potassium	mg/l	355.8	329.2	329.0	327.0
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Nitrite: 0.05mg/l Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 35: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.38	7.27	7.52	7.37
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	33.0	33.8	35.3	33.9
5	Turbidity	NTU	47	46	43	40
6	Total Dissolved Solids	mg/l	37001	32999	38933.0	40080.0
7	Total Suspended Solids	mg/l	529	580	562.9	625.5
8	Total Solids	mg/l	37530	33579	39495.9	40705.5
9	DO	mg/l	5.4	5.6	5.4	5.3
10	COD	mg/l	86.0	94.0	76.0	70.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.36	1.54	1.96	1.80
13	Phosphate	mg/l	0.33	0.64	0.48	0.11
14	Sulphate	mg/l	2429	1628	2529	1651
15	Nitrate	mg/l	0.94	3.56	2.46	2.83
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	721.44	561.12	601.2	641.28
18	Magnesium	mg/l	1603.8	1652.4	1725.3	1652.4
19	Sodium	mg/l	8752.0	8590.0	8658.0	8592.0
20	Potassium	mg/l	326.5	251.8	319.0	314.0
21	Iron	mg/l	BQL	1.68	0.1	1.2
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 36: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	Khori creek			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.51	7.55	7.47	7.25
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	33.6	33.2	33.5	33.0
5	Turbidity	NTU	41	38	41	39
6	Total Dissolved Solids	mg/l	30317	32240	35060.0	42810.0
7	Total Suspended Solids	mg/l	496	513	541.9	580.6
8	Total Solids	mg/l	30813	32753	35601.9	43390.6
9	DO	mg/l	5.5	5.7	5.5	5.7
10	COD	mg/l	68.0	60.0	85.0	82.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.36	1.62	1.80	1.61
13	Phosphate	mg/l	0.46	0.48	0.41	0.58
14	Sulphate	mg/l	1920	2204	1940	2046
15	Nitrate	mg/l	1.60	2.32	2.81	2.67
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	521.04	601.20	681.36	761.52
18	Magnesium	mg/l	1701	1701	1603.8	1603.8
19	Sodium	mg/l	8162.0	8150.0	8067.0	8323.0
20	Potassium	mg/l	313.9	304.2	304.0	310.0
21	Iron	mg/l	0.96	1.04	0.1	1.4
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 37: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.48	7.36	7.31	7.28
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	33.6	32.9	35.3	33.9
5	Turbidity	NTU	47	41	43	38
6	Total Dissolved Solids	mg/l	39489	37081	34974.0	31295.0
7	Total Suspended Solids	mg/l	610	566	695.3	667.4
8	Total Solids	mg/l	40099	37647	35669.3	31962.4
9	DO	mg/l	5.5	5.3	5.8	5.5
10	COD	mg/l	110.0	109.0	90.0	88.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.38	1.76	1.78	1.61
13	Phosphate	mg/l	0.42	0.13	0.91	0.46
14	Sulphate	mg/l	2392	2691	2116	2494
15	Nitrate	mg/l	4.21	1.16	2.89	2.46
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	561.12	681.36	601.2	561.12
18	Magnesium	mg/l	1749.6	1701	1749.6	1798.2
19	Sodium	mg/l	7926.0	7840.0	8704.0	8444.0
20	Potassium	mg/l	299.9	324.6	325.0	321.0
21	Iron	mg/l	0.57	BQL	BQL	0.1
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 38: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.32	Sampling not possible during Low Tide	7.32	Sampling not possible during Low Tide
2	Color	-	Agreeable		Agreeable	
3	Odor	-	Agreeable		Agreeable	
4	Salinity	‰	34.0		34.4	
5	Turbidity	NTU	46		42	
6	Total Dissolved Solids	mg/l	37870		43337.0	
7	Total Suspended Solids	mg/l	625		682.7	
8	Total Solids	mg/l	38495		44019.7	
9	DO	mg/l	5.7		5.7	
10	COD	mg/l	109.0		92.0	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	1.81		1.47	
13	Phosphate	mg/l	0.35		0.58	
14	Sulphate	mg/l	2898		2344	
15	Nitrate	mg/l	3.19		2.81	
16	Nitrite	mg/l	BQL		BQL	
17	Calcium	mg/l	761.52		681.36	
18	Magnesium	mg/l	1603.8		1652.4	
19	Sodium	mg/l	7280.0		7795.0	
20	Potassium	mg/l	325.0		348.0	
21	Iron	mg/l	BQL		1.1	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		BQL	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 39: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.42	7.31	7.42	7.31
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	32.8	32.1	33.5	33.0
5	Turbidity	NTU	42	48	45	37
6	Total Dissolved Solids	mg/l	30232	32299	31650.0	26111.0
7	Total Suspended Solids	mg/l	511	604	525.6	518.2
8	Total Solids	mg/l	30743	32903	32175.6	26629.2
9	DO	mg/l	5.3	5.1	5.4	5.3
10	COD	mg/l	94.0	90.0	94.0	98.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.56	1.44	1.56	1.44
13	Phosphate	mg/l	0.04	0.04	0.43	0.38
14	Sulphate	mg/l	3412	2843	3412	2843
15	Nitrate	mg/l	1.45	2.32	3.92	2.55
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	721.44	601.20	641.28	601.2
18	Magnesium	mg/l	1603.8	1628.1	1652.4	1725.3
19	Sodium	mg/l	7797.0	7368.0	7112.0	6960.0
20	Potassium	mg/l	321.0	348.0	326.1	320.0
21	Iron	mg/l	0.11	0.05	0.2	0.4
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 40: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr. Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.27	7.33	7.36	7.23
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	32.2	31.9	31.7	30.8
5	Turbidity	NTU	32	38	47	41
6	Total Dissolved Solids	mg/l	28887	31949	28106.0	29489.0
7	Total Suspended Solids	mg/l	531	510	530.7	607.2
8	Total Solids	mg/l	29418	32459	28636.7	30096.2
9	DO	mg/l	4.9	4.7	5.4	5.2
10	COD	mg/l	92.0	104.0	100.0	98.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.60	1.52	1.60	1.52
13	Phosphate	mg/l	0.06	0.06	0.62	0.55
14	Sulphate	mg/l	3125	2834	3125	2834
15	Nitrate	mg/l	0.73	0.36	3.62	3.07
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	521.04	681.36	721.44	641.28
18	Magnesium	mg/l	1749.6	1603.8	1676.7	1749.6
19	Sodium	mg/l	7683.0	7305.0	8478.0	8284.0
20	Potassium	mg/l	307.0	336.0	355.0	310.0
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l)



## **8.2 Results & Discussion for Marine water samples**

Marine water quality of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

### **pH**

During spring tide the pH values was ranged from 7.27-7.55 at DPA Kandla and 7.27-7.42 at Vadinar while during Neap Tide pH values was ranged from 7.25-7.52 at DPA Kandla and 7.31-7.42 at Vadinar.

### **Color and Odor**

All marine samples for Odor and Color were found agreeable at all sampling locations.

### **Turbidity**

During spring tide the Turbidity values was ranged from 38-49 NTU at DPA Kandla and 32-48 NTU at Vadinar while during Neap Tide Turbidity values was ranged from 38-52 NTU at DPA Kandla and 37-47 NTU at Vadinar. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity (Yap et al, 2011). Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler, 2004).

### **Total Dissolved Solids (TDS)**

TDS values in the studied area during Spring Tide varied between 30317- 39489 mg/l at DPA Kandla and 28887- 32299 mg/l at Vadinar while during Neap Tide TDS values was varied 30236-43337 mg/l at DPA Kandla and 26111-43337 mg/l at Near Vadinar.

### **Calcium**

Calcium value in the studied area during Spring Tide varied between 521.04-761.52 mg/l at DPA Kandla and 521.04-721.44 mg/l at Vadinar while during Neap Tide calcium values between 561.12-761.52 mg/l at DPA Kandla and 601.20-721.44 mg/l at Vadinar.

### **Magnesium**

Magnesium value in the studied area during Spring Tide varied between 1603.80-1773.90 mg/l at DPA Kandla and 1603.80-1749.60 mg/l at Vadinar while during Neap Tide magnesium values between 1603.80-1798.20 mg/l at DPA Kandla and 1652.4 -1749.60 at Vadinar. Calcium and magnesium both play an important role in antagonizing the toxic effects of various ions and neutralizing the excess acid produced (Narayan R. et. al., 2007)

### **Nitrate**

Nitrate value in the studied area during Spring Tide varied between 0.51-4.28 mg/l at DPA Kandla and 0.36-2.32 mg/l at Vadinar while during Neap Tide Nitrate values between 2.46-2.89 mg/l at DPA Kandla and 2.55-3.92 at Vadinar.

The variations were observed due to variation in phytoplankton excretion, oxidation of ammonia, reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007).

### **Iron**

Iron values in the studied area during Spring Tide ranged from 0.57-2.24 mg/l at DPA Kandla and 0.05-0.11mg/l at Vadinar while during Neap Tide ranged from 0.05-0.11 mg/l while during Neap Tide the iron values was varied 0.06-1.40 mg/l at DPA Kandla and 0.19 to 0.36 mg/l at Vadinar.

### **Sulphates**

Sulphate values in the studied area during Spring Tide ranged from 1628.0-3362.0 mg/l at DPA Kandla and 2834.0- 3412.0 mg/l at Vadinar while during Neap Tide the Sulphate values was varied 1651.0-3019.0 mg/l at DPA Kandla and 2834.0 -3412.0 mg/l at Vadinar.

### **Salinity**

Salinity values in the studied area during Spring Tide varied ranged 31.90 to 34.00 ‰ at DPA Kandla and 31.90 to 32.80 ‰ at Vadinar while during Neap Tide the Salinity values was varied 33.00 to 35.33 ‰ at DPA Kandla and 31.69 to 34.40 ‰ at Vadinar.

### **Sodium and Potassium Salts**

During Spring Tide the Sodium values ranged from 7269.0-8752.0 mg/l at DPA Kandla & 7305.0-7797.0 mg/l at Vadinar and Potassium salts ranged from 251.80-355.80 mg/l at DPA Kandla & 307.0-348.0 mg/l at Vadinar while during Neap Tide the Sodium values was

ranges from 7380.0-8704.0 mg/l at DPA Kandla & 6960.0-8478.0 mg/l at Vadinar and Potassium salts ranged from 304.0-348.0 mg/l at DPA Kandla & 310.0-355.0 mg/l at Vadinar.

## **DO**

The DO refers to the amount of oxygen dissolved in the water and it is particularly important in limnology {(aquatic ecology) (Weiss 1970)}. The fate and behavior of DO is of critical importance to marine organisms in determining the severity of adverse impacts (Best et al. 2007). The major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best et al. 2007). From the studied samples, DO in marine water during Spring Tide was found in ranges from 5.3-5.9 mg/l at DPA Kandla and 4.7-5.3 mg/l at Vadinar while during Neap Tide 5.3-5.8 mg/l at DPA Kandla and 5.2-5.4 mg/l at Vadinar.

## **BOD**

BOD in marine water at all sampling location in the studied samples were found <2.0 mg/l.

## **Heavy Metals in Marine Water**

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

## **9.3 Conclusion**

In the present study period marine water samples were analyzed and found inline as per Primary Water Quality criteria for class-IV WATERS (For Harbour Waters).

## CHAPTER-9

### MARINE SEDIMENT MONITORING

## **9.0 Marine Sediments**

The deep-sea ocean floor is made up of sediment. This sediment is composed of tiny particles such as fine sand, silt, clay, or animal skeletons that have settled on the ocean bottom. Over long periods of time, some of these particles become compressed and form stratified layers. Scientists that study these layers look at particle size, particle composition, and origin to help them create historical records of the deep ocean floor. This process is called weathering. Weathering can be either mechanical or chemical. Mechanical weathering can occur as ice, wind, or water wears away the rock's surface. Chemical weathering can occur as rocks are dissolved by a chemical such as acid rain. The particles created as a result of weathering are called terrigenous sediments. These particles are transported to the ocean by wind and by rivers and streams. Once the particles enter the ocean, they are dispersed by waves, currents, and tides. The heaviest and largest particles that reach the oceans, such as sand, settle very quickly to the bottom as a result of gravity. Sand is deposited near the coast whereas the smaller silt and clay particles are transported farther distances offshore before they settle to the bottom. Sediments are an important component of aquatic ecosystems because they provide nutrients and habitat for aquatic organisms (Benhamed et al. 2016). However, human activities result in accumulation of toxic substances such as heavy metals in marine sediments. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulation. Metals affect the ecosystem because they are not removed from water by self-purification, but accumulate in sediments and enter the food chain (Astakhov et al. 2015).

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Benthic surface grab samplers look like giant metal jaws. They dig into the bottom and take a bite of the sediment. These samplers are good for collecting softer, sandy or silty sediments that do not contain rocks. A box corer is a cross between a surface sampler and a sediment corer. It is a special device that is used to collect an undisturbed sample of the very top surface layers and the sediment underneath. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

## 10.1 Results

The Sediment Quality results are given in below from table no. 41 & 42.

**Table 41: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.19	16.9	3.3	21.7	6.11	23.70	36.68
3	Organic Carbon	mg/kg	0.11	9.75	1.95	12.4	3.51	13.65	21.06
4	Inorganic Phosphate	mg/kg	89.00	84.00	99.00	78.00	105.00	99.00	102.00
5	Moisture	%	17.70	16.34	16.20	18.25	13.34	15.67	14.80
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	6.68	8.34	8.90	4.87	11.82	9.43	13.52
8	Phosphate	mg/kg	768.00	680.00	712.00	889.00	598.00	513.00	634.00
9	Sulphate	mg/kg	724.00	618.00	529.00	489.00	501.00	734.00	534.00
10	Nitrite	mg/kg	0.13	0.09	0.08	0.14	0.13	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	761.00	7402.00	861.00	1823.00	1042.00	1322.00	1663.00
13	Magnesium	mg/kg	437.00	1239.00	486.00	1336.00	656.00	1530.00	1615.00
14	Sodium	mg/kg	344.4	2718.6	972.5	3079.8	1762.3	5205.00	615.00
15	Potassium	mg/kg	41.30	414.20	55.70	518.70	165.20	3073.0	2904.0
16	Chromium	mg/kg	BQL	10.60	13.10	12.90	10.90	15.35	22.36
17	Nickel	mg/kg	BQL	12.20	9.90	10.80	7.50	11.35	15.24
18	Copper	mg/kg	BQL	BQL	BQL	7.20	BQL	21.24	16.53
19	Zinc	mg/kg	BQL	12.60	6.70	14.40	5.30	18.25	23.65
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

**Table 42 : Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.43	0.25	0.64	0.43	0.90	0.86	0.79
3	Organic Carbon	mg/kg	0.25	0.14	0.37	0.25	0.25	0.49	0.45
4	Inorganic Phosphate	mg/kg	104.00	99.25	85.00	83.00	122.00	86.00	92.00
5	Moisture	%	23.25	13.36	15.42	19.52	21.34	22.59	18.18
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	6.78	8.15	9.12	7.11	8.89	8.80	8.98
8	Phosphate	mg/kg	11.23	14.49	18.16	10.07	10.45	474.00	797.00
9	Sulphate	mg/kg	857.00	798.00	815.00	940.00	680.00	842.00	380.00
10	Nitrite	mg/kg	0.15	0.13	0.09	0.14	0.16	0.10	0.12
11	Nitrate	mg/kg	1.11	3.8	19.01	26.6	36.1	3.65	0.87
12	Calcium	mg/kg	1302.00	3647.00	1422.00	1262.00	1442.00	2024.00	1943.00
13	Magnesium	mg/kg	1251.00	328.00	1081.00	583.00	862.00	1956.00	2272.00
14	Sodium	mg/kg	5439.00	8044.30	14361.00	1717.00	3286.00	463.44	445.10
15	Potassium	mg/kg	419.5	555.7	461.8	373.8	487.4	453.48	111.27
16	Chromium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17	Nickel	mg/kg	11.56	10.25	9.98	18.45	21.63	14.25	16.87
18	Copper	mg/kg	BQL	BQL	BQL	BQL	BQL	11.25	17.33
19	Zinc	mg/kg	11.24	12.65	BQL	5.47	BQL	25.42	21.56
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0 mg/kg,Cd: 1.0 mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg)

## **9.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khori and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

## **9.3 Conclusion**

The sediment types are majority Sandy loamy. Also all heavy metals found below Quantification limit wise Al, Pb, Cd, Hg , As and Nitrate for some locations.



## CHAPTER-11

### MARINE ECOLOGICAL MONITORING

## 10.0 INTRODUCTION:

### 10.1 Sampling Stations:

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 03<sup>rd</sup> October 2022 in harbour region of DPA at Kandla Creek, and on 04<sup>th</sup> October 2022 in creeks near by the port during Neap tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 10<sup>th</sup> October, 2022 in harbour region of DPA at Kandla Creek and on 11<sup>th</sup> October, 2022 in creeks near by the port during spring tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of KPT harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during Neap tide on 03/10/2022 and Spring tide period on 10/10/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative and quantitative evaluation of phytoplankton, qualitative and quantitative evaluation of zooplankton density and their population.

**TABLE 43. SAMPLING LOCATIONS**

monitoring requirement	Number of locations
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near I <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

#### Sampling methodology adopted:

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample was taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with Nylobolt cloth of 20µm mesh size. . During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.

#### **Samples Processing for chlorophyll estimation:**

Samples for chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 2017).

#### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is a general term for organisms which have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplanktons are free floating organisms that are capable of photosynthesis and zooplankton is the various free-floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, *plankton* and *nekton* (Lalli and Parsons, 1997). *Plankton* consists of all organisms drifting in the water and is unable to swim against water currents, whereas *Nekton* includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and

functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

#### **Phytoplankton in the marine environment:**

Phytoplanktons are free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio-purifier and bio-indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (Bacillariophyceae) and Dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; Diatoms and Dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (Blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

#### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and

abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of 'biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

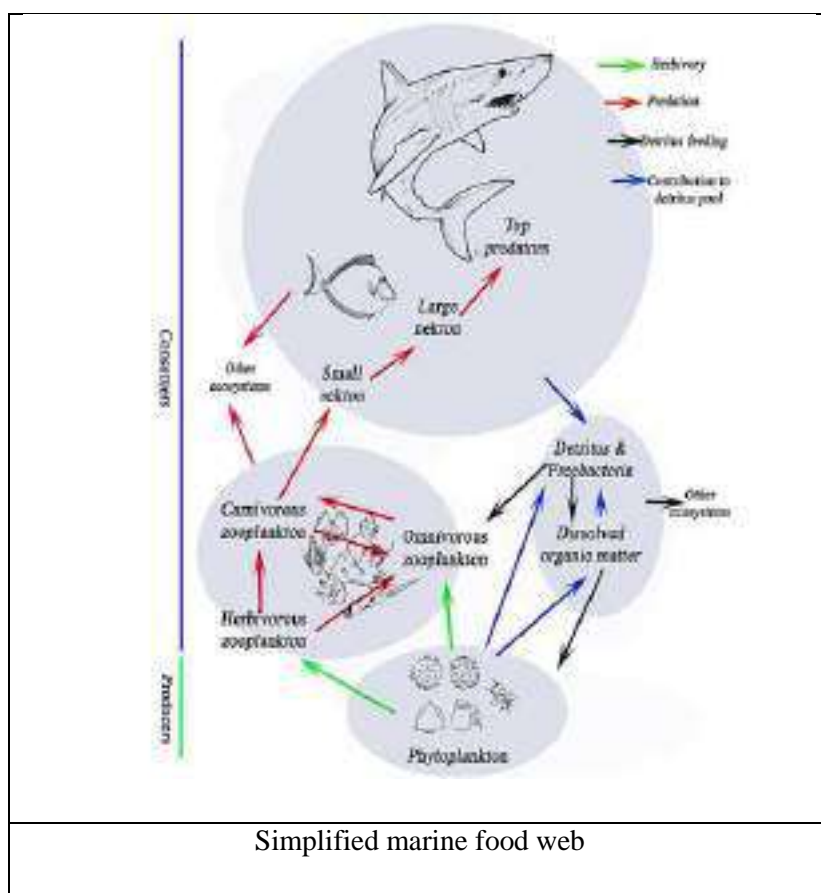
Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the

dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991 ;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplanktons are efficient grazers of the phytoplankton and are referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilo metres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton in the month of October also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

**Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight. After a tow of about 15-30 minutes, plankton net was pulled up and washed down to the tail and the plankton adhered to plankton net is collected in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward. For quantitative evaluation 50 L water samples were collected from subsurface layer and filtered through 20 µm mesh size net by using bucket and filtration assembly.

**Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

**Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

**Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerin to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of phytoplankton and zooplankton that were encountered

**Cell counts by drop count method:**

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22 mm x 60 mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the

left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total amount of phytoplankton in the original volume of sample filtered was calculated as units/L and Zooplankton as  $N/m^3$ .

#### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment–water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than  $42\mu$  in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes

#### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler ( $0.09m^2$ ) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

#### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

#### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.



## DIVERSITY INDICES:

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A. E. (1988)

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H. R. *etal.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate specie richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness (*S*) and evenness (*J*)

### Simpson's diversity index

Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran , 2004).

The formula for calculating D is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where  $n_i$  = the total number of organisms of each individual species

$N$  = the total number of organisms of all species

The value of  $D$  ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When  $D$  increases diversity decreases. Simpson's index is therefore usually expressed as  $1-D$  or  $1/D$ . (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment
- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

### **Species richness indices**

The species richness( $S$ ) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness in may be concomitant with severe or chronic human-induced perturbation (Fair Fair weather 1990) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness( $S$ ) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by Mc Intosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index ( $d$ ), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximised when all types are equally abundant [Rosenzweig, M. L. (1995)]

### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index ( $H$ ), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984).

Shannon-Wiener's index (**H**) reproduces community parameters to a single number by using an equation.

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than

3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

$$H' = - \sum_{j=1}^s \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

## 10.2:- RESULTS:

### CHLOROPHYLL-a:

In the sub surface water chlorophyll-a was varying from 0.462 -0.764 mg/m<sup>3</sup> with an average value 0.621 mg/m<sup>3</sup> in harbour region of DPA in Kandla Creek during sampling done in spring tide period of October 2022. In the nearby creeks chlorophyll-a was varying from 0.409-0.765 mg/m<sup>3</sup> with an average value 0.543mg/m<sup>3</sup>. Pheophytin –a level was below detectable limit- the all the sampling stations during spring tide. Even though the plankton diversity and abundance were more during the spring tide sampling, the chlorophyll -a content was less due to the fact that the phytoplankton communities were mainly represented by bloom diatom *Chaetoceros* sp. and abundance of another diatom; *Ditylum* sp.

In the sub surface water chlorophyll-a was varying from 0.412 - 0.779 mg/m<sup>3</sup> with an average value 0.567 mg/m<sup>3</sup> in harbour region of DPA in Kandla Creek during sampling done in Neap tide period of October 2022. In the nearby creeks chlorophyll-a was varying from 0.526- 0.646 mg/m<sup>3</sup> with an average value 0.564mg/m<sup>3</sup>. Pheophytin –a level was below detectable limit- the all the sampling stations. During neap tide sampling phytoplankton communities were mainly represented by bloom forming diatom *Ditylum* sp.

In the sub surface water chlorophyll-a was varying from 0.308 - 0.528 mg/m<sup>3</sup> in harbour region of DPA OOT in path finder Creek during sampling done in spring tide period of October 2022. In the sub surface water chlorophyll-a was varying from 0.559 - 0.647 mg/m<sup>3</sup> in harbour region of DPA OOT in path finder Creek during sampling done in Neap Tide period of October 2022

**TABLE 44. VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING SPRING TIDE IN OCTOBER 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	DPA-1	High tide	0.764	BDL	51.19
		Low tide	0.562	BDL	37.65
2	DPA- 2	High tide	0.630	BDL	42.21
		Low tide	0.646	BDL	43.28
3	DPA-3	High tide	0.662	BDL	44.35
		Low tide	0.462	BDL	30.95
CREEKS					
4	DPA-4 Khor-I	High tide	0.559	BDL	37.45
		Low tide	0.409	BDL	27.40
5	DPA-5 Nakti-I	High tide	0.765	BDL	51.26
		Low tide	0.442	BDL	29.61
6	DPA-6 Nakti-II	High tide	ND	ND	ND
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.528	BDL	35.38
8		Low tide	0.425	BDL	28.48
9	SPM	High tide	0.308	BDL	20.64
10		Low tide	0.475	BDL	31.83

BDL: Below Detectable Limit., ND: Not detected

**TABLE 45. VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA, NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINARDURING NEAP TIDE IN OCTOBER 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.779	BDL	52.19
		Low tide	0.646	BDL	43.28
2	KPT 2	High tide	0.592	BDL	39.66
		Low tide	0.426	BDL	28.54
3	KPT 3	High tide	0.544	BDL	36.45
		Low tide	0.412	BDL	27.60
CREEKS					
4	KPT-4 Khor-I	High tide	0.543	BDL	36.38
		Low tide	0.646	BDL	43.28
5	KPT-5 Nakti-I	High tide	0.526	BDL	35.24
		Low tide	0.542	BDL	36.31
6	KPT-6 Nakti-II	High tide	ND	ND	ND
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.647	BDL	43.35
8		Low tide	0.647	BDL	43.35
9	SPM	High tide	0.559	BDL	37.45
10		Low tide	0.598	BDL	40.07

BDL: Below Detectable Limit. ND: Not detected

### PHYTOPLANKTON POPULATION:

For the evaluation of the Phytoplankton population in DPA harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 28 genera, Blue green algae were presented by 3 genera and Dinoflagellates were represented by 4 genera during the sampling conducted in spring tide in October, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 84-353 units/ L during high tide period and 242-322 units/ L during low tide of Spring Tide. During spring tide sampling phytoplankton communities were dominated by diatom *Chaetoceros* sp., almost forming a bloom in the Kandla creek and other nearby creek area and abundant population diatoms; *Biddulphia* sp, *Ditylum* sp and *Skeletonema* sp.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 25 genera, Blue green algae were represented 3 genera and Dinoflagellates with 4 genera during the sampling conducted in Neap tide in October, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 71-268 units/ L during high tide period and 249-342 units/ L during low tide of Neap Tide. During Neap tide sampling phytoplankton communities were dominated by, diatom *Ditylum* sp and *Asterionellopsis* sp.

For the evaluation of the Phytoplankton population in DPA OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; jetty area and SPM area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 30 genera, Blue green algae by 3 genera and Dinoflagellates by 5 genera during the sampling conducted in spring tide in October, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty area was 258 units/ L during high tide period and 196 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the SPM area was varying from 148 units/ L during high tide period and 208 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 34 genera and Blue green algae by 2 genera and Dinoflagellates by 7 genera during the sampling conducted in Neap tide in October, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 420 units/L during high tide period and 410 units/L

during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 331 units/ L during high tide period and 397 units/L during low tide of Neap Tide.

#### **Species Richness Indices and Diversity Indices:**

##### **Margalef's diversity index (Species Richness)**

Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 3.837- 5.114 with an average of 4.599 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 4.008- 5.195 with an average of 4.573 during the consecutive low tide period.

Margalef's diversity index (Species Richness) of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 2.514- 3.302 with an average of 2.843 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 1.912- 3.754 with an average of 2.698 during consecutive low tide.

Margalef's diversity index (Species Richness) of phytoplankton communities in the stations was 4.862 at OOT jetty area and 4.202 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the path finder creek near OOT jetty was 4.926 and 4.684 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) of phytoplankton communities in the stations was 4.801 at OOT jetty area and 4.998 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the path finder creek near OOT jetty was 4.322 and SPM area was 4.345 during the consecutive low tide period.

##### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 1.092 - 1.124 between selected sampling stations with an average value of 1.109 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 1.024-1.116 between selected sampling stations with an average value of 1.088 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.762 - 0.876 between selected sampling stations with an average value of 0.822 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton



communities in the sampling stations was in the range of 0.636 - 0.883 between selected sampling stations with an average value of 0.731 during consecutive low tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.041 at OOT jetty area and 0.979 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.092 and 0.988 at SPM during the consecutive low tide period of spring tide.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.011 at OOT jetty area and 1.059 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.975 and at SPM area was 0.899 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.837- 0.915 between selected sampling stations with an average of 0.875 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.833- 0.886 between selected sampling stations with an average of 0.866 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during Neap tide also, which was varying from 0.739- 0.810 with an average value of 0.771 between selected sampling stations during high tide period and 0.616- 0.796 varying from with an average value of 0.692 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.869 at OOT jetty area and 0.839 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.874 and 0.846 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.816 at OOT jetty area and 0.818 at SPM area during the sampling conducted in High tide period of Neap tide at Path



finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.784 and at SPM area was 0.725 during the consecutive low tide period.

Low species diversity suggests a relatively few successful species in this habitat. The environment is well for ecological niches. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

**TABLE 46. PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING SPRING TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% Of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	353	31/35	88.57	5.114	1.092	0.8369
	2	309	29/35	82.86	4.884	1.118	0.8648
	3	315	27/35	77.14	4.52	1.114	0.8764
	4	293	26/35	74.29	4.401	1.103	0.8842
	5	326	29/35	82.86	4.839	1.124	0.8761
	6	84	18/35	51.43	3.837	1.102	0.9145
LOW TIDE	1	302	26/35	74.29	4.378	1.024	0.8334
	2	322	31/35	88.57	5.195	1.115	0.8663
	3	269	26/35	74.29	4.469	1.083	0.8631
	4	273	28/35	80.00	4.813	1.116	0.8823
	5	242	23/35	65.71	4.008	1.103	0.8863

**TABLE.47. PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND ,NEAR BY CREEKS DURING NEAP TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	268	17/32	53.13	2.862	0.7622	0.7391
	2	233	19/32	59.38	3.302	0.876	0.8104
	3	262	15/32	46.88	2.514	0.8365	0.7844
	4	262	17/32	53.13	2.873	0.8283	0.7623
	5	236	17/32	53.13	2.928	0.8336	0.7846
	6	71	12/32	37.50	2.581	0.7935	0.7449
LOW TIDE	1	269	22/32	68.75	3.754	0.8834	0.7957
	2	249	16/32	50.00	2.719	0.7497	0.7133
	3	251	15/32	46.88	2.534	0.6416	0.6161
	4	342	16/32	50.00	2.571	0.7462	0.703
	5	315	12/32	37.50	1.912	0.6361	0.6315

**TABLE 48. ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN OCTOBER2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	83-329	28/35	80.00
			BLUE GREEN ALGAE	1-11	3/35	8.57
			DINOFLAGELLATES	0-18	4/35	11.43
			TOTAL PHYTO PLANKTON	<b>84-353</b>	<b>35</b>	
LOW TIDE	Sub surface	5	DIATOMS	232-300	28/35	80.00
			BLUE GREEN ALGAE	3-6	3/35	8.57
			DINOFLAGELLATES	3-17	4/35	11.43
			TOTAL PHYTO PLANKTON	<b>242-322</b>	<b>35</b>	

**TABLE 49. ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN OCTOBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	DIATOMS	71-264	25/32	78.12
			BLUE GREEN ALGAE	0-9	3/32	9.38
			DINOFLAGELLATES	0-4	4/32	12.50
			TOTAL PHYTO PLANKTON	<b>71-268</b>	<b>32</b>	
LOW TIDE	Sub surface	5	DIATOMS	242-331	25/32	78.12
			BLUE GREEN ALGAE	0-9	3/32	9.38
			DINOFLAGELLATES	0-2	4/32	12.50
			TOTAL PHYTO PLANKTON	<b>249-342</b>	<b>32</b>	

**TABLE 50. PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK, VADINAR & NEAR BY SPM, DURING SPRING TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	258	28/38	73.68	4.862	1.041	0.869
	SPM	148	22/38	57.89	4.202	0.979	0.839
LOW TIDE	Jetty	196	27/38	71.05	4.926	1.092	0.874
	SPM	208	26/38	68.42	4.684	0.988	0.846

**TABLE 51. PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	420	30/43	69.77	4.801	1.011	0.816
	SPM	331	30/43	69.77	4.998	1.059	0.818
LOW TIDE	Jetty	410	27/43	62.79	4.322	0.975	0.784
	SPM	397	27/43	62.79	4.345	0.899	0.725

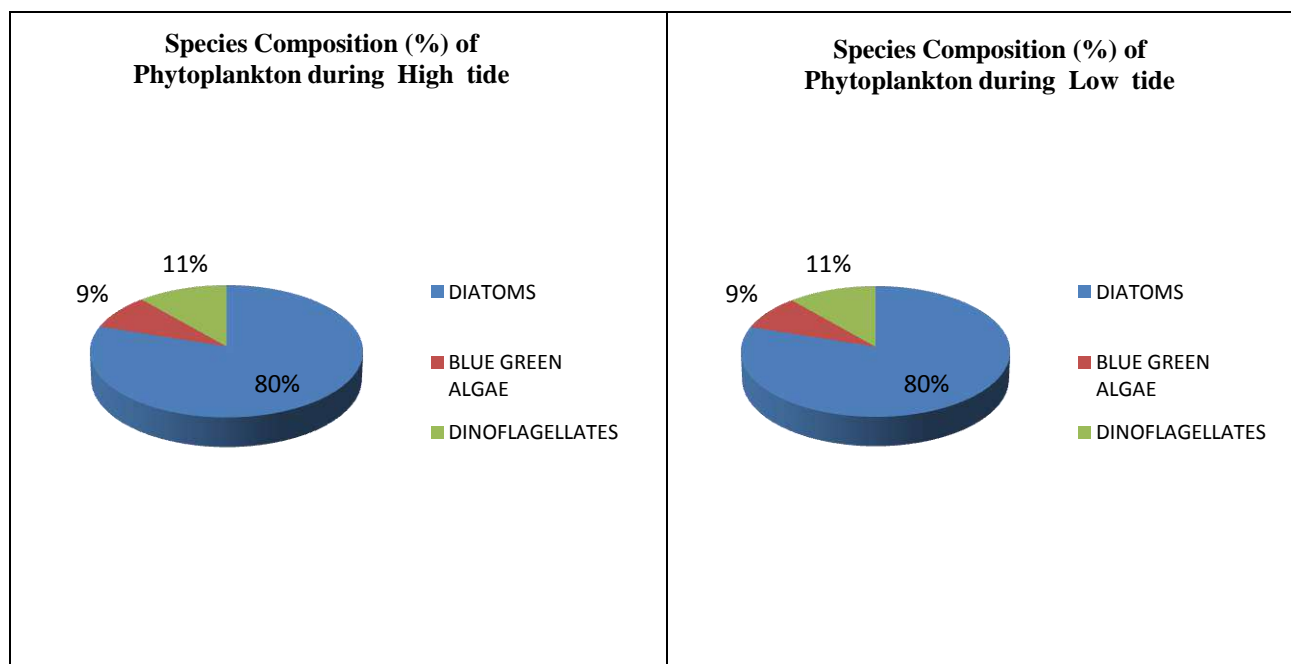
**TABLE 52. ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK, VADINAR & NEAR BY SPM, DURING SPRING TIDE IN OCTOBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	DIATOMS	135-249	30/38	78.95
			BLUE GREEN ALGAE	4-8	3/38	7.89
			DINOFLAGELLATES	5	5/38	13.16
			TOTAL PHYTO PLANKTON	<b>148-258</b>	<b>38</b>	
LOW TIDE	Sub surface	2	DIATOMS	180-199	30/38	78.95
			BLUE GREEN ALGAE	3-10	3/38	7.89
			DINOFLAGELLATES	6	5/38	13.16
			TOTAL PHYTO PLANKTON	<b>196-208</b>	<b>38</b>	

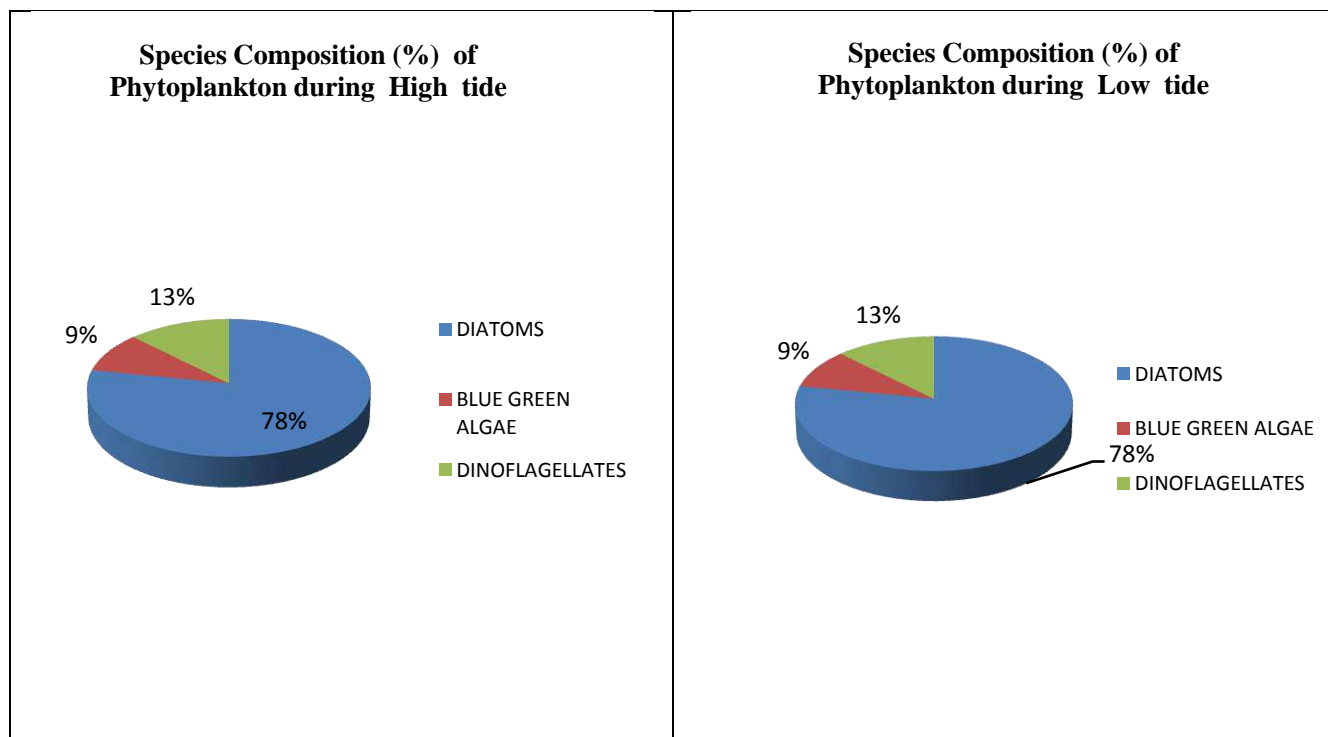
**TABLE 53. ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK, VADINAR & NEAR BY SPM, DURING NEAP TIDE IN OCTOBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	DIATOMS	320-411	34/43	79.07
			BLUE GREEN ALGAE	4	2/43	4.65
			DINOFLAGELLATES	5-7	7/43	16.28
			TOTAL PHYTO PLANKTON	<b>331-420</b>	<b>43</b>	
LOW TIDE	Sub surface	2	DIATOMS	379-397	34/43	79.07
			BLUE GREEN ALGAE	2-4	2/43	4.65
			DINOFLAGELLATES	11-14	7/43	16.28
			TOTAL PHYTO PLANKTON	<b>397-410</b>	<b>43</b>	

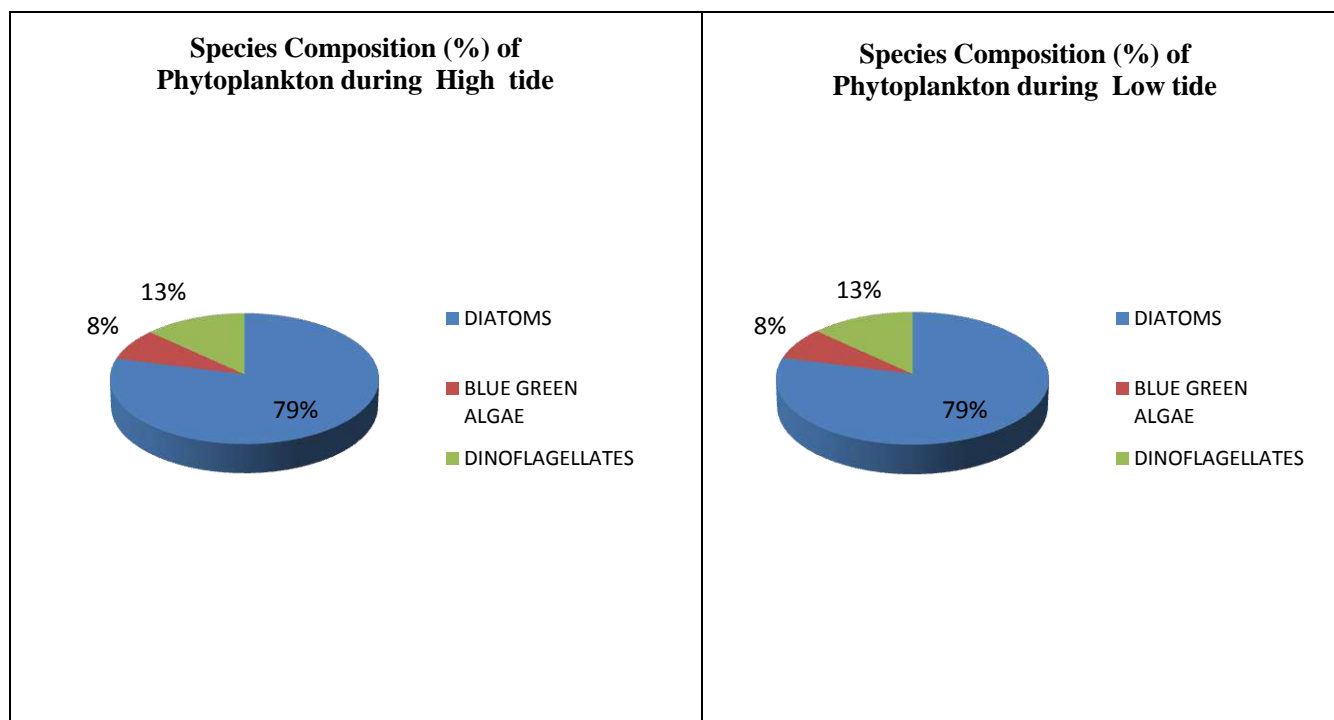
**Species Composition (%) of Phytoplankton during High tide and Low tide period during spring tide in Kandala creek and nearby creeks**



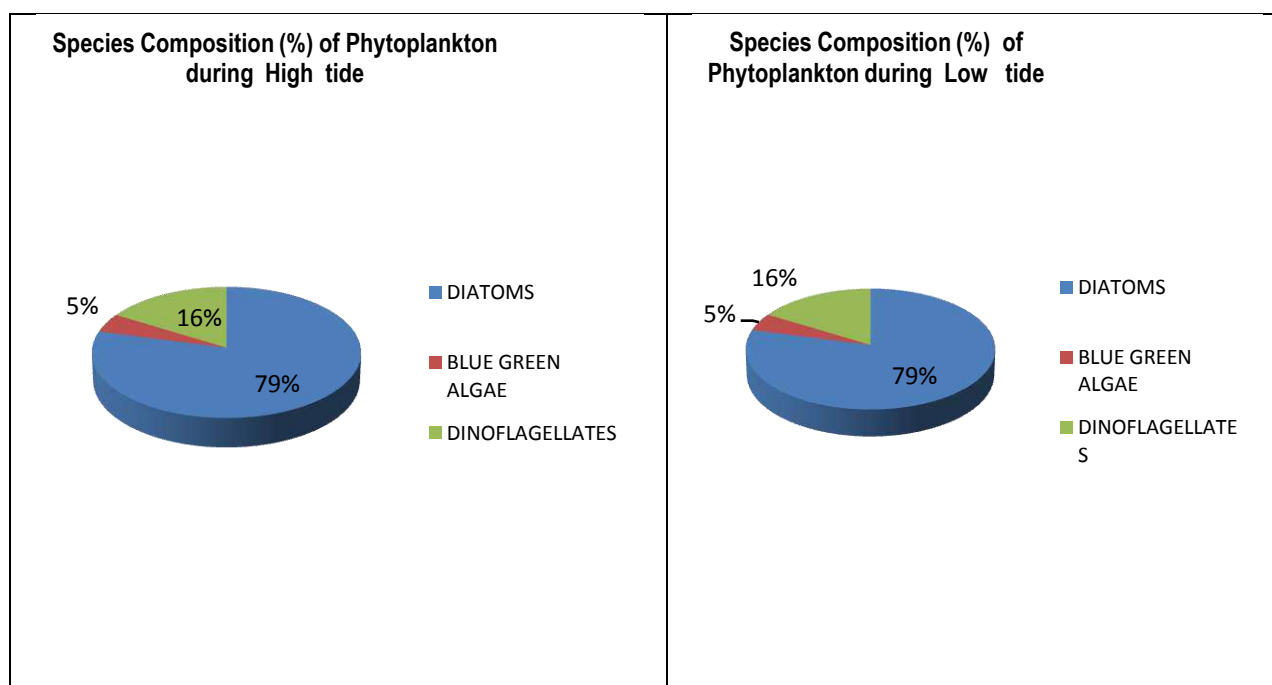
**Species Composition (%) of Phytoplankton during High tide and Low tide period during Neap tide in Kandala creek and nearby creeks**



**Species Composition (%) of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



**Species Composition (%) of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar**



## **ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPA harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khorī creek) during high tide period and low tide period of spring tide and Neap tide in October, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly eight groups; Tintinids, Copepods, Arrow worms, Mysids, Urochordata, Ciliates, Medusa, Nematodes and 8 larval forms. The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly eight groups; Tintinids, Copepods, Arrow worms, Mysids, Urochordata, Ciliates, Medusa, Nematode and 6 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $30-107 \times 10^3 \text{ N/m}^3$  during high tide and  $73-91 \times 10^3 \text{ N/m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $25-124 \times 10^3 \text{ N/m}^3$  during high tide and  $76-107 \times 10^3 \text{ N/m}^3$  during low tide of Neap Tide period.

For the evaluation of the Zooplankton population in DPA OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM).

During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly three groups Tintinids, Copepods, Mysids and 4 larval forms.

The Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by mainly five groups, Tintinids, Copepods, Arrow worms, Mysids, Urochordata and 7 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT Jetty area of path finder creek was  $38 \times 10^3 \text{ N/m}^3$  during high tide and  $38 \times 10^3 \text{ N/m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPASPM area of path finder creek was  $28 \times 10^3 \text{ N/m}^3$  during high tide and  $36 \times 10^3 \text{ N/m}^3$  during low tide of spring Tide period.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT jetty area in path finder creek was recorded  $113 \times 10^3 \text{ N/m}^3$  during high tide and  $103 \times 10^3 \text{ N/m}^3$  during consecutive low tide period of Neap tide. Zooplankton of the sampling stations at sub surface layer in the DPASPM area in



path finder creek was recorded  $89 \times 10^3 \text{ N/m}^3$  during high tide and  $110 \times 10^3 \text{ N/m}^3$  during consecutive low tide period of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness)**

Margalef's diversity index (Species Richness) of Zooplankton communities in the stations Kandla creek region and nearby creeks were varying from 2.352- 5.35 with an average of 3.250 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities varying from 2.031- 3.35 with an average of 2.715 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations were varying from 2.175-4.856 with an average of 3.832 during the sampling conducted in high tide and varying from 3.002-4.265 with an average of 3.596 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.849 and 3.299 respectively. Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.601 and 1.953 respectively.

Margalef's diversity index (Species Richness) of Zooplankton communities near Jetty at Path finder creek were varying from 3.385 and 2.805 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) S of Zooplankton communities near SPM at Path finder creek were varying from 3.565 - 3.404 respectively during the consecutive high tide and low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.768 -1.151 between selected sampling stations with an average value of 0.915 during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.873-0.984 between selected sampling stations with an average value of 0.931 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.784-1.148 between selected sampling stations with an average value of 1.02 during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 0.962-1.09 of between selected sampling stations with an average value of 1.024 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.041-0.891 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 1.013 - 0.787 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.979 - 0.888 respectively during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 0.890-0.987 during the consecutive High tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.791-0.898 between selected sampling stations with an average of 0.839 during high tide period and was varying from 0.844- 0.879 with an average value of 0.862 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of Neap tide except few, which was varying from 0.833- 0.910 between selected sampling stations with an average of 0.879 during high tide period and was varying from 0.866-0.898 with an average value of 0.881 between selected sampling stations during consecutive low tide. This species diversity suggests a relatively few successful species in this habitat during October, 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.902 and 0.821 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.910 and 0.819 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.867- 0.825 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.806 and 0.874 respectively.

**TABLE 54. ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	85	17/36	47.22	3.601	0.9751	0.8655
	2	53	11/36	30.56	2.519	0.8207	0.8113
	3	107	26/36	72.22	5.35	1.151	0.8984
	4	83	14/36	38.89	2.942	0.8995	0.8434
	5	80	13/36	36.11	2.738	0.8775	0.8237
	6	30	9/36	25.00	2.352	0.768	0.7908
LOW TIDE	1	88	16/36	44.44	3.35	0.9836	0.8788
	2	84	10/36	27.78	2.031	0.8727	0.8439
	3	78	12/36	33.33	2.525	0.8933	0.8472
	4	91	15/36	41.67	3.104	0.9755	0.8745
	5	73	12/36	33.33	2.564	0.9305	0.8638

**TABLE 55. ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In $No \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	114	24/32	75.00	4.856	1.148	0.9096
	2	121	22/32	68.75	4.379	1.05	0.8671
	3	113	17/32	53.13	3.385	1.029	0.8911
	4	124	23/32	71.88	4.564	1.103	0.8959
	5	82	17/32	53.13	3.631	1.008	0.8759
	6	25	8/32	25.00	2.175	0.7836	0.8333
LOW TIDE	1	93	18/32	56.25	3.751	1.031	0.881
	2	92	17/32	53.13	3.538	0.998	0.866
	3	86	20/32	62.50	4.265	1.09	0.8977
	4	107	17/32	53.13	3.424	1.041	0.896
	5	76	14/32	43.75	3.002	0.9619	0.866

**TABLE 56. ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS  
IN DPA HARBOUR AREAATKANDLA CREEK AND NEAR BY CREEKS DURING  
SPRING TIDE IN OCTOBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$ Group Range	Genera or species /total Zooplankton	Species Composition (%) (Group level)
HIGH TIDE	Sub surface	6	Tintinids	2-22	10/36	27.78
			Copepods	8-35	11/36	30.56
			Arrow worms	0-2	1/36	2.78
			Mysids	0-1	1/36	2.78
			Urochordata	0-3	2/36	5.56
			Ciliates	0-2	1/36	2.78
			Medusa	0	1/36	2.78
			Larval forms	20-48	8/36	22.20
			Nematode	0-1	1/36	2.78
			TOTAL ZOOPLANKTON N/ M <sup>3</sup>	<b>30-107</b>	<b>36</b>	
LOW TIDE	Sub surface	5	Tintinids	13-17	10/36	27.78
			Copepods	21-24	11/36	30.56
			Arrow worms	0-1	1/36	2.78
			Mysids	0	1/36	2.78
			Urochordata	0	2/36	5.56
			Ciliates	0-1	1/36	2.78
			Medusa	0-1	1/36	2.78
			Larval forms	37-51	8/36	22.20
			Nematode	0	1/36	2.78
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>73-91</b>	<b>36</b>	

**TABLE 57. ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN OCTOBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / \text{m}^3$ Group Range	Genera or species /total Zooplankton	Species Composition (%) (Group level)
HIGH TIDE	Sub surface	6	Tintinids	1-13	6/32	18.74
			Copepods	13-55	12/32	37.50
			Arrow worms	0-1	1/32	3.13
			Mysids	0-4	2/32	6.25
			Urochordata	0-2	2/32	6.25
			Ciliates	0-2	1/32	3.13
			Medusa	0-2	1/32	3.13
			Larval forms	11-53	6/32	18.74
			Nematode	0-1	1/32	3.13
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>25-124</b>	<b>32</b>	
LOW TIDE	Sub surface	5	Tintinids	4-10	6/32	18.74
			Copepods	34-53	12/32	37.50
			Arrow worms	0-2	1/32	3.13
			Mysids	0-2	2/32	6.25
			Urochordata	0-3	2/32	6.25
			Ciliates	0-4	1/32	3.13
			Medusa	0-1	1/32	3.13
			Larval forms	25-43	6/32	18.74
			Nematode	0	1/32	3.13
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>76-107</b>	<b>32</b>	

**Table 58. ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In $\times 10^3 \text{N} / \text{m}^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	38	15/19	78.95	3.849	1.041	0.902
	SPM	28	13/19	68.42	3.601	1.013	0.910
LOW TIDE	Jetty	38	13/19	68.42	3.299	0.891	0.821
	SPM	36	8/19	42.11	1.953	0.787	0.819

**TABLE 59. ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN OCTOBER 2022**

Tide	Sampling Station	Abundance In $\text{N} \times 10^3 / \text{m}^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	113	17/25	68.00	3.385	0.979	0.867
	SPM	89	17/25	68.00	3.565	0.890	0.806
LOW TIDE	Jetty	103	14/25	56.00	2.805	0.888	0.825
	SPM	110	17/25	68.00	3.404	0.987	0.874

**TABLE 60. ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AND PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN OCTOBER 2022**

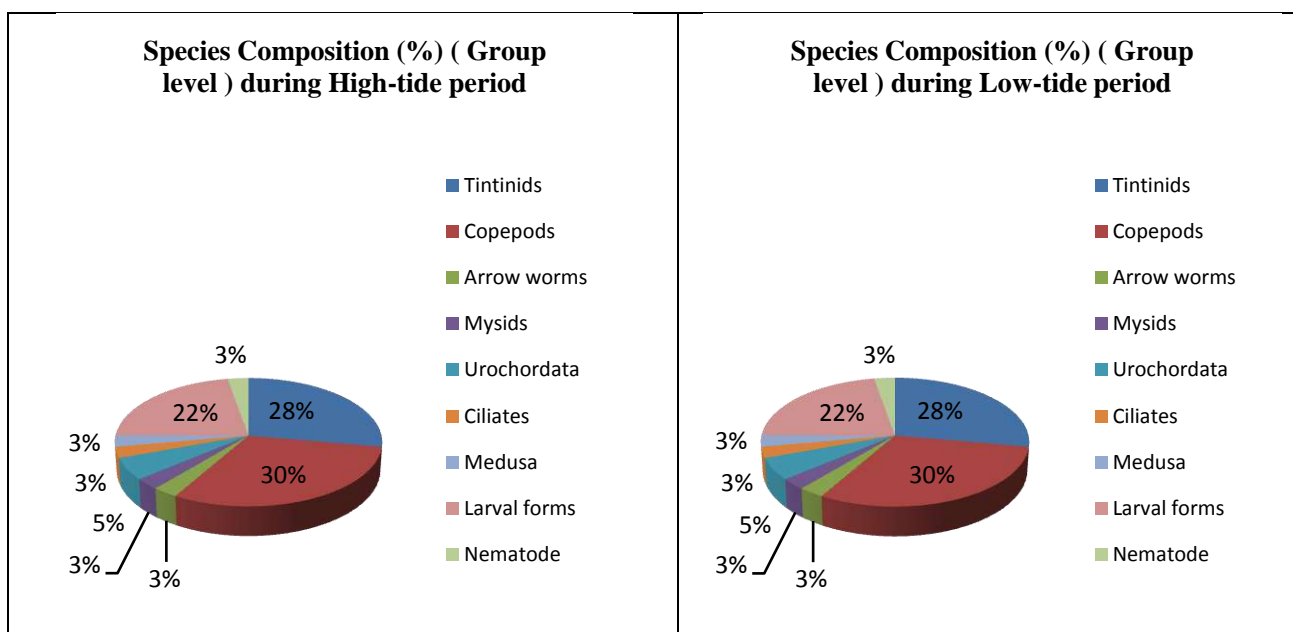
Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / \text{m}^3$ Group Range	Genera or species /total Zooplankton	Species Composition (%) (Group level)
HIGH TIDE	Sub surface	2	Tintinids	8-10	5/19	26.31
			Copepods	12-16	8/19	42.11
			Mysids	0-1	2/19	10.53
			Larval forms	8-11	4/19	21.05
			TOTAL ZOOPLANKTON NO/L	<b>28-38</b>	<b>19</b>	
			Tintinids	6-7	5/19	26.31
			Copepods	14-15	8/19	42.11
			Mysids	0-1	2/19	10.53
			Larval forms	14-17	4/19	21.05
			TOTAL ZOOPLANKTON NO/L	<b>36-38</b>	<b>19</b>	

**TABLE 61. ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN OCTOBER 2022**

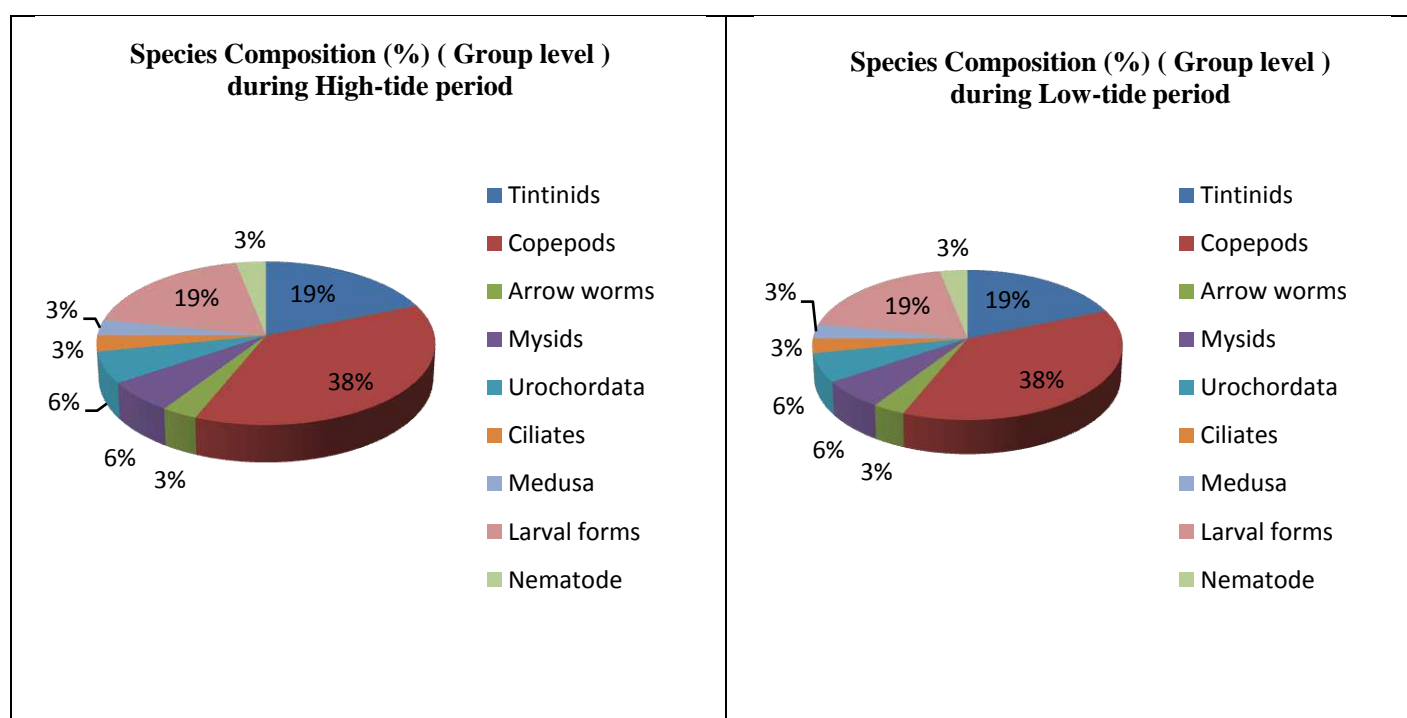
Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / \text{m}^3$ Group Range	Genera or species /total Zooplankton	Species Composition (%) (Group level)
HIGH TIDE	Sub surface	2	Tintinids	17-31	7/25	28.00
			Copepods	26-27	7/25	28.00
			Arrow worms	1-2	1/25	4.00
			Mysids	1-4	1/25	4.00
			Urochordata	1-3	2/25	8.00
			Larval forms	41-48	7/25	28.00
			<b>TOTAL ZOOPLANKTON</b>	<b>89-113</b>	<b>25</b>	
LOW TIDE	Sub surface	2	Tintinids	25-28	7/25	28.00
			Copepods	22-34	7/25	28.00
			Arrow worms	0-1	1/25	4.00
			Mysids	1-2	1/25	4.00
			Urochordata	1-5	2/25	8.00
			Larval forms	46-48	7/25	28.00
			<b>TOTAL ZOOPLANKTON</b>	<b>103-110</b>	<b>25</b>	



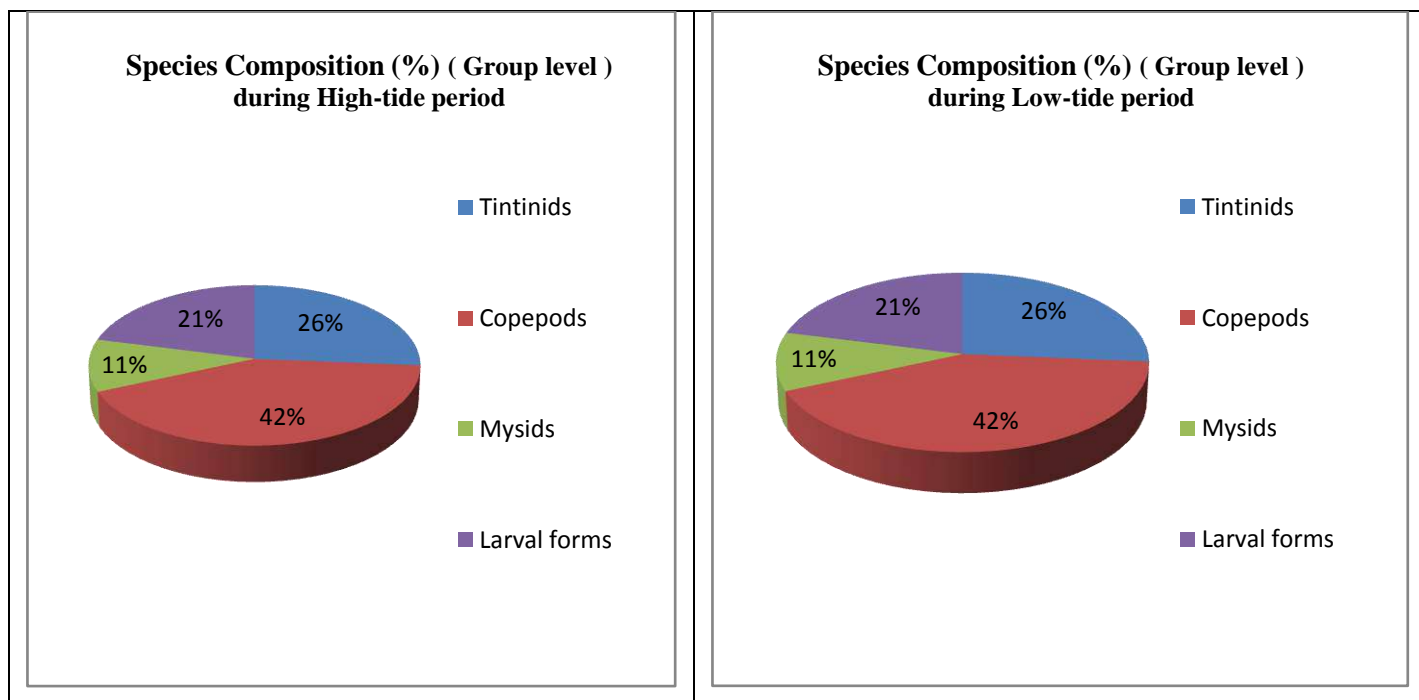
**Species Composition (%) of Zooplankton during High tide and Low tide period of  
Spring tide In Kandla Creek and nearby Creeks**



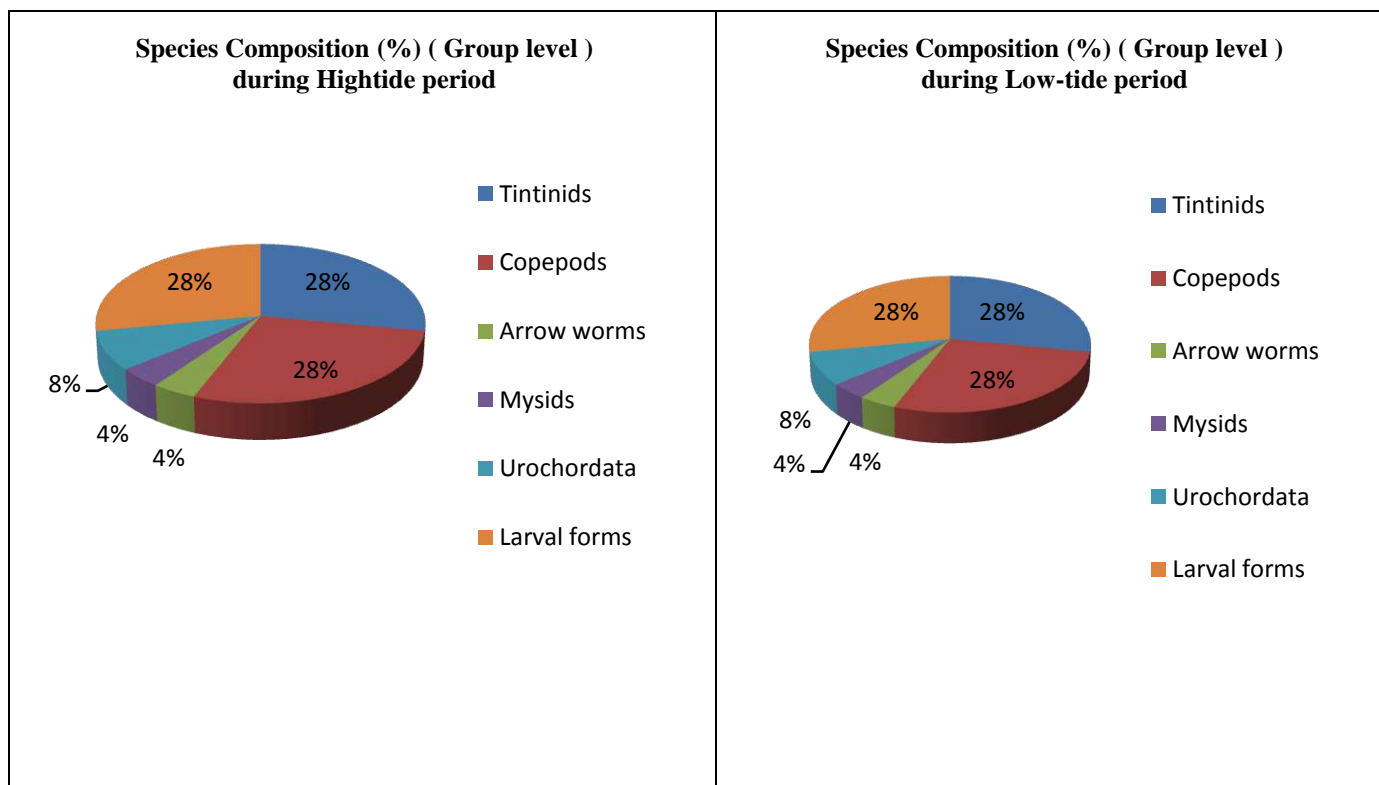
**Species Composition (%) of Zooplankton during High tide and Low tide period of  
Neap tide In Kandla Creek and nearby Creeks**



**Species Composition (%) of Zooplankton during High tide and Low tide period of Spring tide  
In Path Finder Creek and near Jetty**



**Species Composition (%) of Zooplankton during High tide and Low tide period of Neap  
tide In Path Finder Creek near jetty and nearby SPM**



**TABLE 62. SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF OCTOBER 2022**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
			<i>Oscillatoria sp.</i>	B2	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B3	Sparse
Coccinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Sparse
	Corethrales	Corethraceae	<i>Corethron sp</i>	D3	Very sparse
	Coccinodisciales	Coccinodiscaceae	<i>Coccinodiscus sp.</i>	D4	Scattered
	Hemiaulales	Belleracheaceae	<i>Bellerachea sp</i>	D5	Very sparse
		Hemiaulaceae	<i>Eucampia sp</i>	D6	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D7	Sparse
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp</i>	D8	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D9	Dominant
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniellasp</i>	D10	Very sparse
		Lauderiaceae	<i>Lauderia sp</i>	D11	Very sparse
		Skeletonemataceae	<i>Skeletonema sp</i>	D12	Sparse
	Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D13	Very sparse
			<i>Triceratium sp.</i>	D14	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D15	Very sparse
			<i>Nitzschia sp</i>	D16	Very sparse
			<i>Pseudo-Nitzschia sp.</i>	D17	Sparse
	Naviculales	Naviculaceae	<i>Navicula sp.</i>	D18	Very sparse
		Pleurosigmataceae	<i>Pleurosigma sp.</i>	D19	Very sparse
	Surirellales	Surirellaceae	<i>Surirella sp.</i>	D20	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp</i>	D21	Abundant
			<i>Fragilariasp</i>	D22	Very sparse
			<i>Synedrassp</i>	D23	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D24	Scattered
			<i>Thalassiothrix sp.</i>	D25	Scattered
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF2	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
			<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE 63. SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF OCTOBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
			<i>Oscillatoria sp.</i>	B2	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B3	Sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphi</i> sp	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp.	D2	Dominant
	Corethrales	Corethraceae	<i>Corethron</i> sp	D3	Sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus</i> sp.	D4	Scattered
	Hemiaulales	Beller Rocheaceae	<i>Beller Rochea</i> sp	D5	Very sparse
		Hemiaulaceae	<i>Cerataulina</i> sp.	D6	Sparse
			<i>Eucampia</i> sp	D7	Very sparse
		Streptothecaceae	<i>Helicotheca</i> sp	D8	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia</i> sp.	D9	Scattered
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus</i> sp	D10	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum</i> sp	D11	Abundant
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp	D12	Sparse
		Lauderiaceae	<i>Lauderia</i> sp	D13	Sparse
		Skeletonemataceae	<i>Skeletonema</i> sp	D14	Abundant
	Triceratiales	Triceratiaceae	<i>Odontella</i> sp.	D15	Sparse
			<i>Triceratium</i> sp.	D16	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D17	Sparse
			<i>Nitzschia</i> sp	D18	Very sparse
			<i>Pseudo-Nitzschia</i> sp.	D19	Scattered
	Naviculales	Naviculaceae	<i>Navicula</i> sp.	D20	Very sparse
		Pleurosigmataceae	<i>Pleurosigma</i> sp.	D21	Sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis</i> sp.	D22	Very sparse
Surirellaceae		<i>Surirella</i> sp.	D23	Very sparse	
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp	D24	Abundant
			<i>Fragilari</i> sp	D25	Sparse
			<i>Synedr</i> sp	D26	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema</i> sp.	D27	Scattered
			<i>Thalassiothrix</i> sp.	D28	Sparse
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF1	Sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus</i> sp.	DF2	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF3	Sparse
			<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE 64. SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING NEAP TIDE OF OCTOBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B2	Very sparse
Coccinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D1	Scattered
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Dominant
	Corethrales	Corethraceae	<i>Corethron sp.</i>	D3	Sparse
	Coccinodiscals	Coccinodiscaceae	<i>Coccinodiscus sp.</i>	D4	Scattered
	Hemiaulales	Belleracheaceae	<i>Bellerachea sp.</i>	D5	Sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Sparse
			<i>Eucampia sp.</i>	D7	Scattered
			<i>Hemiaulus sp.</i>	D8	Very sparse
		Streptothecaceae	<i>Helicotheca sp.</i>	D9	Very sparse
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp.</i>	D10	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D11	Abundant
	Rhizosoleniales	Rhizosoleniaceae	<i>Dactyliosolen sp.</i>	D12	Very sparse
			<i>Rhizosolenia sp.</i>	D13	Scattered
	Thalassiosirales	Skeletonemataceae	<i>Skeletonema sp.</i>	D14	Very sparse
		Lauderiaceae	<i>Lauderia sp.</i>	D15	Sparse
		Thalassiosiraceae	<i>Planktoniellasp.</i>	D16	Very sparse
			<i>Thalassiosira sp.</i>	D17	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontellasp.</i>	D18	Sparse
			<i>Triceratium sp.</i>	D19	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D20	Abundant
			<i>Hantzschia sp.</i>	D21	Very sparse
			<i>Nitzschia sp.</i>	D22	Scattered
			<i>Pseudo-Nitzschiasp.</i>	D23	Scattered
	Naviculales	Naviculaceae	<i>Meuniera sp.</i>	D24	Very sparse
			<i>Navicula sp.</i>	D25	Very sparse
		Pinnulariaceae	<i>Pinnularia sp.</i>	D26	Very sparse
	Surirellales	Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D27	Sparse
		Entomoneidaceae	<i>Entomoneis sp.</i>	D28	Very sparse
			<i>Campylodiscus sp.</i>	D29	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Surirella sp.</i>	D30	Very sparse
			<i>Asterionellopsis sp.</i>	D31	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Synedra sp.</i>	D32	Very sparse
			<i>Thalassionema sp.</i>	D33	Scattered
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Thalassiothrix sp.</i>	D34	Scattered
			<i>Protoperidinium sp.</i>	DF1	Sparse
	Gonyaulacales	Goniodomataceae	<i>Pyrodinium sp.</i>	DF3	Very sparse
		Pyrophacaceae	<i>Pyrophacus sp.</i>	DF4	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF5	Very sparse
			<i>Ceratium fusus</i>	DF6	Very sparse
			<i>Ceratium tripos</i>	DF7	Very sparse

**TABLE 65. SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPAOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND SPRING TIDE OF OCTOBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
			<i>Oscillatoria sp.</i>	B2	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B3	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp	D1	Scattered
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Dominant
	Corethrales	Corethraceae	<i>Corethron sp.</i>	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D4	Scattered
	Hemiaulales	Bellerocheaceae	<i>Bellerochea sp.</i>	D5	Sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Sparse
			<i>Eucampia sp.</i>	D7	Sparse
		Streptothecaceae	<i>Helicotheca sp.</i>	D8	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Dactyliosolen sp.</i>	D9	Very sparse
			<i>Rhizosolenia sp.</i>	D10	Abundant
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp.</i>	D11	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D12	Abundant
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp	D13	Very sparse
			<i>Thalassiosira sp.</i>	D14	Very sparse
		Lauderiaceae	<i>Lauderia sp.</i>	D15	Very sparse
		Skeletonemataceae	<i>Skeletonema sp.</i>	D16	Sparse
	Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D17	Sparse
			<i>Triceratium sp.</i>	D18	Very sparse
Bacillariophyceae	Achnanthes	Achnanthaceae	<i>Achnanthes sp.</i>	D19	Very sparse
	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D20	Abundant
			<i>Nitzschia sp.</i>	D21	Scattered
			<i>Pseudo-Nitzschia sp.</i>	D22	Very sparse
	Naviculales	Pinnulariaceae	<i>Pinnularia sp.</i>	D23	Very sparse
		Pleurosigmaaceae	<i>Pleurosigma sp.</i>	D24	Very sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D29	Very sparse
		Surirellaceae	<i>Campylodiscus sp.</i>	D26	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp.</i>	D27	Sparse
			<i>Fragilaria</i> sp	D28	Very sparse
			<i>Synedrass</i>	D29	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassiothrix sp.</i>	D30	Very sparse
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF2	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
			<i>Ceratium fusus</i>	DF4	Very sparse
			<i>Ceratium tripos</i>	DF5	Very sparse

**TABLE 66. SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF OCTOBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
		Codonellidae	<i>Tintinnopsis dadayi</i>	T2	Very sparse
			<i>Tintinnopsis failakkaensis</i>	T3	Very sparse
			<i>Tintinnopsis gracilis</i>	T4	Very sparse
			<i>Tintinnopsis radix</i>	T5	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T6	Sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
		Eucalanidae	<i>Pareucalanus sp.</i>	C6	Very sparse
			<i>Subeucalanus sp.</i>	C7	Very sparse
		Temoridae	<i>Temora sp.</i>	C8	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C9	Abundant
	Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C10	Scattered
		Euterpinae	<i>Euterpina sp.</i>	C11	Scattered
	Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C12	Very sparse
Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
		Solenoceridae	<i>Solenocera sp.</i>	M2	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
Hydrozoa			Unidentified medusa	ME1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea larvae	L2	Sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Sparse
			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Polychaeta			Trochophore larvae	L6	Abundant
			Unidentified nematodes	N1	Very sparse



**TABLE 67. SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDES OF OCTOBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
		Codonellidae	<i>Tintinnopsis dadayi</i>	T2	Very sparse
			<i>Tintinnopsis failakkaensis</i>	T3	Very sparse
			<i>Tintinnopsis gracilis</i>	T4	Very sparse
			<i>Tintinnopsis mortensenii</i>	T5	Very sparse
			<i>Tintinnopsis radix</i>	T6	Very sparse
			<i>Tintinnopsis tocaninensis</i>	T7	Very sparse
		Tintinnidae	<i>Amphorides sp.</i>	T8	Very sparse
			<i>Eutintinnus sp.</i>	T9	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T10	Sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Acartiidae	<i>Acartia sp.</i>	C3	Sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
		Eucalanidae	<i>Subeucalanus sp.</i>	C6	Very sparse
		Temoridae	<i>Temora sp.</i>	C7	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C8	Abundant
	Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C9	Very sparse
		Euterpinae	<i>Euterpina sp.</i>	C10	Sparse
	Poecilostomatoida	Corycaeidae	<i>Corycaeus sp.</i>	C11	Very sparse
Sagittioidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CH1	Very sparse
Hydrozoa			Unidentified medusa	ME1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea larvae	L2	Abundant
Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
			Cyphonautes larvae	L4	Very sparse
Superclass: Pisces			Fish larvae	L5	Very sparse
			Ophiopluteus larvae	L6	Very sparse
Polychaeta			Trochophore larvae	L7	Scattered



Pelecypoda			Veliger larvae of bivalves	L8	Very sparse
			Unidentified nematodes	N1	Very sparse

**TABLE 68. SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING NEAP TIDE OF OCTOBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Sparse
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis mortensenii</i>	T4	Very sparse
			<i>Tintinnopsis radix</i>	T5	Sparse
			<i>Tintinnopsis tocaninensis</i>	T6	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T7	Abundant
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Scattered
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Eucalanidae	<i>Subeucalanus sp.</i>	C3	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C4	Scattered
	Harpacticoida	Euterpiniidae	<i>Euterpina sp.</i>	C5	Very sparse
		Ectinosomatidae	<i>Microsetella sp.</i>	C6	Very sparse
	Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C7	Very sparse
Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea larvae	L2	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Scattered
			Ophiopluteus larvae	L4	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L5	Very sparse
Polychaeta			Trochophore larvae	L6	Very sparse
Pelecypoda			Veliger larvae of bivalves	L7	Very sparse

**TABLE 69. SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPAOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF OCTOBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus sp.</i>	T1	Sparse
		Codonellidae	<i>Tintinnopsis dadayi</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T5	Sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C5	Sparse
	Harpacticoida	Euterpinidae	<i>Euterpina sp.</i>	C6	Very sparse
		Ectinosomatidae	<i>Microsetella sp.</i>	C7	Very sparse
	Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C8	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
		Solenoceridae	<i>Solenocera sp.</i>	M2	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Scattered
Gastropoda Streptoneura			Opisthobranchia larvae	L2	Very sparse
Polychaeta			Trochophore larvae	L3	Very sparse
Pelecypoda			Veliger larvae of bivalves	L4	Very sparse

# BENTHIC ORGANISMS:

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPA harbour region and nearby creek. The meio-benthic organisms during spring tide were represented by Polychaetes *Dasybranchus sp.*, *Brittle star larvae* and during Neap tide by *Ophelia sp.* and few Amphipods. Population of benthic fauna was varying from 10-60- N/m<sup>2</sup> during spring tide and 20-30 N/m<sup>2</sup> during Neap tide. The benthic communities at path finder Creek were represented by Polychaetes *Notomastus sp.*, *Dasybranchus sp.*, *Nephtys sp.* and few Amphipods. Their population was varying as 100 N/m<sup>2</sup> at OOT jetty premises and 140 N/m<sup>2</sup> near the SPM area during spring tide and 20 N/m<sup>2</sup> at OOT jetty premises and 40 N/m<sup>2</sup> near the SPM area during Neap tide period.

**TABLE 70. BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING SPRING TIDE IN OCTOBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
Benthic fauna						
POLYCHAETES	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family : CAPITELLIDAE	10	20	20	20	10	
<i>Dasybranchus sp.</i>						NS
<i>Brittle star larvae</i>	0	40	0	0	0	NS
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	10	60	20	20	10	NS

NS: No sample

**TABLE 71. BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING NEAP TIDE IN OCTOBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family : Ophellidae	10	20		10		
<i>Ophelia sp.</i>			10		20	NS
<i>Amphipoda</i>	20	0	10	20	0	
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	30	20	20	30	20	NS

**TABLE 72. BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA, VADINAR DURING SPRING TIDE IN OCTOBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family : Capitellidae	20	70
<i>Notomastus sp.</i>		
Family : Capitellidae	40	10
<i>Dasybranchus sp.</i>		
Family: Nephtyidae	40	30
<i>Nephtys sp.</i>		
<i>Amphipoda</i>	0	30
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	100	140

**TABLE 73. BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA, VADINAR DURING NEAP TIDE IN OCTOBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family: <i>Nephtyidae</i> <i>Nephtys sp.</i>	20	10
FAMILY: <i>Orbinidae</i> <i>Scoloplos sp.</i>	0	30
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	40

## **CHAPTER-11**

### **CONCLUSIVE SUMMARY & REMEDIAL MEASURES**

### 11.0 Conclusive Summary and Remedial measures Suggested

- The AAQ monitoring of six locations at Deendayal Port Kandla indicates that the mean  $PM_{10}$  and  $PM_{2.5}$  values for four locations viz. Marine Bhavan, Oil Jetty, Estate Office and Coal storage area were found higher than the permissible limit (standards  $100 \mu\text{g}/\text{m}^3$ ,  $60 \mu\text{g}/\text{m}^3$ ). The higher concentration of Particulate matter at Marine Bhavan may be due to vehicles emissions during loading-unloading of food grains and timbers; at Estate office due to construction work, vehicles emission produced from trucks, heavy duty vehicles that pass through the road outside Kandla port and Oil jetty area; while at Coal Storage area lifting of coal from grab yard and other coal handling processes. Moreover, the transportation of coal produces pollution from heavy vehicles. At Tuna Port location, concentration of  $PM_{10}$  varied from  $42\text{--}206 \mu\text{g}/\text{m}^3$  and mean value was observed  $128 \mu\text{g}/\text{m}^3$  which was slightly exceed the prescribed standard limit ( $100 \mu\text{g}/\text{m}^3$ ), concentration of  $PM_{2.5}$  was ranged from  $23\text{--}115 \mu\text{g}/\text{m}^3$  and mean was found  $60 \mu\text{g}/\text{m}^3$  which was within the prescribed limit ( $60 \mu\text{g}/\text{m}^3$ ). At Gopalpuri  $PM_{10}$  and  $PM_{2.5}$  were found within permissible limit prescribed by NAAQS.
- At Vadinar, the average concentration of  $PM_{10}$  was  $115 \mu\text{g}/\text{m}^3$  and  $PM_{2.5}$  was  $67 \mu\text{g}/\text{m}^3$  at Admin Colony which was slightly exceed the permissible limit and while at Signal building the concentration  $PM_{10}$  and  $PM_{2.5}$  was within the permissible limit.
- Further, precautionary measures and management strategies to minimize the effect of particulate as well as gaseous pollutants have also been suggested for achieving its ambient levels in and around Kandla Port and Vadinar Port, Gujarat, India.
- Drinking water at all the twenty locations was found potable and it was found within in line of BIS standards (IS: 10500-2012).
- Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. All sampling location were within the permissible limit day time 75 dB (A) and night time 70 dB (A) for the industrial area.
- The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) STP and Vadinar were in line with the standards set by the Central Pollution Control Board.
- It was suggested to monitor the STP performance on regular basis to avoid flow of contamination / Polluted water into the sea.

- Good species diversity suggests a relatively successful species in this habitat. A greater number of successful species and a more stable ecosystem. More ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole.
- The results obtained from the study for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

The mean day time temperature at Deendayal Port was 29.87 °C. The Day time temperature ranged from 23.2-35.1°C. The mean night time temperature recorded was 27.91 °C. The night-time temperature ranged from 23.4-32.5°C. The mean Solar Radiation in October month was 185.99 w/m<sup>2</sup>. The maximum solar radiation was recorded 856.7 w/m<sup>2</sup> on 01.10.2022 and the minimum solar radiation was recorded 1.106 w/m<sup>2</sup> 29.10.2022. The mean Relative humidity was 74.90 % for the month of October. Maximum Relative humidity was recorded 98.0 % and minimum Relative humidity was recorded 30.0 %. The average wind velocity for the entire month of October was 1.22 m/s. Maximum wind velocity was recorded 6.50 m/s. The wind direction was mostly West-South.

- The results obtained from the study for the month of October 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

#### **Reasons for higher Values of PM<sub>10</sub>**

- The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.
- Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.



## Remedial Measures

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of October, 2022 were beyond the permissible limit at 4 locations (Coal Storage, Marine Bhavan, Oil Jetty and Estate office) except Gopalpuri while at the Tuna Port the concentration of particulate matter was slightly exceed . Given below are the remedial measures suggest to minimize the Air pollution.

- During October, 2022 overall ambient air quality of the DPA was within CPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, Marine Bhavan, Oil Jetty and Estate Office. To improve air quality the port was using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

## Solution towards the Green port:

Today, it is increasingly recognized that air pollution hurts human health. Consequently, efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits.

The guidelines can be considered a basis for governments for the implementation of a strategic plan focused on the reduction of multi pollutant emission, as well as of the overall air pollution related risk.

- The plantation should be all along the periphery of the port and inside and outside the port along with the road. Trees having high dust trapping efficiency (*Azadirachta indica*, *Cassia fistula*, *Delonix regia*, *Ficus religiosa*, *Pterocarpus marsupium*) are to be grown alongside the roads.
- The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.
- The vehicles should be covered during transportation and the vehicle carrying the coal should not be overloaded by raising the height of carriage.

- The water sprinklers should be use during transportation of loaded heavy vehicles on raw road.
- It should be ensure that regular sweeping of coal internal, main road and space a free circulation.
- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle- Mask advised in sensitive areas.
- Department for use maintenance should have a routine checkup noise level by replacing bearings, tights of all loose parts that can vibrate.
- Speed control is also an effective way to mitigate noise pollution, the lowest sound emission arise from vehicles moving smoothly.
- Use of renewable energy like solar energy should be optimal and ensure to work continuously.
- Keep neat and clean public transport and all basic items at public interaction places as much as possible.
- Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.
- Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.
- Initiate Natural Gas (CNG) as fuel by all buses and trucks.

### **Green Ports Initiative**

- Deendayal Port is committed to sustainable development and adequate measures are being taken to maintain the Environmental well-being of the Port and its surrounding environs. Weighing in the environmental perspective for sustained growth, the Ministry of Shipping had started “Project Green Ports” which will help in making the Major Ports across India cleaner and greener. “Project Green Ports” will have two verticals - one is “Green Ports Initiatives” related to environmental issues and second is “Swachh Bharat Abhiyaan”.
- The Green Port Initiatives include twelve initiatives such as preparation and monitoring plan, acquiring equipments required for monitoring environmental pollution, acquiring dust suppression system, setting up of waste water treatment plants/ garbage disposal plant, setting up Green Cover area, projects for energy generation from renewable energy sources, completion of shortfalls of Oil Spill Response (OSR) facilities (Tier-I),

prohibition of disposal of almost all kind of garbage at sea, improving the quality of harbour wastes etc.

- Deendayal port has also appointed GEMI as an Advisor for “Making Deendayal Port a Green Port - Intended Sustainable Development under the Green Port Initiatives.
- Deendayal Port has also signed MOU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Trust. The plantation is being carried out by the Social Forestry division of Kachchh.

## **CHAPTER-12**

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## ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY



**REPORT** : DCPL/DPA/21-22/31

**Mont** : November 01

**Issue** : 00

**Revision** : 00

**Prepare** : DETOX CORPORATION PVT. LTD.,

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## EXECUTIVE SUMMARY

## **ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTAL MONITORING REPORT- NOVEMBER, 2022**

### **1. EXECUTIVE SUMMARY**

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to understand status of various parameters in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### **A) Ambient Air**

The monitoring of Ambient Air quality at 6-locations at Deendayal Port Authority Kandla and 2- location at Vadinar Port on 24 hourly basis for TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> and NMHC in twice a week 24 hourly at uniform intervals (as per NAAQS) at Gopalpuri, Tuna Port, Marine Bhavan Building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and Vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The Maximum TSPM values in month of November 2022 were found 846 µg/m<sup>3</sup> at Coal Storage area on 25.11.2022 and minimum 107 µg/m<sup>3</sup> at Gopalpuri Hospital on 01.11.2022. The Maximum PM<sub>10</sub> values were 654 µg/m<sup>3</sup> at Coal Storage area on 25.11.2022 and minimum was 67 µg/m<sup>3</sup> at Gopalpuri Hospital 01.11.2022. Maximum PM<sub>2.5</sub> values were 187 µg/m<sup>3</sup> at Coal Storage area on 25.11.2022 and minimum was 34 µg/m<sup>3</sup> at Gopalpuri on 01.11. 2022. The PM<sub>10</sub> and PM<sub>2.5</sub> values were found for all monitoring locations (Marine Bhavan Building, Oil Jetty, Estate Office, Gopalpuri, Coal Storage Area and Tuna Port) to exceed the Standard limit (NAAQS).

At Gopalpuri location the mean concentration of PM<sub>10</sub> was 127 µg/m<sup>3</sup> & PM<sub>2.5</sub> was 66 µg/m<sup>3</sup> which are slightly exceed the Standard limit (NAAQS).

The AAQ monitoring for Vadinar at Admin building the mean TSPM, PM<sub>10</sub> and PM<sub>2.5</sub> were 237 µg/m<sup>3</sup>, 138 µg/m<sup>3</sup> and 97 µg/m<sup>3</sup> respectively which was exceed the Standard limit (NAAQS) the while at Signal Building the mean TSPM, PM<sub>10</sub> and PM<sub>2.5</sub> were 113 µg/m<sup>3</sup>, 74 µg/m<sup>3</sup> and 38 µg/m<sup>3</sup> respectively slightly exceed the Standard limit (NAAQS).

The overall values of November for Gaseous SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> concentration were within the permissible limit at all location and NMHC were found BQL (Below Quantification Limit).

## **B) Weather**

The mean day time temperature at Deendayal Port was 27.92 °C. The day-time maximum temperature was 32.9°C and minimum was 21.1 °C. The mean night time temperature recorded was 25.47 °C. The night-time maximum temperature was 29.7°C and minimum was 20.0 °C. The mean Solar Radiation in November month was 167.27 w/m<sup>2</sup>. The maximum solar radiation was recorded 759 w/m<sup>2</sup> in 4<sup>th</sup> November, 2022 and the minimum solar radiation was recorded 1.80 w/m<sup>2</sup> in 30<sup>th</sup> November, 2022. The mean Relative humidity was 69.00 % for the month of November. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 34.0 %. The average wind velocity for the entire month of November was 1.21 m/s. Maximum wind velocity was recorded 10.19 m/s. The wind direction was mostly West-South.

## **C) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:**

The results obtained from the study for the month of November 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

## **D) Drinking Water Quality**

The drinking water being supplied to Deendayal Port Authority was safe for drinking purpose. At all drinking water monitoring stations around port area were in line with the standard limit as per the drinking water specifications given in IS 10500:2012 as per tested parameters only.

The average results for 20 locations were as: pH were found Min 7.24 and maximum 7.52, TDS were found min 300.0 mg/l and Max found 1060.0 mg/l, Chloride were found Min 140.31 mg/l and Max 576.28 mg/l, Total Hardness were found Min 270.0 mg/l and Max 380.0 mg/l and Calcium were found Min 34.47 mg/l and Max 43.29 mg/l, color were colorless and odor were odorless. In all water samples BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count (E-coli & Coliform) is absent in all drinking water samples.

### **E) Monitoring Performance of Sewage Treatment Plant**

It was seen that the performance of STP at Deendayal Township Gopalpuri, DPA STP Plant Kandla and Vadinar STP plant was satisfactory by overall. The treatment plant was well maintained during [November 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. At Gopalpuri STP, the pollutant removal efficiency for TSS, BOD and COD was ranged from 49.66-81.04%, 58.97-68.42% and 45.45-73.33% respectively. At Kandla STP, removal efficiency for TSS, BOD and COD was ranged from 53.47-73.49%, 46.15-76.74% and 50.00-82.35% respectively & at Vadinar STP removal efficiency for TSS, BOD and COD was ranged from 42.09-56.69%, 50.00-78.12% and 60.00-84.61% respectively. At all STP location treated waste water the pH were ranged from 7.21-7.42, Total Suspended Solids were found 16.9-67.9 mg/l, Residual Chlorine were below Detection Limit (< 0.5), COD were found 20-60 mg/l and 3day BOD @ 27 °C were found 7.0-16.0 mg/l.

### **F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 53.2 dB(A) to 70.4 dB(A) while at Vadinar port 3 location ranged from 52.5 dB(A) to 60.6 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 45.4 dB to 61.7 dB(A) while at Vadinar port ranged from 52.5 dB (A) to 60.6 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.





# **CHAPTER-1**

## **INTRODUCTION**

### **DEENDAYAL PORT AUTHORITY**

## **1.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 Kms. From the mouth of Gulf of Kachchh. Latitude: 23° 01" N Longitude: 70° 13"E. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rise to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15 consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 127.10 million metric tons of cargo during the FY 2021-22, as against 117.566 million metric tons in FY 2020-21. Showing a growth of 8.11 %. Incidentally, DPA is the only major Indian port of handle more than 127 MMT cargo throughout and it has also registered the highest cargo throughput in its history. While the port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in Sept. 2021. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural up-gradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32 MMTPA Essar Oil Refinery in Jamnagar District. Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the prescribed standards by GPCB/CPCB/MoEF& CC. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port. The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.

## **CHAPTER-2**

### **AMBIENT AIR QUALITY MONITORING**

## 2. Introduction

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth's atmosphere. It may cause diseases, allergies or death of humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty. The consequences of industrialization and the demand for improved quality of life has been increased exposure to air pollution (Vallero, 2014). An air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Any gas could qualify as pollution if it reached a high enough concentration to do harm. Theoretically, that means there are dozens of different pollution gases. In practice, about ten different substances cause most concern. Heavy metals represent a class of omnipresent pollutants, with toxic potential, in some cases even at low exposure levels. They concentrate in each tropic level because of their weak mobility, so the concentration in plants is higher than in soil, in herbivore animals higher than in plants, in carnivores' tissues higher than in herbivore, the highest concentration being reached at the end of the tropic chain, at big predacious and human bodies. Globally, one of the main contributors to emissions of atmospheric pollutants and a significant user of energy is the industrial sector (Conti et al. 2015).

The concentration of air pollutants depends not only on the quantities that are emitted from the polluting sources, but also on the ability of the atmosphere to either absorb or disperse such emissions (USEPA, 2008).

Nowadays, the shipping sector provides low-cost and reliable delivery services in the economic field (Arunachalam et al. 2015). Nevertheless, shipping-related activities have a considerable impact on air pollution, especially in coastal areas but also globally (Buccolieri et al. 2016). The primary air pollutants are PM, VOCs, NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub>, and CO (Bailey and Solomon 2004). As a consequence, a wide range of options toward “greener” seaports is needed (Bailey and Solomon 2004). Some of these measures are easy to adopt such as the regulation of fuel quality (by using low-sulfur alternative fuels), the speed reduction (Lack et al. 2011), and the use of alternative transportation equipment (Lai et al. 2011).

Clean air is the basic requirement of all living organisms. In recent times, due to population growth, urban sprawl, industrial development, and vehicular boom, the quality of air is deteriorating and being polluted. Pollutants of major public health concerns include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, which pose serious threats to human health and hygiene. In the present study, prime particulate pollutants (PM<sub>10</sub>, PM<sub>2.5</sub>), and gaseous pollutants (SO<sub>2</sub>, and NO<sub>2</sub>) were estimated at seven stations in and around Dahej Port, Gujarat, India (Soni and Jagruti Patel, 2017).

Among particulate pollutants, particulate matter (PM) is a ubiquitous entity, and is especially a grave problem due to its higher suspension rate into the atmosphere, and adverse health effects on plants, animals, humans, and materials in the form of visibility reduction, soiling of buildings, etc. (Horaginamani and Ravichandran, 2010; Chaurasia *et al.*, 2013).

The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

## 2.1 Ambient Air Quality Monitoring

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

**Table: 1. Ambient Air Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Marine Bhavan	AL-1	23° 0' 26.524"N	70° 13' 22.414"E	<b>DPA-Kandla</b>
2.	Oil Jetty	AL-2	23° 1' 45.613"N	70° 13' 11.052"E	
3.	Estate Office	AL-3	23° 1' 11.273"N	70° 12' 48.657"E	
4.	Gopalpuri Hospital	AL-4	23° 4' 53.551"N	70° 8' 7.047"E	
5.	Coal Storage Area	AL-5	22° 59' 31.812"N	70° 13' 9.979"E	
6.	Tuna Port	AL-6	22° 59' 15.291"N	70° 58' 57.018"E	
7.	Signal Building	AL-7	22° 26' 26.750"N	69° 40' 22.127"E	<b>DPA-Vadinar</b>
8.	Admin Building	AL-8	22° 26' 25.223"N	69° 40' 19.358"E	

### ● Air Quality Monitoring Methodology

Air quality is measured in all the stations, for 24 hour for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> & Benzene and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours for gaseous parameters. The absorbing reagents for SO<sub>2</sub>:- Absorbing Reagent TCM (Potassium Tetrachloromercurate 0.04M): Mercuric Chloride, Potassium Chloride and EDTA used. For NO<sub>2</sub>:- Absorbing Reagent Sodium Hydroxide (NaOH): Sodium Hydroxide and Sodium Arsenite used. For NH<sub>3</sub> need Conc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>. The GFA filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected two consecutive days a week as per CPCB guidelines, from all the eight locations as mentioned in the EMP.

## 2.2 Results

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the month of November 2022 are given in Tables 2 to 7. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 8 to 9.

The Movement of heavy transport with uncovered coal transportation, raw road around ambient location may be causes fugitive dust emission from dry conditions. Particulate Matter then enters the atmosphere through the action of wind, vehicular movement, or other activities. The dust produces tends to float in air and spread all around the vicinity. Direction and speed of wind affect the dispersion of the dust particulate matter. Humidity of air also has strong effect on the spreading of particulate matter. With increasing humidity, moisture particles eventually grow in size to a point where 'dry deposition' occurs, reducing PM<sub>10</sub> concentrations in the atmosphere.

**Location 1: Marine Bhavan (AL1)**

**Table 2 : Results of Air Pollutant Concentration at Marine Bhavan**

	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL1 – 1	01.11.2022	435	302	121	3.93	3.93	5.19	14.43	2.07	4.11
					6.04		23.66		6.33	
					1.81		14.43		3.91	
AL1 – 2	04.11.2022	344	228	106	3.32	2.52	17.31	12.70	2.42	3.72
					2.72		8.66		5.18	
					1.51		12.12		3.57	
AL1 – 3	08.11.2022	398	281	116	2.31	3.84	25.39	17.31	4.72	3.57
					6.34		17.89		2.42	
					2.88		8.66		3.57	
AL1 – 4	11.11.2022	445	315	124	3.63	6.35	17.89	13.08	4.03	3.61
					9.07		12.70		4.72	
					6.35		8.66		2.07	
AL1 – 5	15.11.2022	364	253	110	4.53	4.53	11.54	13.85	4.60	3.07
					6.35		19.62		2.88	
					2.72		10.39		1.73	
AL1 - 6	18.11.2022	442	315	121	8.46	4.84	23.08	16.54	3.22	4.37
					3.32		8.66		5.87	
					2.72		17.89		4.03	
AL1 - 7	22.11.2022	375	266	106	3.32	4.43	17.89	18.47	4.83	4.45
					7.55		25.97		5.87	
					2.42		11.54		2.65	
AL1 – 8	25.11.2022	483	350	129	4.53	4.63	23.66	21.55	3.22	3.68
					6.95		28.86		5.29	
					2.42		12.12		2.53	
AL1 – 9	29.11.2022	534	383	142	6.35	5.84	17.89	19.04	3.57	3.57
					8.46		25.97		4.95	
					2.72		13.27		2.19	
Monthly Average		424	299	119		4.55		16.33		3.79
Standard Deviation		61	48	12		1.12		3.03		0.44



**Table 2 : Results of Air Pollutant Concentration at Marine Bhavan**

	Date	C6H6 [µg/m <sup>3</sup> ]	HC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>	ppm	4.0 mg/m <sup>3</sup>	-
AL1 – 1	01.11.2022	1.09	BQL	1.44	444
AL1 – 2	04.11.2022	1.2	BQL	1.54	374
AL1 – 3	08.11.2022	1.17	BQL	1.08	538
AL1 – 4	11.11.2022	1.1	BQL	1.14	470
AL1 – 5	15.11.2022	1.11	BQL	1.26	481
AL1 - 6	18.11.2022	1.1	BQL	1.64	500
AL1 - 7	22.11.2022	1.12	BQL	1.35	620
AL1 - 8	25.11.2022	1.16	BQL	1.69	511
AL1 - 9	29.11.2022	1.21	BQL	1.16	522
Monthly Average		1.14	-	1.37	495.56
Standard Deviation		0.05	-	0.22	67.59

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 424 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 299 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 119 µg/m<sup>3</sup> which is above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.55 µg/m<sup>3</sup>, 16.33 µg/m<sup>3</sup> & 3.79 µg/m<sup>3</sup> respectively; these values were within the standard limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.14 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.37 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup> prescribed by NAAQS.

**Location 3: Oil Jetty (AL2)**

**Table 2 : Results of Air Pollutant Concentration at Oil Jetty**

Table 2 : Results of Air Pollutant Concentration at Oil Jetty										
	Date	TSPM [µg/m3 ]	PM10 [µg/m3]	PM2.5 [µg/m3 ]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL2 -1	01.11.2022	150	99	50	2.42	3.22	6.35	13.66	2.88	4.53
					4.53		13.27		6.79	
					2.72		21.35		3.91	
AL2 -2	04.11.2022	253	180	70	2.72	3.53	5.77	11.73	0.81	3.18
					3.32		17.89		4.03	
					4.53		11.54		4.72	
AL2 -3	08.11.2022	235	166	67	2.59	2.50	5.19	14.04	2.19	2.80
					3.46		13.27		2.65	
					1.44		23.66		3.57	
AL2 -4	11.11.2022	275	194	76	6.35	4.53	10.39	14.24	2.42	2.42
					4.53		20.20		3.80	
					2.72		12.12		1.04	
AL2 – 5	15.11.2022	245	169	71	3.02	4.53	8.66	14.04	3.57	2.38
					6.65		16.16		2.30	
					3.93		17.31		1.27	
AL2 – 6	18.11.2022	185	119	53	5.74	4.94	14.43	13.47	4.95	3.84
					2.72		17.31		3.57	
					6.35		8.66		2.99	
AL2 – 7	22.11.2022	373	252	109	3.02	4.03	20.20	14.24	3.80	3.80
					6.35		12.12		5.53	
					2.72		10.39		2.07	
AL2 -8	25.11.2022	292	199	86	1.81	3.83	14.43	14.43	3.57	4.76
					6.35		19.62		4.72	
					3.32		9.23		5.99	
AL1 – 9	29.11.2022	299	194	97	3.63	4.63	5.19	13.47	2.88	3.49
					7.55		23.66		4.95	
					2.72		11.54		2.65	
Monthly Average		256	175	75		3.97		13.70		3.47
Standard Deviation		65	45	19		0.79		0.81		0.85

<b>Table 3 : Results of Air Pollutant Concentration at Oil Jetty</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL2-1</b>	01.11.2022	1.17	BQL	1.22	467
<b>AL2-2</b>	04.11.2022	1.01	BQL	1.53	451
<b>AL2-3</b>	08.11.2022	1.1	BQL	1.65	502
<b>AL2-4</b>	11.11.2022	1.19	BQL	1.04	447
<b>AL2 -5</b>	15.11.2022	1.24	BQL	1.27	634
<b>AL2 -6</b>	18.11.2022	1.16	BQL	1.22	531
<b>AL2-7</b>	22.11.2022	1.2	BQL	1.28	800
<b>AL2-8</b>	25.11.2022	1.06	BQL	1.89	1023
<b>AL2-9</b>	29.11.2022	1.22	BQL	1.46	576
<b>Monthly Average</b>		<b>1.15</b>	<b>-</b>	<b>1.40</b>	<b>603.44</b>
<b>Standard Deviation</b>		<b>0.08</b>	<b>-</b>	<b>0.26</b>	<b>193.07</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

Oil Jetty Area, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> was mainly by motor vehicle emission produced from various types of vehicles at Oil Jetty Area. The mean TSPM value at Oil Jetty was 256 µg/m<sup>3</sup>. The mean PM<sub>10</sub> value was 175 µg/m<sup>3</sup> and mean PM<sub>2.5</sub> value was 75 µg/m<sup>3</sup> which was above the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit prescribed by NAAQS. The mean concentration of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.97 µg/m<sup>3</sup>, 13.70 µg/m<sup>3</sup> and 3.47 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.15 µg/m<sup>3</sup> which was well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.40 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 3: Kandla Colony – Estate Office (AL-3)**

**Table 4 : Results of Air Pollutant Concentration at Estate Office**

Table 4 : Results of Air Pollutant Concentration at Estate Office										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL3 – 1	01.11.2022	245	172	69	1.51	2.32	10.39	9.62	3.68	5.10
					3.32		13.27		7.02	
					2.12		5.19		4.60	
AL3 – 2	04.11.2022	577	445	130	4.53	2.32	5.19	10.39	3.57	2.49
					1.51		17.31		2.88	
					0.91		8.66		1.04	
AL3 – 3	08.11.2022	440	321	109	6.05	3.94	19.04	12.31	4.72	3.64
					2.59		12.12		2.42	
					3.17		5.77		3.80	
AL3 – 4	11.11.2022	518	403	111	3.32	4.23	18.47	10.58	1.38	2.42
					2.72		8.66		3.57	
					6.65		4.62		2.30	
AL3 – 5	15.11.2022	451	340	107	1.81	3.73	23.08	15.97	3.22	2.42
					6.04		14.43		2.30	
					3.32		10.39		1.73	
AL3 – 6	18.11.2022	459	346	112	4.53	4.43	16.16	15.97	5.76	4.14
					2.72		8.66		4.72	
					6.04		23.08		1.96	
AL3 – 7	22.11.2022	453	325	116	2.42	4.33	19.62	17.31	3.91	3.84
					4.23		23.66		5.18	
					6.35		8.66		2.42	
AL3 – 8	25.11.2022	337	252	83	6.04	3.93	15.00	15.58	3.80	3.91
					3.32		23.08		5.76	
					2.42		8.66		2.19	
AL1 – 9	29.11.2022	491	359	129	4.84	4.63	17.89	16.16	3.57	3.57
					6.95		24.24		5.18	
					2.12		6.35		1.96	
Monthly Average		441	329	107		3.76		13.77		3.50
Standard Deviation		98	80	20		0.87		3.00		0.91

**Table 4 : Results of Air Pollutant Concentration at Estate Office**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
NAAQMS limit					
AL3 -1	01.11.2022	1.06	BQL	1.27	508
AL3 -2	04.11.2022	1.1	BQL	1.19	508
AL3 -3	08.11.2022	1.1	BQL	1.65	502
AL3 -4	11.11.2022	1.09	BQL	1.83	429
AL3 - 5	15.11.2022	1.09	BQL	1.76	813
AL3 - 6	18.11.2022	1.2	BQL	1.14	559
AL3 - 7	22.11.2022	1.19	BQL	2.18	1022
AL3 - 8	25.11.2022	1.11	BQL	2	1026
	29.11.2022	1.06	BQL	1.22	537
Monthly Average		1.11	-	1.58	656.00
Standard Deviation		0.05	-	0.39	234.02

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Kandla Port Colony (Estate Office) was attributed by vehicle emission produced from trucks and heavy duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Estate Office were 441 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 329 µg/m<sup>3</sup>, and PM<sub>2.5</sub> value was 107 µg/m<sup>3</sup> which was above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.76 µg/m<sup>3</sup>, 13.77 µg/m<sup>3</sup> and 3.50 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.11 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide was 1.58 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 4: Gopalpuri Hospital (AL-4)**

**Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital**

Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL4 -1	01.11.2022	107	67	34	1.21	2.22	5.77	6.93	2.42	2.53
					3.02		10.39		4.14	
					2.42		4.62		1.04	
AL4 -2	04.11.2022	177	117	54	0.91	2.22	5.19	10.00	1.61	2.49
					4.53		8.66		2.42	
					1.21		16.16		3.45	
AL4 -3	08.11.2022	148	101	44	1.15	2.21	6.93	9.81	1.73	1.69
					2.88		17.31		2.42	
					2.59		5.19		0.92	
AL4 -4	11.11.2022	184	111	68	1.51	2.62	6.93	12.89	1.04	2.30
					3.63		14.43		2.42	
					2.72		17.31		3.45	
AL4 – 5	15.11.2022	202	125	72	2.12	2.42	12.12	12.70	2.42	2.49
					3.63		8.66		3.45	
					1.51		17.31		1.61	
AL4 – 6	18.11.2022	233	153	78	1.21	2.92	8.66	12.89	2.42	2.49
					4.84		17.89		1.61	
					2.72		12.12		3.45	
AL4 – 7	22.11.2022	268	168	94	0.60	2.22	5.77	12.70	1.73	2.88
					3.32		14.43		3.68	
					2.72		17.89		3.22	
AL4 – 8	25.11.2022	202	142	56	2.12	3.42	14.43	12.50	2.07	2.99
					5.14		17.89		4.03	
					3.02		5.19		2.88	
AL1 – 9	29.11.2022	249	157	91	3.02	4.03	8.66	11.54	1.38	2.49
					6.35		20.20		3.80	
					2.72		5.77		2.30	
Monthly Average		197	127	66		2.70		11.33		2.49
Standard Deviation		50	32	20		0.65		2.05		0.37

<b>Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL4 -1</b>	01.11.2022	1.14	BQL	1.26	503
<b>AL4 -2</b>	04.11.2022	1.15	BQL	1.26	450
<b>AL4 -3</b>	08.11.2022	1.03	BQL	1.73	506
<b>AL4 -4</b>	11.11.2022	1.02	BQL	1.82	462
<b>AL4 – 5</b>	15.11.2022	1.09	BQL	1.04	1048
<b>AL4 – 6</b>	18.11.2022	1.14	BQL	1.32	543
<b>AL4 – 7</b>	22.11.2022	1.16	BQL	1.83	758
<b>AL4 – 8</b>	25.11.2022	1.22	BQL	1.8	816
<b>AL4 – 9</b>	29.11.2022	1.16	BQL	1.36	665
<b>Monthly Average</b>		<b>1.12</b>	<b>-</b>	<b>1.49</b>	<b>639.00</b>
<b>Standard Deviation</b>		<b>0.07</b>	<b>-</b>	<b>0.30</b>	<b>201.83</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 197 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 127 µg/m<sup>3</sup> and PM<sub>2.5</sub> was 66 µg/m<sup>3</sup> which was exceed the standard limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 2.70 µg/m<sup>3</sup>, 11.33 µg/m<sup>3</sup> and 2.49 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon monoxide concentration was 1.49 mg/m<sup>3</sup> which is well below the permissible limit of 4.0 mg/m<sup>3</sup>.

Location 5: Coal Storage Area (AL-5)

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL6 – 1	01.11.2022	779	598	175	2.72	4.33	6.35	16.54	3.68	5.06
					6.65		25.97		8.17	
					3.63		17.31		3.34	
AL6 – 2	04.11.2022	635	492	137	2.12	3.53	23.08	17.70	6.79	6.60
					5.44		12.12		8.17	
					3.02		17.89		4.83	
AL6 – 3	08.11.2022	538	412	125	8.94	5.00	23.66	21.74	2.53	3.88
					3.46		12.12		2.07	
					2.59		29.43		7.02	
AL6 – 4	11.11.2022	815	635	178	4.53	4.73	18.47	17.70	5.87	4.41
					2.72		8.66		2.65	
					6.95		25.97		4.72	
AL6 – 5	15.11.2022	792	614	176	6.35	6.65	18.47	13.66	4.72	3.88
					9.07		10.39		3.68	
					4.53		12.12		3.22	
AL6 – 6	18.11.2022	771	595	171	9.37	7.15	20.20	17.12	4.83	4.37
					5.74		8.08		2.53	
					6.35		23.08		5.76	
AL6 – 7	22.11.2022	706	543	156	4.84	4.53	10.39	18.47	4.83	5.03
					6.04		23.66		5.99	
					2.72		21.35		4.26	
AL6 – 8	25.11.2022	846	654	187	3.32	5.24	17.31	19.81	3.91	4.95
					7.86		25.97		6.91	
					4.53		16.16		4.03	
AL1 – 9	29.11.2022	801	621	172	5.14	5.64	16.16	18.28	3.57	4.30
					9.07		28.86		6.22	
					2.72		9.81		3.11	
Monthly Average		743	574	164		5.20		17.89		4.72
Standard Deviation		99	78	21		1.14		2.22		0.84



**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL5 – 1	01.11.2022	1.1	BQL	1.12	483
AL5 – 2	04.11.2022	1.06	BQL	1.48	475
AL5 – 3	08.11.2022	1.08	BQL	1.66	421
AL5 – 4	11.11.2022	1.06	BQL	1.69	492
AL5 – 5	15.11.2022	1.06	BQL	1.06	702
AL5 – 6	18.11.2022	1.22	BQL	1.18	483
AL5 – 7	22.11.2022	1.11	BQL	1.86	564
AL5 – 8	25.11.2022	1.2	BQL	1.54	777
AL5 – 9	29.11.2022	1.22	BQL	1.89	895
Monthly Average		1.12	-	1.50	588.00
Standard Deviation		0.07	-	0.31	164.11

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 743 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 574 µg/m<sup>3</sup>, and the PM<sub>2.5</sub> value was 164 µg/m<sup>3</sup> which was above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 5.20 µg/m<sup>3</sup>, 17.89 µg/m<sup>3</sup> and 4.72 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.12 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.50 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 6: Tuna Port (AL-6)**

**Table 7 : Results of Air Pollutant Concentration at Tuna Port**

Table 7 : Results of Air Pollutant Concentration at Tuna Port										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL5 -1	01.11.2022	141	88	47	0.91	1.61	2.89	6.16	2.07	2.84
					2.72		12.12		4.03	
					1.21		3.46		2.42	
AL5 – 2	04.11.2022	232	166	64	1.51	2.22	6.35	7.89	1.38	2.76
					3.02		5.19		4.49	
					2.12		12.12		2.42	
AL5 – 3	08.11.2022	184	120	55	1.44	2.40	10.39	13.08	1.73	2.61
					3.46		11.54		2.65	
					2.31		17.31		3.45	
AL5 – 4	11.11.2022	233	153	78	2.12	2.32	11.54	11.54	1.27	1.57
					3.93		17.89		1.04	
					0.91		5.19		2.42	
AL5 – 5	15.11.2022	221	145	74	1.21	2.32	6.35	12.12	3.57	2.49
					3.32		12.12		2.30	
					2.42		17.89		1.61	
AL5 – 6	18.11.2022	248	162	83	1.81	2.01	17.31	17.12	2.30	10.21
					1.21		23.66		15.57	
					3.02		10.39		12.76	
AL5 – 7	22.11.2022	214	139	74	1.51	2.52	8.66	8.46	3.57	2.84
					2.72		12.70		2.88	
					3.32		4.04		2.07	
AL5 – 8	25.11.2022	255	175	77	2.72	3.02	8.66	8.08	3.45	3.30
					4.84		11.54		4.72	
					1.51		4.04		1.73	
AL1 – 9	29.11.2022	245	155	87	1.51	3.63	12.70	11.73	1.04	2.88
					6.04		17.31		5.18	
					3.32		5.19		2.42	
Monthly Average		219	145	71		2.45		10.69		3.50
Standard Deviation		36	27	13		0.58		3.37		2.56

**Table 7 : Results of Air Pollutant Concentration at Tuna Port**

		<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>		<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>	<b>Date</b>	<b>8 hr</b>	<b>*NMHC</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL6 -1</b>	01.11.2022	1.12	BQL	1.43	543
<b>AL6 – 2</b>	04.11.2022	1.17	BQL	1.41	463
<b>AL6 – 3</b>	08.11.2022	1.13	BQL	1.39	410
<b>AL6 – 4</b>	11.11.2022	1.13	BQL	1.74	509
<b>AL6 – 5</b>	15.11.2022	1.17	BQL	1.08	911
<b>AL6 – 6</b>	18.11.2022	1.17	BQL	1.1	528
<b>AL6 – 7</b>	22.11.2022	1.06	BQL	1.88	565
<b>AL6 – 8</b>	25.11.2022	1.1	BQL	1.89	999
	29.11.2022	1.22	BQL	1.89	895
<b>Monthly Average</b>		<b>1.14</b>	<b>-</b>	<b>1.53</b>	<b>647.00</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.33</b>	<b>222.45</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port was 219 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 145 µg/m<sup>3</sup> and the mean PM<sub>2.5</sub> value was 71 µg/m<sup>3</sup> which was exceed the standard limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 2.45 µg/m<sup>3</sup>, 10.69 µg/m<sup>3</sup> and 3.50 µg/m<sup>3</sup> respectively and were all within the standard limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.14 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.53 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 7: Admin Building (Vadinar) (AL-7)**

Table 8 : Results of Air Pollutant Concentration at Admin Building										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL7 -1	01.11.2022	150	98	51	2.20	3.52	9.53	10.59	5.36	5.28
					4.84		16.51		2.81	
					3.52		5.72		7.66	
AL7 -2	04.11.2022	177	115	61	3.08	4.69	17.78	21.81	2.81	6.13
					7.03		21.60		8.93	
					3.96		26.04		6.64	
AL7 -3	08.11.2022	193	113	73	6.15	6.30	6.99	11.43	3.83	7.49
					8.79		20.96		10.47	
					3.96		6.35		8.17	
AL7 -4	11.11.2022	200	121	78	3.96	6.01	17.78	15.24	10.47	6.81
					5.28		22.23		5.87	
					8.79		5.72		4.08	
AL7 -5	15.11.2022	179	108	69	1.76	5.28	7.62	18.00	3.06	5.62
					5.71		26.04		5.87	
					8.35		20.33		7.91	
AL7 -6	18.11.2022	223	121	96	2.64	4.54	8.89	15.03	5.62	5.70
					4.40		16.51		8.17	
					6.59		19.69		3.32	
AL1 -7	22.11.2022	162	104	57	4.84	5.28	14.61	14.61	13.02	9.10
					7.03		5.72		8.68	
					3.96		23.50		5.62	
AL1-8	25.11.2022	237	138	97	6.59	4.40	9.53	15.24	7.91	8.00
					3.96		14.61		5.62	
					2.64		21.60		10.47	
AL1-9	28.11.2022	203	112	87	3.96	3.66	6.99	13.76	5.62	6.04
					2.20		14.61		7.91	
					4.84		19.69		4.60	
Monthly Average		191	114	74		4.85		15.08		6.68
Standard Deviation		28	12	17		0.96		3.34		1.28

**Table 8 : Results of Air Pollutant Concentration at Admin Building Vadinar**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [ $\mu\text{g}/\text{m}^3$ ]	*NMHC	CO [ $\text{mg}/\text{m}^3$ ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 $\mu\text{g}/\text{m}^3$		4.0 $\text{mg}/\text{m}^3$	-
AL7 -1	01.11.2022	1.08	BQL	1.43	225
AL7 -2	04.11.2022	1.13	BQL	1.54	236
AL7 -3	08.11.2022	1.17	1.81	1.53	455
AL7 -4	11.10.2022	1.14	BQL	1.61	443
AL7 -5	15.10.2022	1.03	BQL	1.1	347
AL7 -6	18.10.2022	1.06	BQL	1.57	416
AL7 -7	22.10.2022	1.10	BQL	1.05	372
AL7 -8	25.10.2022	1.20	BQL	1.79	464
AL7 -9	28.10.2022	1.13	BQL	1.42	487
Monthly Average		1.12	-	1.46	388
Standard Deviation		0.06	-	0.25	75

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Admin Building, Vadinar the mean TSPM value was  $191 \mu\text{g}/\text{m}^3$ , the mean PM<sub>10</sub> value was  $114 \mu\text{g}/\text{m}^3$  and the mean PM<sub>2.5</sub> value was  $74 \mu\text{g}/\text{m}^3$  which was slightly exceed the standard limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were  $4.85 \mu\text{g}/\text{m}^3$ ,  $15.08 \mu\text{g}/\text{m}^3$  and  $6.68 \mu\text{g}/\text{m}^3$  respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was  $1.12 \mu\text{g}/\text{m}^3$ , well below the permissible limit of  $5.0 \mu\text{g}/\text{m}^3$ . NMHC's were below the detectable limit and Carbon Monoxide concentration was  $1.46 \text{mg}/\text{m}^3$ , well below the permissible limit of  $4.0 \text{mg}/\text{m}^3$ .

**Location 8: Signal Building (Vadinar) (AL-8)**

Table 9 : Results of Air Pollutant Concentration at Signal Building, Vadinar										
	Date	TSPM [µg/m3]	PM10 [µg/m3]	PM2.5 [µg/m3]	SO2 [µg/m3]		NOx [µg/m3]		NH3 [µg/m3]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m3	60 µg/m3		80 µg/m3		80 µg/m3		400 µg/m3
AL8 -1	01.11.2022	113	74	38	3.96	4.40	6.99	13.34	2.30	7.15
					6.59		19.05		8.68	
					2.64		13.97		10.47	
AL8 -2	04.11.2022	146	93	49	2.64	4.40	14.61	15.88	5.36	6.13
					4.84		22.23		8.42	
					5.71		10.80		4.60	
AL8 -3	08.11.2022	124	82	42	3.08	3.52	14.61	16.73	5.62	5.62
					5.28		26.04		7.91	
					2.20		9.53		3.32	
AL8 -4	11.11.2022	175	105	67	2.20	4.40	8.26	13.76	8.93	9.02
					7.03		19.05		12.76	
					3.96		13.97		5.36	
AL8 -5	15.11.2022	152	97	52	3.52	4.98	5.72	13.13	6.89	7.57
					4.84		13.34		10.98	
					6.59		20.33		4.85	
AL8 -6	18.11.2022	176	111	61	3.08	3.81	15.24	17.57	7.15	8.42
					3.96		26.04		7.91	
					4.40		11.43		10.21	
AL8 -7	22.11.2022	214	118	93	3.52	5.71	5.72	12.91	7.91	8.25
					5.28		13.34		6.38	
					8.35		19.69		10.47	
AL8-8	25.11.2022	219	125	92	3.08	4.54	9.53	11.01	5.36	6.04
					4.84		17.78		8.17	
					5.71		5.72		4.60	
AL8-9	28.11.2022	154	97	57	5.71	3.81	10.80	16.94	7.15	8.76
					3.96		22.23		8.93	
					1.76		17.78		10.21	
Monthly Average		164	100	61		4.40		14.59		7.44
Standard Deviation		36	16	20		0.67		2.25		1.27

**Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar**

		<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>		<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>	<b>Date</b>	<b>8 hr</b>	<b>*NMHC</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL8 -1</b>	01.11.2022	1.06	BQL	1.5	467
<b>AL8 -2</b>	04.11.2022	1.05	BQL	1.46	501
<b>AL8 -3</b>	08.11.2022	1.14	1.81	1.31	489
<b>AL8 -4</b>	11.11.2022	1.16	BQL	1.38	439
<b>AL8 -5</b>	15.11.2022	1.17	BQL	1.29	231
<b>AL8 -6</b>	18.11.2022	1.10	BQL	1.31	244
<b>AL8 -7</b>	22.11.2022	1.00	BQL	1.34	227
<b>AL8 -8</b>	25.11.2022	1.05	BQL	1.37	261
<b>AL8 -9</b>	28.11.2022	1.02	BQL	1.29	234
<b>Monthly Average</b>		<b>1.16</b>	<b>-</b>	<b>1.46</b>	<b>442</b>
<b>Standard Deviation</b>		<b>0.05</b>	<b>-</b>	<b>0.27</b>	<b>63</b>

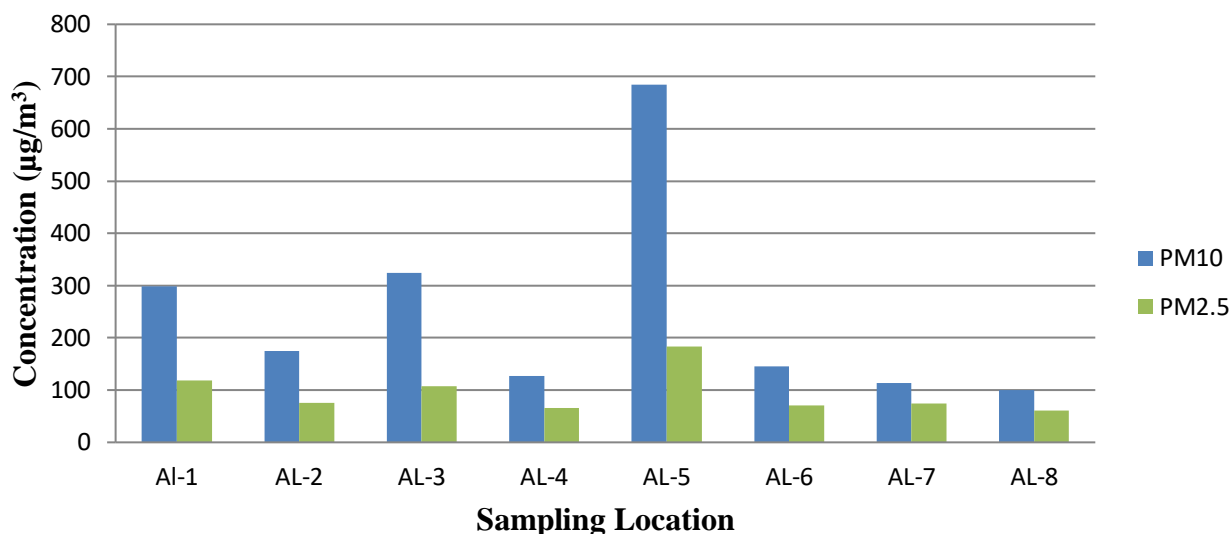
\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

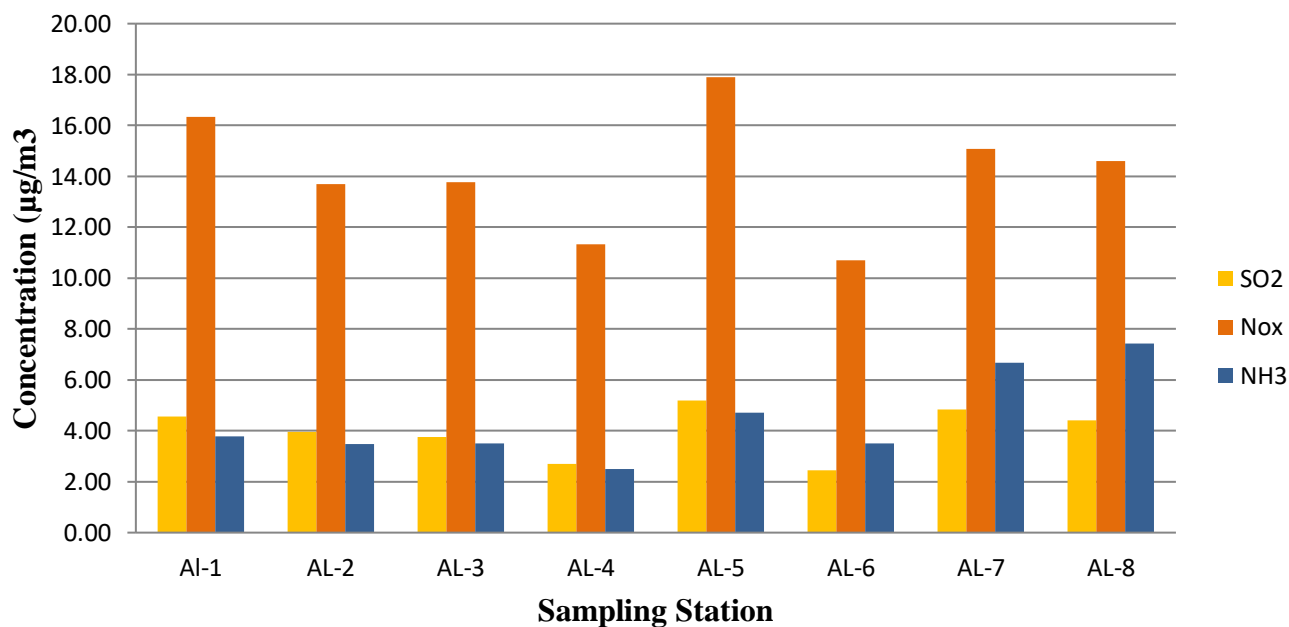
At Signal Building, Vadinar the mean TSPM value was 164 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 100 µg/m<sup>3</sup> which was boundary line of the permissible limit, the mean PM<sub>2.5</sub> value was 61 µg/m<sup>3</sup> which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were 4.40 µg/m<sup>3</sup>, 14.59 µg/m<sup>3</sup> and 7.44 µg/m<sup>3</sup> respectively and were all within the standard limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.16 µg/m<sup>3</sup>, well below the standard limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.46 mg/m<sup>3</sup>, well below the standard limit of 4.0 mg/m<sup>3</sup>.

**Fig. No:-1 Average ambient air quality (PM) month of November-2022 at DPA and Vadinar Sampling Station**

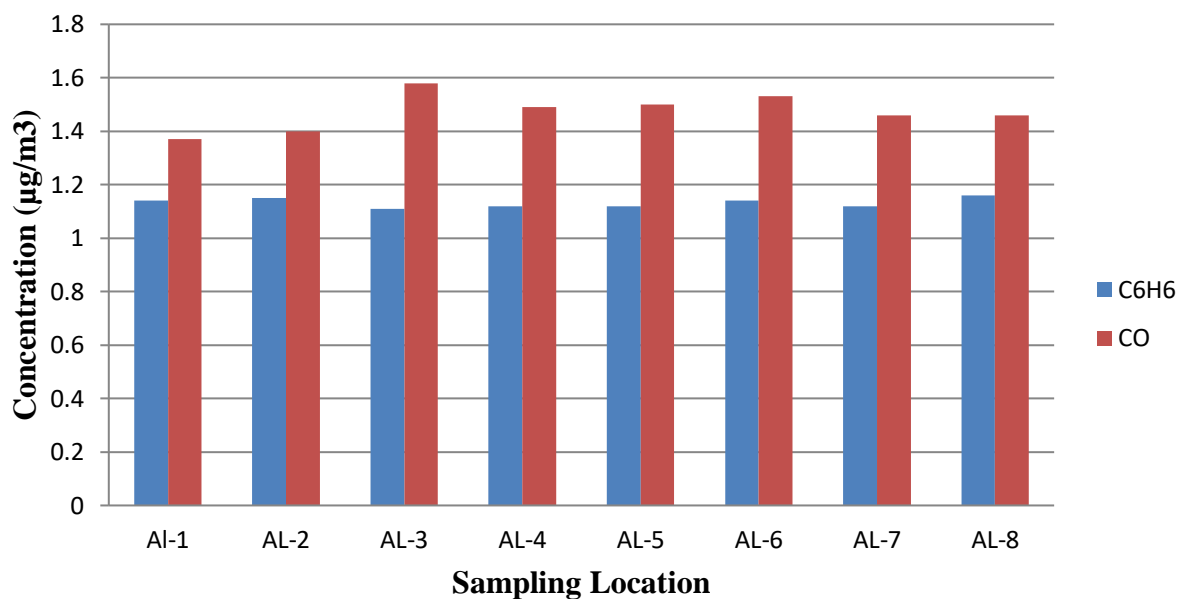


**Fig. No:-2. Average ambient air quality (Gaseous) month of November-2022 at DPA and Vadinar sampling location**

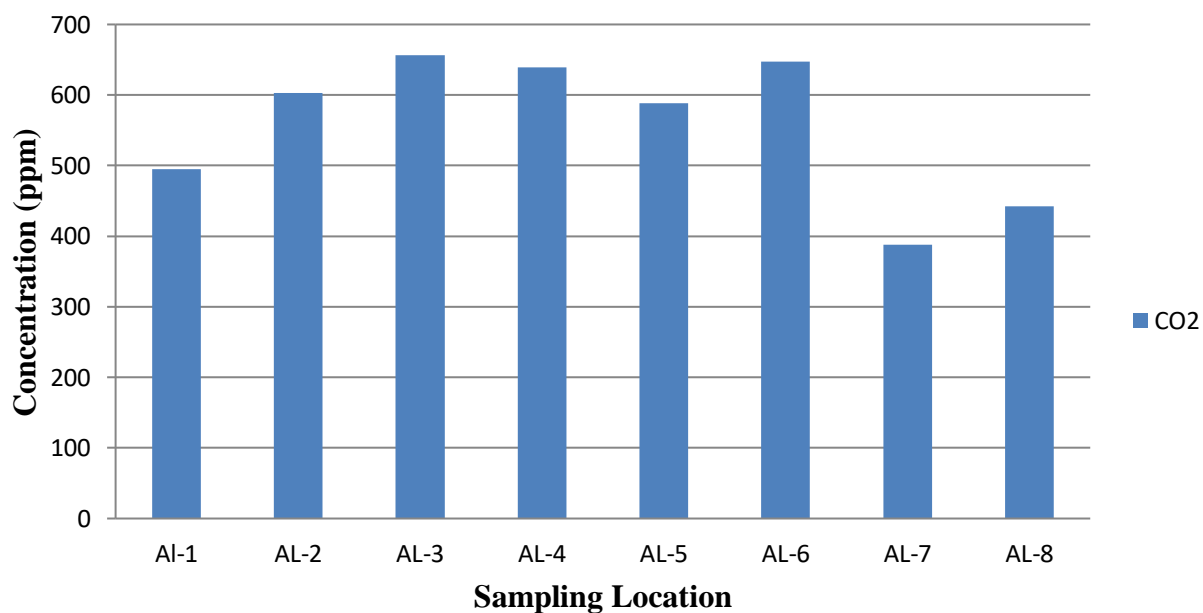




**Fig. No:-3. Average ambient air quality (Gaseous) month of November-2022 at DPA and Vadinar sampling location**



**Fig. No:-4. Average ambient air quality (Gaseous) month of November-2022 at DPA and Vadinar sampling location**



### 2.3 Observations and Conclusion

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Total Suspended Particulate matter as TSPM, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at locations at all ambient air sampling location.

The concentration of PM<sub>10</sub> and PM<sub>2.5</sub> were slightly exceeded at Gopalpuri and Tuna Port.

The mean concentration of PM<sub>10</sub> and PM<sub>2.5</sub> were slightly exceeded at Admin building Vadinar & at Signal building Vadinar was very close to the standard limit.

## **CHAPTER-3**

### **METEOROLOGICAL OBSERVATIONS**

#### **4.1 Meteorological Data**

Automatic Weather station (ID KAZPHOEN424) have been installed in Seva Sadan-3 at the Deendayal Port which records the data on Temperature (°C), Relative Humidity (%), Wind speed (m/s), Wind Direction (°), Solar radiation (w/m<sup>2</sup>) and Rainfall mm.

Meteorological factors play an important role in environmental pollution studies particularly in pollutant transport irrespective of their entry into the environment. The wind speed and direction play a major role in dispersion of environment pollutants. Effects of pollution on receptors animate and inanimate depends on atmospheric condition.

##### **Temperature**

At Deendayal Port, the day time temperature was found range 21.1-32.9<sup>0</sup>C. The average day time temperature was 27.92°C. The night time temperature was range from 20.0-29.7<sup>0</sup>C. The mean night time temperature recorded was 25.47 °C.

##### **Solar Radiation**

The mean Solar Radiation in November month was 167.27 w/m<sup>2</sup>. The maximum solar radiation was recorded 759.0 w/m<sup>2</sup> in 4<sup>th</sup> November, 2022 and the minimum solar radiation was recorded 1.80 w/m<sup>2</sup> in 30<sup>th</sup> November, 2022.

##### **Rainfall**

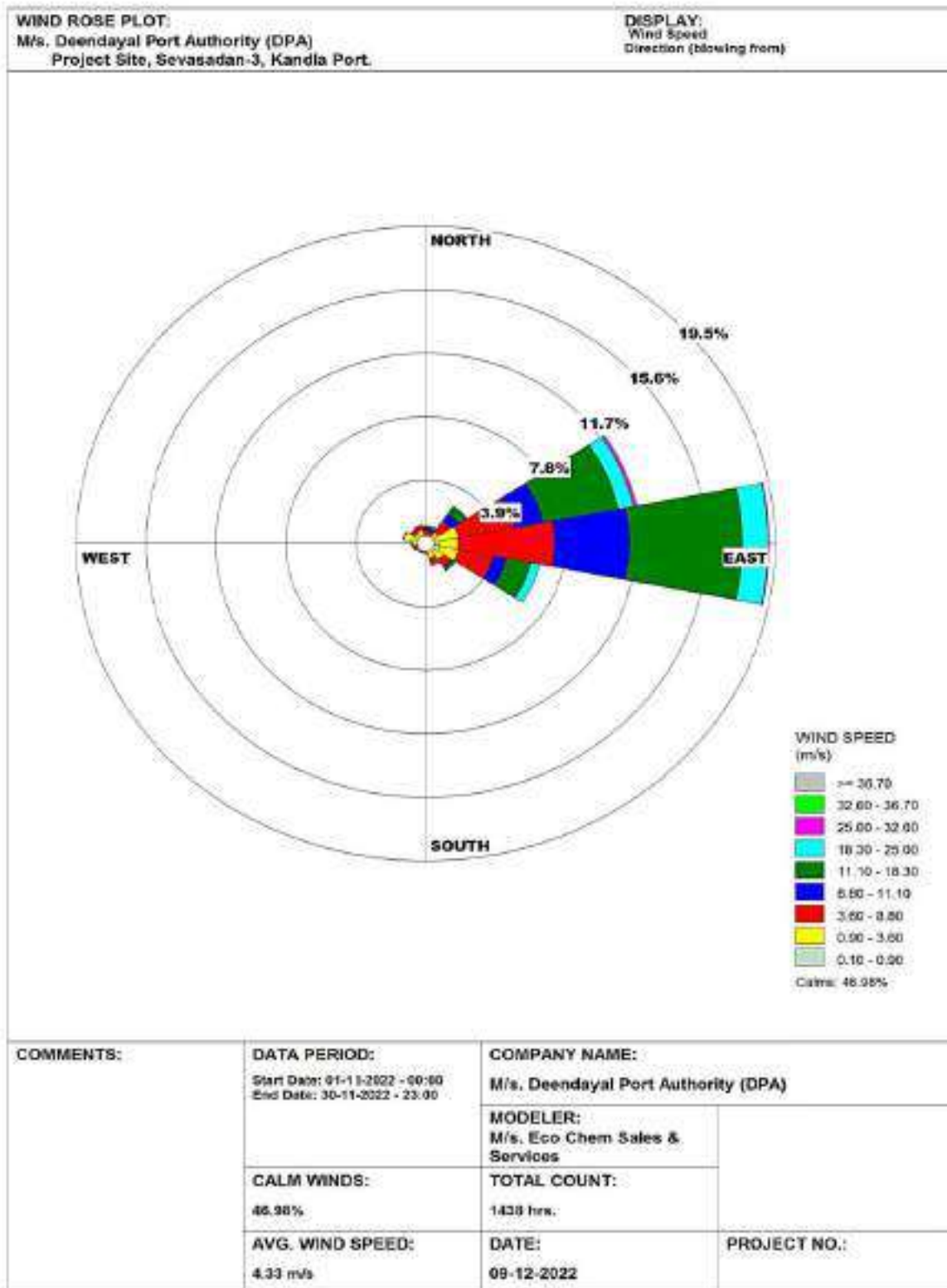
Rain fall of November month was recorded 0.00 mm.

##### **Relative Humidity**

The mean Relative humidity was 69.00 % for the month of November. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 34.0 %.

##### **Wind Velocity and Wind Direction**

Velocity and direction of wind have a significant role in the dispersion of air borne materials and therefore determines the air quality of the area. The average wind velocity for the entire month of November was 1.21 m/s. Maximum wind velocity was recorded 10.19 m/s. The wind direction was mostly North-East.



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## CHAPTER-4

### DRINKING WATER QUALITY MONITORING

#### 4.0 Drinking Water Quality Monitoring

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

**Table No:-10. Drinking Water Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude
1.	Nirman Building	DL-1	23° 0' 27"N	70° 13' 21"E
2.	P & C Building	DL-2	23° 0' 33"N	70° 13' 20"E
3.	North Gate	DL-3	23° 0' 26.97"N	70° 13' 21.87"E
4.	KPT-Canteen	DL-4	23° 2' 17.2674"N	70° 13' 18.2814"E
5.	West Gate	DL-5	23° 59' 40.48"N	70° 12' 50.96"E
6.	Wharf Area	DL-6	22° 59' 52.2"N	70° 13' 22.95"E
7.	Sevasadan-3	DL-7	23° 0' 22.55"N	70° 13' 15.34"E
8.	Workshop	DL-8	23° 0' 33.74"N	70° 13' 20.05"E
9.	Custom Building	DL-9	23° 1' 8.70"N	70° 12' 52.0"E
10.	Kandla Colony	DL-10	23° 11' 14.9"N	70° 12' 48.4"E
11.	KPT Hospital	DL-11	23° 1' 5.02"N	70° 12' 44.38"E
12.	A.O. Building	DL-12	23° 3' 42.89"N	70° 8' 41.5"E
13.	Gopalpuri School	DL-13	23° 5' 1.03"N	70° 7' 55.42"E
14.	Gopalpuri Guest House	DL-14	23° 4' 43.14"N	70° 7' 51.92"E
15.	E-Type Quarters	DL-15	23° 4' 59.90"N	70° 7' 56.72"E
16.	F-Type Quarters	DL-16	23° 4' 38.45"N	70° 8' 8.63"E
17.	Gopalpuri Hospital	DL-17	23° 4' 54.09"N	70° 8' 7.5"E
18.	Tuna Port	DL-18	23° 58' 23.06"N	70° 5' 35.6"E
19.	Vadinar Jetty	DL-19	22° 25' 51.73"N	69° 41' 36.62"E
20.	Vadinar Colony	DL-20	22° 30' 26.25"N	69° 39' 45.03"E

#### **4.1 Drinking Water Monitoring Methodology**

Samples for physico-chemical analysis were collected in 2 Carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS: 3025 Part-1, analysis was done as per IS: 3025/APHA standard methods and, the analysis results compare with IS 10500:2012. The water samples were analyzed for various parameters, viz. Color , Odor, Turbidity , Conductivity , pH , Chlorides , TDS, Total Hardness, Iron , Sulphate, Salinity , DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (CFU) .

#### **4.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 11 to Table No. 17



**Table 11: Drinking Water Quality Monitoring Parameters for Nirman Building, P & C Building and Main Gate (North) at Kandla.**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C Building	Main Gate North	Acceptable Limits as per IS 10500 :2012 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.35	7.33	7.41	7.35	6.5 to 8.5
2	Total Dissolved Solids	mg/l	690	670	670	690	2000
3	Turbidity	NTU	0	1	1	0	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1229	1194	1211	NS*	NS*
7	Biochemical Oxygen	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	576.28	355.79	340.76	250	1000
9	Ca as Ca	mg/l	43.29	41.68	39.28	75	200
10	Mg as Mg	mg/l	58.8060	57.3480	56.3760	30	100
11	Total Hardness	mg/l	350	340	330	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.35	0.37	0.31	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	35.80	30.20	28.30	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	12.70	16.70	15.50	45	No Relaxation
17	Salinity	‰	1.04	0.64	0.62	NS*	NS*
18	Sodium as Na	mg/l	204.00	180.00	192.00	NS*	NS*
19	Potassium as K	mg/l	3.22	3.15	3.18	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/10 0ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified

BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Table 12: Drinking Water Quality Monitoring Parameters for Canteen, West Gate – I & Wharf Area at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per IS 10500 :	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.48	7.52	7.36	7.48	6.5 to 8.5
2	Total Dissolved Solids	mg/l	640	650	680	640	2000
3	Turbidity	NTU	0	1	0	0	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1166	1152	1196	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	335.75	360.80	350.78	250	1000
9	Ca as Ca	mg/l	40.88	38.48	40.08	75	200
10	Mg as Mg	mg/l	62.6940	66.5820	53.4600	30	100
11	Total Hardness	mg/l	360	370	320	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.32	0.30	0.35	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	31.20	28.30	26.00	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	6.60	11.40	5.80	45	No Relaxation
17	Salinity	‰	0.61	0.65	0.63	NS*	NS*
18	Sodium as Na	mg/l	202.00	200.00	-	NS*	NS*
19	Potassium as K	mg/l	3.38	3.48	3.16	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 13: Drinking Water Quality Monitoring Parameters for Sewa sadan-3, Workshop I and Custom Building at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.45	7.38	7.29	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	700	670	910	500	2000
3	Turbidity	NTU	0	1	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1213	1164	1564	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	365.81	370.82	340.76	250	1000
9	Ca as Ca	mg/l	42.48	37.68	39.28	75	200
10	Mg as Mg	mg/l	59.2920	59.7780	53.9460	30	100
11	Total Hardness	mg/l	350	340	320	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.41	0.30	0.35	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	24.90	34.20	27.2	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	6.90	3.90	11.00	45	No Relaxation
17	Salinity	‰	0.66	0.67	0.62	NS*	NS*
18	Sodium as Na	mg/l	-	-	-	NS*	NS*
19	Potassium as K	mg/l	3.26	4.03	3.29	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 14: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla and A.O. Building at Gandhidham.**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 :
1	pH	-	7.39	7.31	7.24	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	760	710	1060	500	2000
3	Turbidity	NTU	1	0	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1328	1251	1821	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	335.75	345.77	365.81	250	1000
9	Ca as Ca	mg/l	41.68	42.48	40.88	75	200
10	Mg as Mg	mg/l	50.0580	54.4320	62.6940	30	100
11	Total Hardness	mg/l	310	330	360	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.35	0.32	0.46	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	28.10	24.50	24.50	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	20.20	7.40	15.60	45	No Relaxation
17	Salinity	‰	0.61	0.62	0.66	NS*	NS*
18	Sodium as Na	mg/l	192.80	193.60	194.50	NS*	NS*
19	Potassium as K	mg/l	4.13	4.18	3.26	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 15: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House) and E - Type Quarter at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.3	7.24	7.26	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	830	950	1030	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1435	1638	1769	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	355.79	350.78	340.76	250	1000
9	Ca as Ca	mg/l	39.28	43.29	39.28	75	200
10	Mg as Mg	mg/l	61.2360	61.2360	51.5160	30	100
11	Total Hardness	mg/l	350	360	310	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.45	0.42	0.47	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	24.90	26.00	30.20	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	7.10	8.30	12.60	45	No Relaxation
17	Salinity	‰	0.64	0.63	0.62	NS*	NS*
18	Sodium as Na	mg/l	199.00	193.80	193.00	NS*	NS*
19	Potassium as K	mg/l	3.90	3.26	3.18	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 16: Drinking Water Quality Monitoring Parameters for F-Type Quarter, Hospital Gopalpuri and Tuna Port.**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.28	7.42	7.51	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	1050	990	600	500	2000
3	Turbidity	NTU	1	1	-	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	1796	1700	1044	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	345.77	360.80	380.85	250	1000
9	Ca as Ca	mg/l	38.48	40.88	32.87	75	200
10	Mg as Mg	mg/l	61.7220	62.6940	72.41	30	100
11	Total Hardness	mg/l	350	360	380	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.42	0.45	0.43	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	26.00	26.10	24.50	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	10.30	6.80	3.00	45	No Relaxation
17	Salinity	‰	0.62	0.65	0.69	NS*	NS*
18	Sodium as Na	mg/l	201.00	201.00	193.60	NS*	NS*
19	Potassium as K	mg/l	3.15	3.16	3.21	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 17: Drinking Water Quality Monitoring Parameters for Vadinar Jetty and Port Colony at Vadinar.**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500 : 2012	Permissible Limits in the absence of Alternate Source as per IS 10500 : 2012
1	pH	-	7.4	7.43	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	320	300	500	2000
3	Turbidity	NTU	0.00	1.00	1	5
4	Odor	-	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	5	15
6	Conductivity	µs/cm	570	300	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	160.36	140.31	250	1000
9	Ca as Ca	mg/l	36.87	34.47	75	200
10	Mg as Mg	mg/l	43.25	52.00	30	100
11	Total Hardness	mg/l	270	300	200	600
12	Iron as Fe	mg/l	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.25	0.22	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	0.75	0.24	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	15.60	12.70	45	No Relaxation
17	Salinity	‰	0.29	0.25	NS*	NS*
18	Sodium as Na	mg/l	191.6	192.0	NS*	NS*
19	Potassium as K	mg/l	BQL	BQL	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



### **4.3 Results & Discussion**

The colour of all drinking water samples was found Colourless and odour of the samples also agreeable. All parameters were found within the specified limit as per the Drinking water Standard.

#### **pH**

The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. At DPA Site the pH values for drinking water samples ranged from 7.24-7.52 and mean value was 7.36 while at Vadinar pH ranged from 7.40-7.43 and mean value was 7.42. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Turbidity**

The selected drinking water sample location turbidity range from 0-1NTU at all location of DPA and Vadinar in month of November. The Turbidity values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Total Dissolved Solids (TDS)**

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc.

TDS values at DPA varied between 600-1060 mg/l. The average TDS value was found 792 mg/l. The minimum value for TDS was 600 mg/l at Hospital Gopalpuri and maximum was 980 mg/l at Tuna Port while at Vadinar TDS ranged from 280-300 mg/l and mean was 290.0 mg/l. The TDS values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the month of November DPA ranged from 1044.0  $\mu\text{S}/\text{cm}$  at Tuna Port to 1821.0  $\mu\text{S}/\text{cm}$  at A.O. Building and mean value was 1381.72  $\mu\text{S}/\text{cm}$  while at Vadinar ranged from 300-570  $\mu\text{S}/\text{cm}$  and mean was 435  $\mu\text{S}/\text{cm}$ .



## **BOD**

BOD value in the studied area of DPA and Vadinar was found Below Quantification Limit (<2.0 mg/l). IS 10500:2012 does not show any standard values for BOD in drinking water.

## **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. The Chloride value in the studied area of DPA ranged from 335.75-576.28 mg/l. The mean value was 365.53 mg/l. The minimum chloride was 335.75 mg/l at Port colony and maximum was 576.28 mg/l at Nirmal Building while at Vadinar location chloride ranged from 140.31-160.36 mg/l and mean was 150.33 mg/l. The Chloride was found within the Permissible limit of the Drinking Water Standard.

## **Calcium**

Calcium is most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases.

The Calcium value in the studied area of DPA ranged from 32.87-43.29 mg/l. The mean value was 40.12 mg/l. The minimum calcium was 32.87 mg/l at Tuna Port and maximum was 43.29 mg/l at Gopalpuri Hospital while at Vadinar location Calcium ranged from 34.47-36.87 and mean was 35.67 mg/l. All the locations had calcium within the prescribed limits of 75-200 mg/L.

## **Magnesium**

The magnesium value in the studied area of DPA ranged from 50.06-72.41 mg/l. The mean value was 59.24 mg/l. The minimum magnesium was 50.06 mg/l at Port Colony and maximum was 74.41 mg/l at Tuna Port while at Vadinar location magnesium ranged from 43.25-52.00 and mean was 47.61 mg/l. All the locations had magnesium within the prescribed limits of 30-100 mg/L.

## **Total Hardness**

Total Hardness value in the studied area of DPA ranged from 310.0 mg/l at Port Colony to 380.0 mg/l at Tuna Port and mean value was 343.89 mg/l while at Vadinar location total hardness ranged from 270.0-300.00 mg/l and mean was 285.0 mg/l. The values of total

hardness were found within the Permissible limit of the Drinking Water Standard (200-600 mg/L). These results clear, that hardness of water is according to the IS standards and it is not harmful for local inhabitants.

### **Iron**

Iron values in the studied area of DPA & Vadinar were Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards are 0.3 mg/L.

### **Fluoride**

Fluoride value in the studied area of DPA varied between 0.3-0.47 mg/l and mean was 0.38 mg/l. The minimum value was 0.3 mg/ at West gate workshop and maximum was 0.47 mg/l at E-Type and mean was 0.38 mg/l while at Vadinar location fluoride ranged from 0.22-0.25 mg/l and mean was 0.24 mg/l. The Fluoride values were well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphate**

Sulphate value in the studied area of DPA varied between 24.5–35.8 mg/l and mean was 27.83 mg/l. The minimum value was 24.5 mg/ at A.O. Building, Hospital Kandla and Tuna Port and maximum was 35.8 mg/l at Nirmal Building while at Vadinar location Sulphate ranged from 0.24-0.75 mg/l and mean was 0.50 mg/l. All the sampling points showed Sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

The all values of Nitrite were found BQL (<0.05 mg/l) and Nitrate were well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected at DPA ranged from 0.61 ‰ at Canteen to 1.04 ‰ at Nirmal Building and average salinity was 0.66 ‰ while at Vadinar sampling location salinity ranged from 0.25-0.29 ‰. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected at DPA ranged from 180 - 204 mg/l and average was 195.74 mg/l while at Vadinar sodium ranged from 191.6- 192.0 mg/l and average was 191.8 mg/l . Potassium salts ranged at DPA ranged from 3.15 to 4.18 mg/l while average was 3.42 mg/l while at Vadinar sampling locations potassium were BQL (<2.0 mg/l). There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter (E-coli and total coliform) at all location shows that Bacteria were not detectable. This shows that drinking water samples were safe for human consumption as per tested parameters.

## **4.4 Conclusions**

These results were compared with permissible limits as prescribed in IS 10500:2012 – Drinking Water Specification. It was seen from the analysis data that during the study period at selected sampling location the water was safe for human consumption as per analyzed parameters at all drinking water monitoring stations.

## CHAPTER-5

### NOISE MONITORING

## 5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 5.1 Method of Monitoring

Sampling was done at all stations for 24 hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 5.2 Results

**Table 18: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	Sampling Time	6:00 am to 10:00 PM	10:00PM to 6:00 AM
1	Marine Bhavan	60.8	51.9
2	Nirman Building 1	69.9	52.0
3	Tuna Port	53.2	45.4
4	Main Gate North	63.3	51.9
5	West Gate I	67.7	58.1
6	Canteen Area	68.2	51.2
7	Main Road	66.3	52.2
8	ATM Building	69.1	51.1
9	Wharf Area /Jetty Area	70.4	61.7
10	Port & Custom Office	54.7	50.2
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	55.0	53.5
12	Nr. Port Colony, Vadinar	60.6	57.6
13	Nr. Vadinar Jetty	52.5	51.0

### 5.3 Conclusions

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships.

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 53.2 dB(A) to 70.4 dB(A) while at Vadinar port 3 location ranged from 52.5 dB(A) to 60.6 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 45.4 dB to 61.7 dB(A) while at Vadinar port ranged from 52.5 dB (A) to 60.6 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.

## CHAPTER-6

### SOIL MONITORING

## 6.0 Soil Monitoring

Sampling and analysis of soil samples were undertaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

**Table No.:-19. Soil Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Tuna Port	SL-1	22° 58' 10.18"N	70° 6' 3.7"E	Near main gate of Port
2.	IFFCO Plant	SL-2	23° 26' 8.37"N	70° 13' 4.4"E	10 m away from main gate
3.	Khori creek	SL-3	22° 58' 10.18"N	70° 6' 3.7"E	Sand from creek after tide
4.	Nakti Creek	SL-4	23° 2' 1.10"N	70° 9' 33.6"E	
5.	DPA admin site	SL-5	22° 26' 30.9"N	69° 40' 37.03"E	Vadinar
6.	DPA colony	SL-6	22° 23' 57.09"N	69° 42' 49.42"E	

## 6.1 Methodology

The soil samples were collected in the month of November 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.



## 6.2 Results

**Table-20: Chemical Characteristics of Soil in the Study Area for Tuna port, IFFCO, Khori Creek, Nakti Creek, DPA admin site, DPA colony.**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main	Sand from creek after tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	7.79	7.80	7.54	7.58	8.14	7.54
3	Electrical Conductivity	µs/cm	35000.0	36100.0	26,820.00	12,700.0	155.0	594.0
4	Phosphorus	mg/kg	10.3	10.5	9.19	8.49	6.00	4.80
5	Moisture	%	15.9	20.3	20.90	3.50	7.20	10.10
6	Total Organic	%	4.04	1.7	3.64	7.80	2.30	2.00
7	Alkalinity	mg/kg	900.0	1000.0	800.0	500.0	800.0	600.0
8	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
9	Sulphate	mg/kg	820.00	982.00	1,080.00	810.00	30.0	70.0
10	Chloride	mg/kg	15598.0	14275.0	12,600.00	2,950.00	140.00	525.00
11	Calcium	mg/kg	2,605.00	2,505.00	31,600.00	3,086.00	1,729.00	1,849.00
12	Sodium	mg/kg	5657	7136.0	7,649.00	4,675.00	33.02	116.90
13	Potassium	mg/kg	552	694	708.00	437.00	44.60	44.52
14	Copper as Cu	mg/kg	27.4	15.5	30.50	14.50	54.10	31.60
15	Lead as Pb	mg/kg	7.4	7.4	9.50	6.30	74.10	75.30
16	Nickel as Ni	mg/kg	39.40	32.70	44.40	27.20	30.30	32.00
17	Zinc as Zn	mg/kg	62.4	77.40	79.20	56.50	50.60	86.00
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg)

### 6.3 Discussion

- DPA Kandla soil sampling data shows that value of pH ranges from 7.54 at Khori Creek to 7.80 at IFFCO Plant while the average value was 7.68. At Vadinar sampling location pH were 7.54 at DPA colony and 8.14 at DPA Admin Site.
- The Electrical Conductivity of DPA Kandla soil sample ranged from 12700.0  $\mu\text{S}/\text{cm}$  at Nakti Creek (Sand from creek after tide) to 36100  $\mu\text{S}/\text{cm}$  at IFFCO Plant and mean was 27655  $\mu\text{S}/\text{cm}$  while Vadinar soil sampling location conductivity were 155  $\mu\text{S}/\text{cm}$  at DPA Admin Site and 594  $\mu\text{S}/\text{cm}$  at DPA Colony site.
- Total organic Carbon of DPA Kandla soil sample ranged from 1.7 % at IFFCO Plant to 7.80 % at Nakti Creek (Sand from creek after tide) and mean was 4.30 % while Vadinar soil sample were 2.0 % at DPA Colony and 2.30 % at DPA admin Site.
- The concentration of Phosphorus in the soil samples of DPA Kandla varies from 8.49 mg/kg at Nakti Creek (Sand from creek after tide) and 10.5 mg/kg at IFFCO Plant and mean was 9.62 mg/kg while the Vadinar soil sample for Phosphorus were 4.80 mg/kg at DPA Colony and 6.00 mg/kg at DPA Admin Site.
- Chloride in soil sample of DPA ranged from 2950.00 mg/kg at Nakti Creek (Sand from creek after tide) to 15598 mg/kg at Tuna Port and mean was 11356 mg/kg while Vadinar soil sample were 140 mg/kg at DPA admin and 525 mg/kg at DPA Colony.
- The Concentration of Potassium in the soil samples of DPA Kandla ranged from 437 mg/kg at Nakti creek and 708 mg/kg at Khori Creek and mean was 597.75 mg/kg while the Vadinar soil sample for Potassium were 44.52 mg/kg at DPA Colony Site and 44.60 mg/kg at DPA Admin Site.
- The concentration of Sodium in the soil samples of DPA Kandla ranged from 4675.0 mg/kg at Nakti creek and 7649.0 mg/kg at Khori Creek and mean was 6279 mg/kg while the Vadinar soil sample for Sodium were 33.00 mg/kg at DPA Admin Site and 117 mg/kg at DPA Colony.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL3 & SL4 (Khori Creek & Nakti Creek) were coastal soil; where as other locations are inland locations and have different chemical properties.

### Heavy Metals in the Soil

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port Authority Kandla and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### 6.4 Conclusion

The soils of Deendayal Port Authority Kandla and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

## **CHAPTER-7**

### **SEWAGE TREATMENT PLANT MONITORING**

## 7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guidelines of State Pollution Control Board and other statutory bodies.

### 7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

A new STP with an improved capacity of 1 MLD is being constructed at Gopalpuri Colony.

**Table No. 21. Sewage Treatment Plant**

Sr. No.	Location of STP	Types of Treatment	STP Capacity	Treated water Utilization
1.	Gopalpuri Township	MBBR	450 KLD	Plantation and Gardening
2.	Deendayal Port, Kandla	MBBR	600 KLD	Discharge to marine through pipeline, Plantation, Gardening
3.	Vadinar Port Colony	MBBR	1.5 MLD	Plantation and Gardening

## 7.2 Results

**Table 22: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	03.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.55	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	100.6	46.8	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	80.8	30.3	100
5	BOD @ 27 °C	mg/l	22	11	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	14.0		
7	MLVSS	%	99.73		

**Table 23: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	10.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.41	7.36	6.5 - 8.5
2	Total Suspended Solids	mg/l	127	52.6	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	90.9	40.4	100
5	BOD @ 27 °C	mg/l	23	11	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	18.0		
7	MLVSS	%	85.00		

**Table 24: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	17.11.2022
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Sr. No.	Parameters	Unit	Results		CPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.48	7.29	6.5 - 8.5
2	Total Suspended Solids	mg/l	86.4	22.9	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	101	50.5	100
5	BOD @ 27 °C	mg/l	26	14	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	20.0		
7	MLVSS	%	98.0		

**Table 25: Sewage Water Monitoring at Kandla STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	24.10.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.41	7.29	6.5 - 8.5
2	Total Suspended Solids	mg/l	164.2	58.7	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	171.7	30.3	100
5	BOD @ 27 °C	mg/l	43	10	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	20.0		
7	MLVSS	%	89.0		

**Table 26: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	03.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.47	7.31	6.5 - 8.5
2	Total Suspended Solids	mg/l	121.2	61	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	111.1	60.6	100
5	BOD @ 27 °C	mg/l	32	13	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	22.0		
7	MLVSS	%	97.16		

**Table 27: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	10.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.35	7.27	6.5 - 8.5
2	Total Suspended Solids	mg/l	189	67.9	100
3	Residual Chlorine	mg/l			-
4	COD	mg/l	141.4	60.6	100
5	BOD @ 27 °C	mg/l	37	15	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	16.0		
7	MLVSS	%	89.6		

**Table 28: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	17.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.41	7.36	6.5 - 8.5
2	Total Suspended Solids	mg/l	127	52.6	100
3	Residual Chlorine	mg/l			-
4	COD	mg/l	90.9	40.4	100
5	BOD @ 27 °C	mg/l	23	11	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	08.0		
7	MLVSS	%	98.0		

**Table 29: Sewage Water Monitoring at Gopalpuri STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	24.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.48	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	110.2	42.1	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	78	40	100
5	BOD @ 27 °C	mg/l	24.0	12.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	18.0		
7	MLVSS	%	90.0		



**Table 30: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	03.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.35	7.25	6.5 - 8.5
2	Total Suspended Solids	mg/l	74.9	39.5	100
3	Residual Chlorine	mg/	-	<0.5	-
4	COD	mg/l	101	40.4	100
5	BOD @ 27 °C	mg/l	26.0	10.0	30

**Table 31: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	10.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.38	7.21	6.5 - 8.5
2	Total Suspended Solids	mg/l	69.6	40.3	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	131.3	50.5	100
5	BOD @ 27 °C	mg/l	32.0	7.0	30

**Table 32: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	17.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.51	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	38.6	16.9	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	80.8	20.2	100
5	BOD @ 27 °C	mg/l	24.0	12.0	30

**Table 33: Sewage Water Monitoring at Vadinar STP (4<sup>th</sup> Week)**

<b>Date of Sampling</b>	24.11.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.61	7.42	6.5 - 8.5
2	Total Suspended Solids	mg/l	76.9	33.3	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	131.3	20.2	100
5	BOD @ 27 °C	mg/l	20.0	8.0	30

**Table No. 34. General Standards for discharge of Environmental Pollutant Part-A**

Sr. No.	Parameter	Inland Surface Water	Land Irrigation	Marine Coastal Areas
1.	pH	5.5-9.0	5.5-9.0	5.5-9.0
2.	Total Suspended Solids (mg/l)	100	200	100
3.	Residual Chlorine (mg/l)	1.0	-	1.0
4.	BOD (mg/l)	30	100	100
5.	COD (mg/l)	250	-	250

**Sources:-CPCB****7.3 Results & Discussion**

The STP Sample carried out to evaluate the efficiency and performance of the wastewater treatment plant at Gopalpuri, Kandla and Vadinar STP. The performance of these plants is an essential parameter to monitor because the treated sewage water is discharged for irrigation purposes and discharge into marine. Wastewater samples were collected from different unit operations of the plant i.e, the inlet, aeration tank and the final treated outlet. These samples were analyzed for various physico-chemical characteristics such as pH, TSS, Residual Chlorine, COD, BOD, MLSS and MLVS.

The final treated outlet observed pH values were within the allowed range at STP Gopalpuri, STP Kandla & STP Vadinar ranged from 7.22 -7.35, 7.29-7.42 & 7.21-7.42 respectively. The wastewater treatment makes it suitable for irrigation. These values are below the allowed limit of the GPCB.

- The final treated outlet observed Total suspended solid values at Gopalpuri, DPA Kandla & Vadinar ranged from 27.10-67.90 mg/l, 22.90-58.70 mg/l & 16.60-40.30 mg/l respectively. These values are below the allowed limit of the GPCB.
- The final treated outlet observed Residual Chlorine values were <0.5 at Gopalpuri, DPA Kandla & Vadinar. These values are below the allowed limit of the CPCB.
- The final treated outlet observed COD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 40.40-60.60 mg/l, 30.30-50.50 mg/l & 20.20-50.50 mg/l respectively. These values are below the allowed limit of the CPCB.

- The main focus of wastewater treatment plants is supposed to reduce the BOD in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The final treated outlet observed BOD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 12.0-16.0 mg/l, 10.0-14.0 mg/l & 7.0-12.0 mg/l respectively. These values are below the allowed limit of the GPCB.

#### **7.4 Conclusions:**

All parameters for STP outlet are within limit prescribed by CPCB. After the final treatment, it is found that the treated water is satisfactory.

## CHAPTER-8

### MARINE WATER MONITORING

## **8.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 underscored the importance of ‘green thinking’. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the “fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”.

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at “integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources.” The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 01<sup>st</sup> & 02<sup>nd</sup> November-2022 in harbor regions of DPA & Vadinar during Neap tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 8<sup>th</sup> & 9<sup>th</sup> November-2022 in harbor regions of DPA & Vadinar during Spring tide period first quarter of Lunar Cycle.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbor area and two stations in Nakti creek and one station in Khorī creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same month. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this month. Collected water samples were processed for estimation

of Chlorophyll- a, Pheophytin- a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

### Sampling Locations

Offshore monitoring requirement	Number of locations
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khori creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

### 8.1 Marine Water Quality and Results

Marine water quality of marine waters of Deendayal Port Harbor waters, Khori & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The results of marine water quality from table no 35 to 42. During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.

**Table 35: Marine Water Quality Monitoring Parameters for Location Near DPA Colony**

Sr. No.	Parameters	Unit	Kandla Creek Near DPA Colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.61	7.58	7.55	7.46
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	19.0	19.9	20.4	19.0
5	Turbidity	NTU	38	35	42	35
6	Total Dissolved Solids	mg/l	34152.0	30868.0	30941.0	31974.0
7	Total Suspended Solids	mg/l	639.6	600.6	646.4	595.6
8	Total Solids	mg/l	34791.6	31468.6	31587.4	32569.6
9	DO	mg/l	5.8	5.6	5.7	5.5
10	COD	mg/l	88.0	79.0	82.0	86.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.06	0.82	0.99	0.91
13	Phosphate	mg/l	0.48	0.31	0.09	0.04
14	Sulphate	mg/l	3580	3407	3708.0	3658
15	Nitrate	mg/l	4.70	0.50	0.75	0.42
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	521.04	440.88	561.12	480.96
18	Magnesium	mg/l	1773.9	1749.6	1701	1773.9
19	Sodium	mg/l	8011.0	8399.0	8396.0	8699.0
20	Potassium	mg/l	299.0	385.0	391.0	395.0
21	Iron	mg/l	BQL	BQL	0.88	0.57
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).



**Table 36: Marine Water Quality Monitoring Parameters for Location Near Passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.43	7.28	7.33	7.41
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	20.8	20.4	19.9	18.6
5	Turbidity	NTU	43	48	36	41
6	Total Dissolved Solids	mg/l	35468.0	37102.0	34662.0	33398.0
7	Total Suspended Solids	mg/l	679.7	665.5	703.7	663.8
8	Total Solids	mg/l	36147.7	37767.5	35365.7	34061.8
9	DO	mg/l	5.9	6.2	5.6	5.2
10	COD	mg/l	86.0	94.0	90.0	92.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.26	0.86	1.33	0.85
13	Phosphate	mg/l	0.29	0.13	0.33	0.19
14	Sulphate	mg/l	3571	3470	4072	3407
15	Nitrate	mg/l	3.40	2.70	1.17	4.36
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	561.12	601.20	601.2	521.04
18	Magnesium	mg/l	1701	1603.8	1749.6	1701
19	Sodium	mg/l	9142.0	9345.0	9247.0	9219.0
20	Potassium	mg/l	370.0	385.0	370.0	380.0
21	Iron	mg/l	0.47	BQL	1.76	0.30
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Nitrite: 0.05mg/l Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 37: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.37	7.51	7.53	7.25
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	18.6	18.1	19.5	20.8
5	Turbidity	NTU	33	42	38	45
6	Total Dissolved Solids	mg/l	39222.0	37586.0	37123.0	36668.0
7	Total Suspended Solids	mg/l	540.2	638.4	620.6	580.2
8	Total Solids	mg/l	39762.2	38224.4	37743.6	37248.2
9	DO	mg/l	7.3	6.4	7.1	6.5
10	COD	mg/l	81.0	874.0	88.0	84.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.56	0.98	0.69	1.76
13	Phosphate	mg/l	0.06	0.56	0.12	0.61
14	Sulphate	mg/l	4222	3458	2981	3758
15	Nitrate	mg/l	2.20	4.60	2.68	4.70
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	480.96	641.28	641.28	721.44
18	Magnesium	mg/l	1628.1	1628.1	1676.7	1603.8
19	Sodium	mg/l	8346.0	9380.0	9245.0	9814.0
20	Potassium	mg/l	391.0	300.0	392.0	384.0
21	Iron	mg/l	BQL	BQL	BQL	1.34
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 38: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	Khori creek			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.48	7.27	7.34	7.21
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	20.4	19.5	18.6	17.7
5	Turbidity	NTU	35	31	43	39
6	Total Dissolved Solids	mg/l	32557.0	34294.0	30473.0	33329.0
7	Total Suspended Solids	mg/l	641.2	616.3	594.7	731.2
8	Total Solids	mg/l	33198.2	34910.3	31067.7	34060.2
9	DO	mg/l	7.6	6.3	7.3	6.8
10	COD	mg/l	85.0	96.0	92.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.78	1.04	1.39	1.18
13	Phosphate	mg/l	0.44	0.67	0.35	0.42
14	Sulphate	mg/l	4047	3646	3157	3170
15	Nitrate	mg/l	3.70	1.10	1.34	5.20
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	561.12	480.96	480.96	561.12
18	Magnesium	mg/l	1725.3	1676.7	1701	1628.1
19	Sodium	mg/l	9112.0	8436.0	7966.0	8696.0
20	Potassium	mg/l	299.0	385.0	382.0	377.0
21	Iron	mg/l	0.44	BQL	0.17	0.31
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	0.02
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 39: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.41	7.36	7.48	7.23
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	19.0	18.6	19.0	19.5
5	Turbidity	NTU	45	36	40	42
6	Total Dissolved Solids	mg/l	30214.0	28996.0	31047.0	31957.0
7	Total Suspended Solids	mg/l	642.7	526.2	682.5	606.8
8	Total Solids	mg/l	30856.7	29522.2	31729.5	32563.8
9	DO	mg/l	8.1	7.5	6.4	7.2
10	COD	mg/l	94.0	112.0	98.0	100.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.12	1.20	1.42	1.22
13	Phosphate	mg/l	0.71	0.37	0.46	0.12
14	Sulphate	mg/l	4172	3846	3445	3433
15	Nitrate	mg/l	1.50	1.70	5.12	1.69
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	440.88	641.28	601.2	521.04
18	Magnesium	mg/l	1725.3	1555.2	1701	1773.9
19	Sodium	mg/l	8639.0	9143.0	8655.0	7939.0
20	Potassium	mg/l	395.0	386.0	384.0	386.0
21	Iron	mg/l	BQL	0.33	0.34	0.18
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 40: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.45	Sampling not possible during Low Tide	7.45	Sampling not possible during Low Tide
2	Color	-	Agreeable		Agreeable	
3	Odor	-	Agreeable		Agreeable	
4	Salinity	‰	19.9		20.8	
5	Turbidity	NTU	45		44	
6	Total Dissolved Solids	mg/l	30288.0		32796.0	
7	Total Suspended Solids	mg/l	529.6		595.7	
8	Total Solids	mg/l	30817.6		33391.7	
9	DO	mg/l	7.4		6.9	
10	COD	mg/l	118.0		110.0	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	1.02		0.16	
13	Phosphate	mg/l	0.75		0.46	
14	Sulphate	mg/l	4109		4961	
15	Nitrate	mg/l	2.70		3.52	
16	Nitrite	mg/l	<0.05		BQL	
17	Calcium	mg/l	681.36		641.28	
18	Magnesium	mg/l	1506.6		1628.1	
19	Sodium	mg/l	9280.0		8528.0	
20	Potassium	mg/l	427.0		427.0	
21	Iron	mg/l	BQL		0.54	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		0.01	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1 mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 41: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.43	7.26	7.36	7.29
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	20.4	20.8	19.0	19.9
5	Turbidity	NTU	39	42	38	42
6	Total Dissolved Solids	mg/l	35265.0	37685.0	36325.0	36681.0
7	Total Suspended Solids	mg/l	585.3	590.8	681.4	657.6
8	Total Solids	mg/l	35850.3	38275.8	37006.4	37338.6
9	DO	mg/l	5.7	5.4	6.3	5.8
10	COD	mg/l	87.0	89.0	96.0	92.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.55	0.45	0.36	0.28
13	Phosphate	mg/l	0.18	0.42	0.33	0.19
14	Sulphate	mg/l	3608	3558	3683	3645
15	Nitrate	mg/l	2.35	1.09	1.00	2.43
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	480.96	601.20	521.04	480.96
18	Magnesium	mg/l	1603.8	1652.4	1676.7	1749.6
19	Sodium	mg/l	9448.0	7368.0	7810.0	8912.0
20	Potassium	mg/l	371.0	354.0	452.0	456.0
21	Iron	mg/l	BQL	BQL	0.31	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.29	BQL	0.77	0.35

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 42: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr. Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.37	7.22	7.41	7.35
2	Color	-	Agreeable	Agreeable	Agreeable	Agreeable
3	Odor	-	Agreeable	Agreeable	Agreeable	Agreeable
4	Salinity	‰	19.0	17.7	19.5	18.6
5	Turbidity	NTU	37	40	37	39
6	Total Dissolved Solids	mg/l	39961.0	39198.0	42642.0	40730.0
7	Total Suspended Solids	mg/l	545.5	493.6	714.3	657.9
8	Total Solids	mg/l	40506.5	39691.6	43356.3	41387.9
9	DO	mg/l	6.1	5.5	5.6	6.1
10	COD	mg/l	95.0	98.0	96.0	94.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.47	0.37	0.34	0.30
13	Phosphate	mg/l	1.08	0.19	0.46	0.28
14	Sulphate	mg/l	3495	3796	3745	4008
15	Nitrate	mg/l	3.86	2.18	4.95	2.10
16	Nitrite	mg/l	<0.05	<0.05	BQL	BQL
17	Calcium	mg/l	561.12	400.80	681.36	641.28
18	Magnesium	mg/l	1628.1	1676.7	1555.2	1628.1
19	Sodium	mg/l	8473.0	10386.0	9131.0	8526.0
20	Potassium	mg/l	452.0	406.0	413.0	441.0
21	Iron	mg/l	BQL	BQL	0.24	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.28	BQL	0.40	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l)

## **8.2 Results & Discussion for Marine water samples**

Marine water quality of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and mostly found below quantification limit.

### **pH**

During spring tide the pH values was ranged from 7.27-7.61 at DPA Kandla and 7.22-7.43 at Vadinar while during Neap Tide pH values was ranged from 7.21-7.55 at DPA Kandla and 7.29-7.41 at Vadinar.

### **Color and Odor**

All marine samples for Odor and Color were found agreeable at all sampling locations.

### **Turbidity**

During spring tide the Turbidity values was ranged from 31-48 NTU at DPA Kandla and 37-42 NTU at Vadinar while during Neap Tide Turbidity values was ranged from 35-45 NTU at DPA Kandla and 37-42 NTU at Vadinar. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity (Yap et al, 2011). Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler, 2004). The turbidity affects the amount of light penetrating to the plants for photosynthesis.

### **Total Dissolved Solids (TDS)**

TDS values in the studied area during Spring Tide varied between 28966- 39222 mg/l at DPA Kandla and 35265-39961 mg/l at Vadinar while during Neap Tide TDS values was varied 30473-37123 mg/l at DPA Kandla and 36325-42642 mg/l at Near Vadinar.

### **Calcium**

Calcium value in the studied area during Spring Tide varied between 440.9-681.4 mg/l at DPA Kandla and 400.8-601.2 mg/l at Vadinar while during Neap Tide calcium values between 481.0-721.4 mg/l at DPA Kandla and 481.0-681.4 mg/l at Vadinar.



### **Magnesium**

Magnesium value in the studied area during Spring Tide varied between 1506.6-1773.9 mg/l at DPA Kandla and 1603.8-1676.7 mg/l at Vadinar while during Neap Tide magnesium values between 1603.80-173.9 mg/l at DPA Kandla and 1555.2 -1749.60 at Vadinar. Calcium and magnesium both play an important role in antagonizing the toxic effects of various ions and neutralizing the excess acid produced (Narayan R. et. al., 2007)

### **Nitrate**

Nitrate value in the studied area during Spring Tide varied between 0.5-4.7 mg/l at DPA Kandla and 1.09-3.86 mg/l at Vadinar while during Neap Tide Nitrate values between 0.42-5.2 mg/l at DPA Kandla and 1.0-4.95 at Vadinar.

The variations were observed due to variation in phytoplankton excretion, oxidation of ammonia, reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007).

### **Iron**

Iron values in the studied area during Spring Tide ranged from 0.33-0.47 mg/l at DPA Kandla and at Vadinar were BQL (<0.10 ) while during Neap Tide Iron values ranged from 0.17-1.76 mg/l at DPA Kandla and 0.24-0.31 mg/l at Vadinar.

### **Sulphates**

Sulphate values in the studied area during Spring Tide ranged from 3407-4222 mg/l at DPA Kandla and 3495-3796 mg/l at Vadinar while during Neap Tide the Sulphate values was varied 2981-4961 mg/l at DPA Kandla and 3645-4008mg/l at Vadinar.

### **Salinity**

Salinity values in the studied area during Spring Tide varied ranged 18.11 to 20.82 ‰ at DPA Kandla and 17.65 to 20.82 ‰ at Vadinar while during Neap Tide the Salinity values was varied 17.65 to 20.82 ‰ at DPA Kandla and 18.55 to 19.92 ‰ at Vadinar.

### **Sodium and Potassium Salts**

During Spring Tide the Sodium values ranged from 8011-9380 mg/l at DPA Kandla & 7368-10386 mg/l at Vadinar and Potassium salts ranged from 299-427 mg/l at DPA Kandla & 354-452 mg/l at Vadinar while during Neap Tide the Sodium values was ranges from 7939-

9814 mg/l at DPA Kandla & 7810-9131 mg/l at Vadinar and Potassium salts ranged from 370-427 mg/l at DPA Kandla & 413-456 mg/l at Vadinar.

## **DO**

The DO refers to the amount of oxygen dissolved in the water and it is particularly important in limnology {(aquatic ecology) (Weiss 1970)}. The fate and behavior of DO is of critical importance to marine organisms in determining the severity of adverse impacts (Best et al. 2007). The major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best et al. 2007). From the studied samples, DO in marine water during Spring Tide was found in ranges from 5.6-8.1 mg/l at DPA Kandla and 5.4-6.1 mg/l at Vadinar while during Neap Tide 5.2-7.3 mg/l at DPA Kandla and 5.6-6.3 mg/l at Vadinar.

## **BOD**

BOD in marine water at all sampling location in the studied samples were found BQL (<2.0 mg/l).

## **Heavy Metals in Marine Water**

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. Maximum heavy metals parameters were well Below the Quantification limits.

## **9.3 Conclusion**

In the present study period marine water samples were analyzed and found inline as per Primary Water Quality criteria for class-IV WATERS (For Harbour Waters).

## CHAPTER-9

### MARINE SEDIMENT MONITORING

## 9.0 Marine Sediments

The deep-sea ocean floor is made up of sediment. This sediment is composed of tiny particles such as fine sand, silt, clay, or animal skeletons that have settled on the ocean bottom. Over long periods of time, some of these particles become compressed and form stratified layers. Scientists that study these layers look at particle size, particle composition, and origin to help them create historical records of the deep ocean floor. This process is called weathering. Weathering can be either mechanical or chemical. Mechanical weathering can occur as ice, wind, or water wears away the rock's surface. Chemical weathering can occur as rocks are dissolved by a chemical such as acid rain. The particles created as a result of weathering are called terrigenous sediments. These particles are transported to the ocean by wind and by rivers and streams. Once the particles enter the ocean, they are dispersed by waves, currents, and tides. The heaviest and largest particles that reach the oceans, such as sand, settle very quickly to the bottom as a result of gravity. Sand is deposited near the coast whereas the smaller silt and clay particles are transported farther distances offshore before they settle to the bottom. Sediments are an important component of aquatic ecosystems because they provide nutrients and habitat for aquatic organisms (Benhamed et al. 2016). However, human activities result in accumulation of toxic substances such as heavy metals in marine sediments. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulation. Metals affect the ecosystem because they are not removed from water by self-purification, but accumulate in sediments and enter the food chain (Astakhov et al. 2015).

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Benthic surface grab samplers look like giant metal jaws. They dig into the bottom and take a bite of the sediment. These samplers are good for collecting softer, sandy or silty sediments that do not contain rocks. A box corer is a cross between a surface sampler and a sediment corer. It is a special device that is used to collect an undisturbed sample of the very top surface layers and the sediment underneath. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.

## 10.1 Results

The Sediment Quality results are given in below from table no. 43 & 44.

**Table 43: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	1.32	0.6	0.1	0.1	0.16	1.14	1.59
3	Organic Carbon	mg/kg	0.76	0.35	0.07	0.06	0.09	0.66	0.91
4	Inorganic Phosphate	mg/kg	89.00	90.00	101.00	92.00	100.00	90.00	100.00
5	Moisture	%	3.90	2.37	4.12	3.00	4.10	3.40	4.00
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	7.30	7.68	8.90	9.30	9.10	8.90	9.60
8	Phosphate	mg/kg	5.20	4.99	4.09	5.25	9.00	3.28	10.40
9	Sulphate	mg/kg	759.00	849.00	555.00	496.00	768.00	732.00	496.00
10	Nitrite	mg/kg	0.11	0.11	0.10	0.10	0.12	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	2765.00	1523.00	861.00	961.00	981.00	1162.00	2485.00
13	Magnesium	mg/kg	1372.00	1300.00	1020.00	1263.00	1032.00	1089.00	2065.00
14	Sodium	mg/kg	2410.0	2760.0	2644.0	2940.0	2722.0	1394.00	1082.00
15	Potassium	mg/kg	404.00	459.00	390.00	510.00	447.00	811.0	560.0
16	Chromium	mg/kg	61.30	71.90	66.00	53.30	56.40	42.80	49.70
17	Nickel	mg/kg	26.80	31.70	29.00	23.00	24.10	13.80	29.20
18	Copper	mg/kg	17.40	19.40	17.80	15.50	15.80	13.80	47.10
19	Zinc	mg/kg	43.40	55.80	49.80	41.80	46.00	32.00	64.30
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	5.20	6.20	5.70	9.80	8.40	12.00	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO3:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

**Table 44 : Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.91	0.50	1.52	0.37	0.27	1.45	1.68
3	Organic Carbon	mg/kg	0.52	0.29	0.87	0.21	0.15	0.83	0.97
4	Inorganic Phosphate	mg/kg	98.00	90.00	80.00	78.00	100.00	88.00	90.00
5	Moisture	%	17.00	8.70	15.00	6.60	4.80	14.24	13.14
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	7.20	8.26	9.02	5.50	7.80	9.20	10.02
8	Phosphate	mg/kg	7.87	9.29	6.16	5.75	9.49	11.61	10.80
9	Sulphate	mg/kg	745.00	862.00	585.00	490.00	510.00	590.00	396.00
10	Nitrite	mg/kg	0.11	0.12	0.12	0.11	0.10	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	12.00	16.6	26.2	BQL	BQL
12	Calcium	mg/kg	1723.00	1057.00	1320.00	1220.00	1390.00	1907.00	1643.00
13	Magnesium	mg/kg	1044.00	716.00	1090.00	690.00	896.00	1563.00	2320.00
14	Sodium	mg/kg	2733.00	2720.00	2578.00	2107.00	1558.00	1042.00	952.00
15	Potassium	mg/kg	302.00	332.00	378.0	357.0	87.8	384.00	325.00
16	Chromium	mg/kg	38.00	24.40	51.70	16.10	60.00	48.90	69.20
17	Nickel	mg/kg	15.60	9.50	21.70	6.00	24.70	19.70	28.30
18	Copper	mg/kg	7.80	BQL	11.30	31.40	16.40	12.10	19.90
19	Zinc	mg/kg	30.10	21.90	35.70	13.70	44.90	31.50	51.90
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0 mg/kg, Cd: 1.0 mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg)

## **9.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each month. The Heavy metal analyzed and found below quantification limit.

## **9.3 Conclusion**

The sediment types are majority Sandy loamy. Also maximum heavy metals parameters found below Quantification limit wise, Pb, Cd, Hg, As, Al was not Detected and Nitrate for some locations.

## CHAPTER-11

### MARINE ECOLOGICAL MONITORING



## 10.0 INTRODUCTION:

### 10.1 Sampling Stations:

The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 01<sup>st</sup> November 2022 in harbour region of DPA at Kandla Creek, and on 02<sup>nd</sup> November 2022 in creeks near by the port during Neap tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 08<sup>th</sup> November, 2022 in harbour region of DPA at Kandla Creek and on 09<sup>th</sup> November, 2022 in creeks near by the port during spring tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar Jetty at Path Finder Creek during Neap tide on 01/11/2022 and Spring tide period on 08/11/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative and quantitative evaluation of phytoplankton, qualitative and quantitative evaluation of zoo plankton density and their population.

**TABLE 43. SAMPLING LOCATIONS**

<b>monitoring requirement</b>	<b>Number of locations</b>
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near I <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

### Sampling methodology adopted:

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the underlying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample was taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with Nylobolt cloth of 20µm mesh size. . During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.

#### **Samples Processing for chlorophyll estimation:**

Samples for chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminium foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, under cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 2017).

#### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is a general term for organisms which have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplanktons are free floating organisms that are capable of photosynthesis and zooplankton is the various free-floating animals.

Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, *plankton* and *nekton* (Lalli and Parsons, 1997). *Plankton* consists of all organisms drifting in the water and is unable to swim against water currents, whereas *Nekton* includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better understanding of the dynamics and

functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

#### **Phytoplankton in the marine environment:**

Phytoplanktons are free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio-purifier and bio-indicators of the aquatic ecosystems of which diverse array of the life depends .They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (Bacillariophyceae) and Dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; Diatoms and Dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (Blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

#### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and

abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of organic carbon to deep ocean layers and thus act as key drivers of 'biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorisation of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorised into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

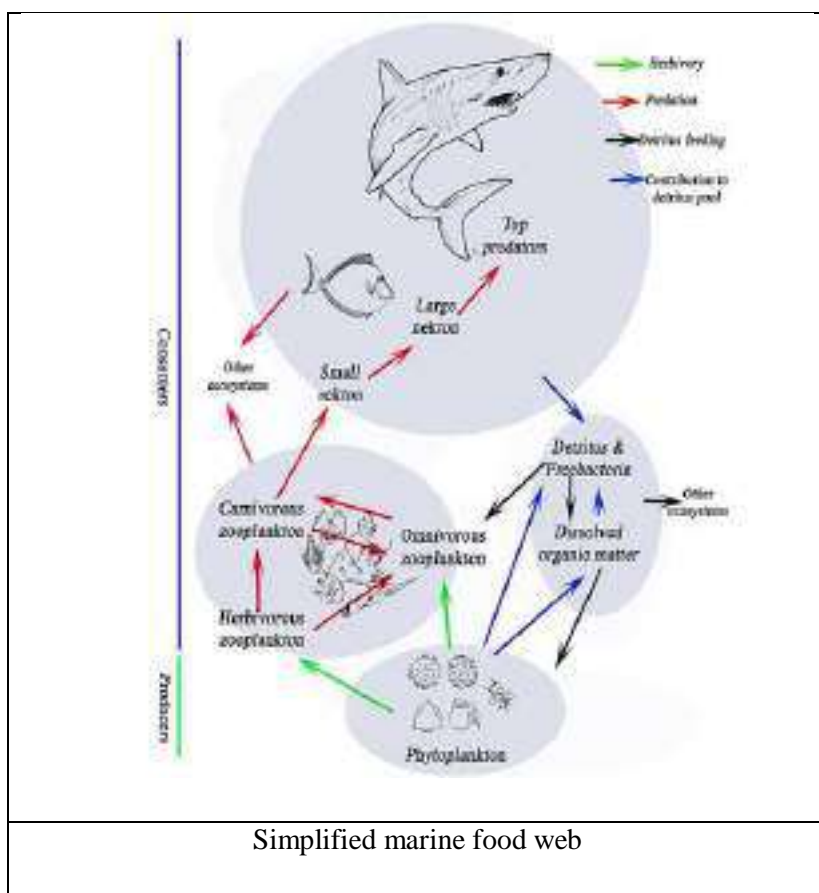
Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Athropoda) and Tintinids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the

dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991 ;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplanktons are efficient grazers of the phytoplankton and are referred to as living machines transforming plant material into animal tissue. Hence they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilo metres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

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At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist.

Plankton in the month of November also exhibit vertical patchiness. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

#### **Methodology adopted for Plankton sampling:**

##### **Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

##### **Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

##### **Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerin to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of phytoplankton and zooplankton that were encountered

##### **Cell counts by drop count method:**

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22 mm x 60 mm was placed under the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated plankton, total amount of phytoplankton in the original volume of sample filtered was calculated as units/L and Zooplankton as  $N/m^3$ .

### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment–water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42μ in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes

### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

#### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

#### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

### **DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A. E. (1988))



A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample showing that more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species within a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H. R. *et al.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate specie richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness ( $S$ ) and evenness ( $J$ )

### **Simpson's diversity index**

Simpson's index ( $D$ ) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran, 2004).

The formula for calculating  $D$  is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where  $n_i$  = the total number of organisms of each individual species

$N$  = the total number of organisms of all species

The value of  $D$  ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When  $D$  increases diversity decreases. Simpson's index is therefore usually expressed as  $1-D$  or  $1/D$ . (Magurran, 2004)

Low species diversity suggests:

- relatively few successful species in the habitat
- the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment



- food webs which are relatively simple
- change in the environment would probably have quite serious effects

High species diversity suggests:

- a greater number of successful species and a more stable ecosystem
- more ecological niches are available and the environment is less likely to be hostile complex food webs
- environmental change is less likely to be damaging to the ecosystem as a whole

### **Species richness indices**

The species richness( $S$ ) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness in may be concomitant with severe or chronic human-induced perturbation (Fair Fair weather 1990) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001)

Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness( $S$ ) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by Mc Intosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index ( $d$ ), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximised when all types are equally abundant [Rosenzweig, M. L. (1995)]

### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index ( $H$ ), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index ( $H$ ) reproduces community parameters to a single number by using an equation.

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxon. It varies from 0 for communities with only single taxa to high values for community with many taxon each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range

of polluted and unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than

3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

## 10.2:- RESULTS:

### CHLOROPHYLL-a:

$$H' = - \sum_{j=1}^x \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

In the sub surface water chlorophyll-a was varying from 0.472-0.969 mg/m<sup>3</sup> with an average value 0.645 mg/m<sup>3</sup> in harbour region of DPA in Kandla Creek during sampling done in spring tide period of November 2022. In the nearby creeks chlorophyll-a was varying from 0.359-0.717 mg/m<sup>3</sup> with an average value 0.552 mg/m<sup>3</sup> Pheophytin –a level was below detectable limit- the all the sampling stations during springtide. Even though the plankton diversity and abundance were more during the spring tide sampling, the chlorophyll-content was detected lesser than expected because, the phytoplankton communities were mainly represented by diatoms *Skeletonema* sp. *Coscinodiscus* sp. and *Chaetoceros* sp.

In the sub surface water chlorophyll-a was varying from 0.338-0.547 mg/m<sup>3</sup> with an average value 0.437 mg/m<sup>3</sup> in harbour region of DPA in Kandla Creek during sampling done in Neap tide period of November 2022. In the nearby creeks chlorophyll-a was varying from 0.205- 0.440mg/m<sup>3</sup> with an average value 0.370 mg/m<sup>3</sup>. Pheophytin–a level was below detectable limit- the all the sampling stations. During neap tide sampling phytoplankton communities were mainly represented by *Coscinodiscus* sp. and *Ditylum* sp.

In the sub surface water chlorophyll-a was varying from 0.598-0.968 mg/m<sup>3</sup> in harbour region of DPA OOT in path finder Creek during sampling done in spring tide period of November 2022. In the sub surface water chlorophyll-a was varying from 0.709 - 0.987mg/m<sup>3</sup> in harbour region of DPA OOT in path finder Creek during sampling done in Neap Tide period of November 2022

**TABLE:-45 VARIATIONS IN CHLOROPHYLL-a PHEOPHYTIN-a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK ,NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING SPRING TIDE IN NOVEMBER 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.969	BDL	64.92
		Low tide	0.647	BDL	43.35
2	KPT 2	High tide	0.511	BDL	34.24
		Low tide	0.521	BDL	34.91
3	KPT 3	High tide	0.749	BDL	50.18
		Low tide	0.472	BDL	31.62
CREEKS					
4	KPT-4 Khor-I	High tide	0.638	BDL	42.75
		Low tide	0.359	BDL	24.05
5	KPT-5 Nakti-I	High tide	0.717	BDL	48.04
		Low tide	0.493	BDL	33.03
6	KPT-6 Nakti-II	High tide	ND	ND	ND
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.968	BDL	64.86
8		Low tide	0.732	BDL	49.04
9	SPM	High tide	0.953	BDL	63.85
10		Low tide	0.598	BDL	

BDL: Below Detectable Limit., ND: Not detected

**TABLE:-46. VARIATIONS IN CHLOROPHYLL-a PHEOPHYTIN-a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPA HARBOUR AREA, NEAR BY CREEKS AND DPA OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN NOVEMBER 2022**

Sr.No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPA HARBOUR AREA KANDLA CREEK					
1	KPT1	High tide	0.547	BDL	
		Low tide	0.450	BDL	
2	KPT 2	High tide	0.338	BDL	
		Low tide	0.409	BDL	
3	KPT 3	High tide	0.354	BDL	
		Low tide	0.523	BDL	
CREEKS					
4	KPT-4 Khor-I	High tide	0.440	BDL	
		Low tide	0.408	BDL	
5	KPT-5 Nakti-I	High tide	0.205	BDL	
		Low tide	0.426	BDL	
6	KPT-6 Nakti-II	High tide	ND	ND	ND
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.799	BDL	
8		Low tide	0.709	BDL	
9	SPM	High tide	0.857	BDL	
10		Low tide	0.987	BDL	

BDL: Below Detectable Limit.ND: Not detected

### PHYTOPLANKTON POPULATION:

For the evaluation of the Phytoplankton population in DPA harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by, Diatoms, blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 26 genera, Blue green algae were represented by 2 genera and Dinoflagellates were represented by 6 genera during the sampling conducted in spring tide in November, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 39-243units/ L during high tide period and 115-199 units/L during low tide of Spring Tide. During spring tide sampling phytoplankton communities were dominated by *Skeletonema* sp almost forming a bloom in the Kandla creek and other nearby creek area and abundant population of *Coscinodiscus* sp. and *Chaetoceros* sp.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 24 genera, Blue green algae were represented 2 genera and Dinoflagellates with 5 genera during the sampling conducted in Neap tide in November, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 43-299 units/ L during high tide period and 143-193 units/L during low tide of Neap Tide. During Neap tide sampling phytoplankton communities were dominated by, *Ditylum* sp and *Coscinodiscus* sp.

For the evaluation of the Phytoplankton population in DPA OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; Jetty area and SPM area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 25 genera, Blue Green algae by 5 genera and Dinoflagellates by 6 genera during the sampling conducted in spring tide in November, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty area was 209 units/L during high tide period and 177 units/L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the SPM area was varying from 206 units/ L during high tide period and 131 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green and Dinoflagellates during Neap tide period. Diatoms were represented by 32 genera and Blue green algae by 4 genera and Dinoflagellates by 6 genera during the sampling conducted in Neap tide in November, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 244units/ L during high tide period and 200

units/L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 259 units/L during high tide period and 294 units/L during low tide of Neap Tide.

#### **Species Richness Indices and Diversity Indices:**

##### **Margalef's diversity index (Species Richness)**

Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 2.184- 4.688 with an average of 3.346 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 1.963- 3.589 with an average of 2.835 during the consecutive low tide period.

Margalef's diversity index (Species Richness) of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 2.393-4.279 with an average of 3.586 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.821- 3.86 with an average of 3.357 during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 4.867 at OOT jetty area and 4.129 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 4.443 and 3.692 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) of phytoplankton communities in the stations was 4.73 at OOT jetty area and 4.139 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) of phytoplankton communities in the path finder creek near OOT jetty was 4.152 and SPM area was 5.454 during the consecutive low tide period.

##### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.786- 1.034 between selected sampling stations with an average value of 0.925 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.790-0.915 between selected sampling stations with an average value of 0.855 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.867–1.022 between selected sampling stations with an average value of 0.932 during high tide period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton

communities in the sampling stations was in the range of 0.926- 1.001 between selected sampling stations with an average value of 0.951 during consecutive low tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.037 at OOT jetty area and 0.946 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.043 and 0.982 at SPM during the consecutive low tide period of spring tide.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 0.998 at OOT jetty area and 1.035 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.942 and at SPM area was 1.036 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.778-0.851 between selected sampling stations with an average of 0.823 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks except few, which was varying from 0.787-0.842 between selected sampling stations with an average of 0.814 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during Neap tide also, which was varying from 0.813-0.874 with an average value of 0.847 between selected sampling stations during high tide period and 0.840-0.871 varying from with an average value of 0.858 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.863 at OOT jetty area and 0.820 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.876 and 0.867 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.838 at OOT jetty area and 0.881 at SPM area during the sampling conducted in High tide period of Neap tide at Path

finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.832 and at SPM area was 0.867 during the consecutive low tide period.



**Table:-47 4PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND , NEAR BY CREEKS DURING SPRING TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% Of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	207	26/34	76.47	4.688	1.034	0.8511
	2	183	22/34	64.71	4.031	1.005	0.8437
	3	193	13/34	38.24	2.28	0.811	0.7778
	4	243	18/34	52.94	3.095	0.9391	0.8192
	5	193	21/34	61.76	3.8	0.9777	0.8281
	6	39	9/34	26.47	2.184	0.786	0.8178
LOW TIDE	1	178	14/34	41.18	2.509	0.8042	0.787
	2	199	20/34	58.82	3.589	0.8982	0.8075
	3	115	14/34	41.18	2.74	0.8696	0.8365
	4	154	18/34	52.94	3.375	0.915	0.8416
	5	163	11/34	32.35	1.963	0.7895	0.7957

**Table:-48 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	216	24/31	77.42	4.279	0.98	0.8568
	2	229	22/31	70.97	3.865	0.958	0.853
	3	228	22/31	70.97	3.868	1.022	0.8743
	4	299	23/31	74.19	3.859	0.8667	0.8127
	5	254	19/31	61.29	3.251	0.8929	0.8307
	6	43	10/31	32.26	2.393	0.8712	0.8571
LOW TIDE	1	183	18/31	58.06	3.263	0.9504	0.8636
	2	143	15/31	48.39	2.821	0.946	0.8666
	3	178	21/31	67.74	3.86	1.001	0.8708
	4	193	19/31	61.29	3.42	0.931	0.84
	5	193	19/31	61.29	3.42	0.9259	0.8469

**Table:-49 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN NOVEMBER2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Species Composition % (Group level)
HIGH TIDE	Sub surface	6	BLUE GREEN ALGAE	0-8	2/34	5.88
			DIATOMS	38-238	26/34	76.47
			DINOFLAGELLATES	0-11	6/34	17.65
			TOTAL PHYTO PLANKTON	<b>39-243</b>	<b>34</b>	
LOW TIDE	Sub surface	5	BLUE GREEN ALGAE	1-6	2/34	5.88
			DIATOMS	110-190	26/34	76.47
			DINOFLAGELLATES	1-7	6/34	17.65
			TOTAL PHYTO PLANKTON	<b>115-199</b>	<b>34</b>	

**TABLE:-50 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Species Composition % (Group level)
HIGH TIDE	Sub surface	6	BLUE GREEN ALGAE	0-6	2/31	6.45
			DIATOMS	43-293	24/31	77.42
			DINOFLAGELLATES	0-9	5/31	16.13
			TOTAL PHYTO PLANKTON	<b>43-299</b>	<b>31</b>	
LOW TIDE	Sub surface	5	BLUE GREEN ALGAE	2-6	2/31	6.45
			DIATOMS	133-186	24/31	77.42
			DINOFLAGELLATES	3-8	5/31	16.13
			TOTAL PHYTO PLANKTON	<b>143-193</b>	<b>31</b>	

**TABLE:-51 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	209	27/36	75.00	4.867	1.037	0.863
	SPM	206	23/36	63.89	4.129	0.946	0.820
LOW TIDE	Jetty	177	24/36	66.67	4.443	1.043	0.876
	SPM	131	19/36	52.78	3.692	0.982	0.867

**TABLE:-52 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	244	27/42	64.29	4.73	0.998	0.838
	SPM	259	24/42	57.14	4.139	1.035	0.881
LOW TIDE	Jetty	200	23/42	54.76	4.152	0.942	0.832
	SPM	294	32/42	76.19	5.454	1.036	0.867

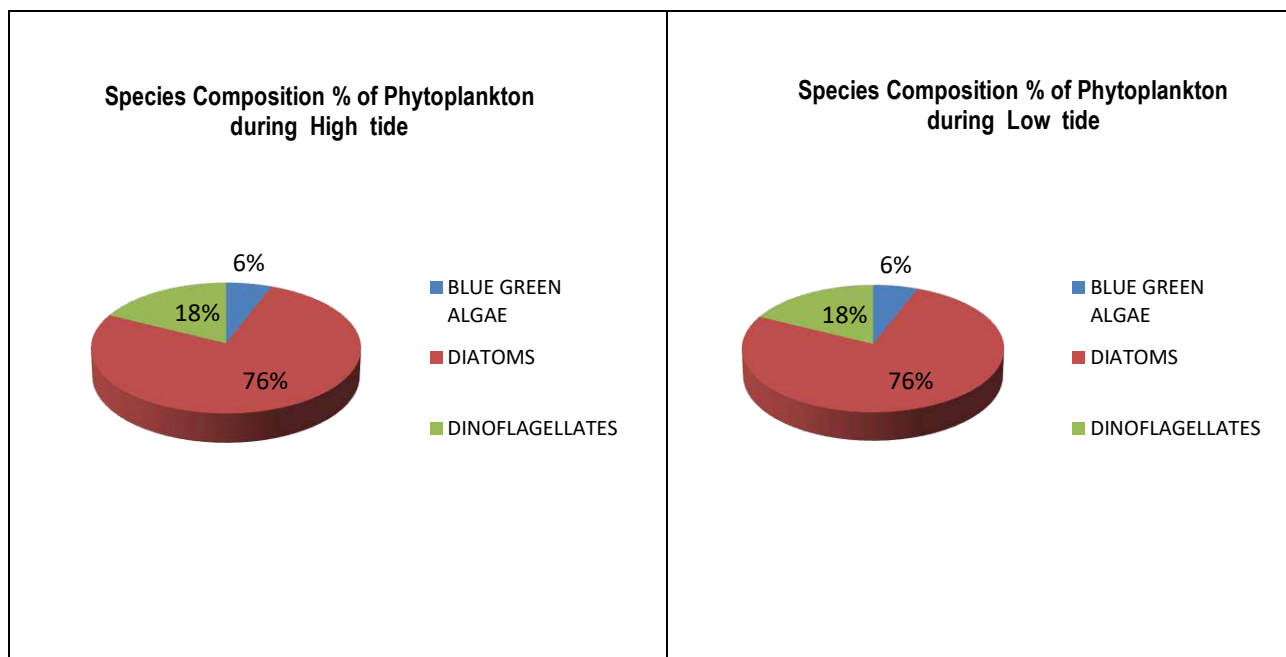
**TABLE:-53 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPAOOT AT PATH FINDER CREEK, VADINAR & NEAR BY SPM, DURING SPRING TIDE IN NOVEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAE	14-20	5/36	13.89
			DIATOMS	180-192	25/36	69.44
			DINOFLAGELLATES	3-6	6/36	16.67
			TOTAL PHYTO PLANKTON	206-209	36	
LOW TIDE	Sub surface	2	BLUE GREEN ALGAE	12-19	5/36	13.89
			DIATOMS	118-156	25/36	69.44
			DINOFLAGELLATES	1-2	6/36	16.67
			TOTAL PHYTO PLANKTON	131-177	36	

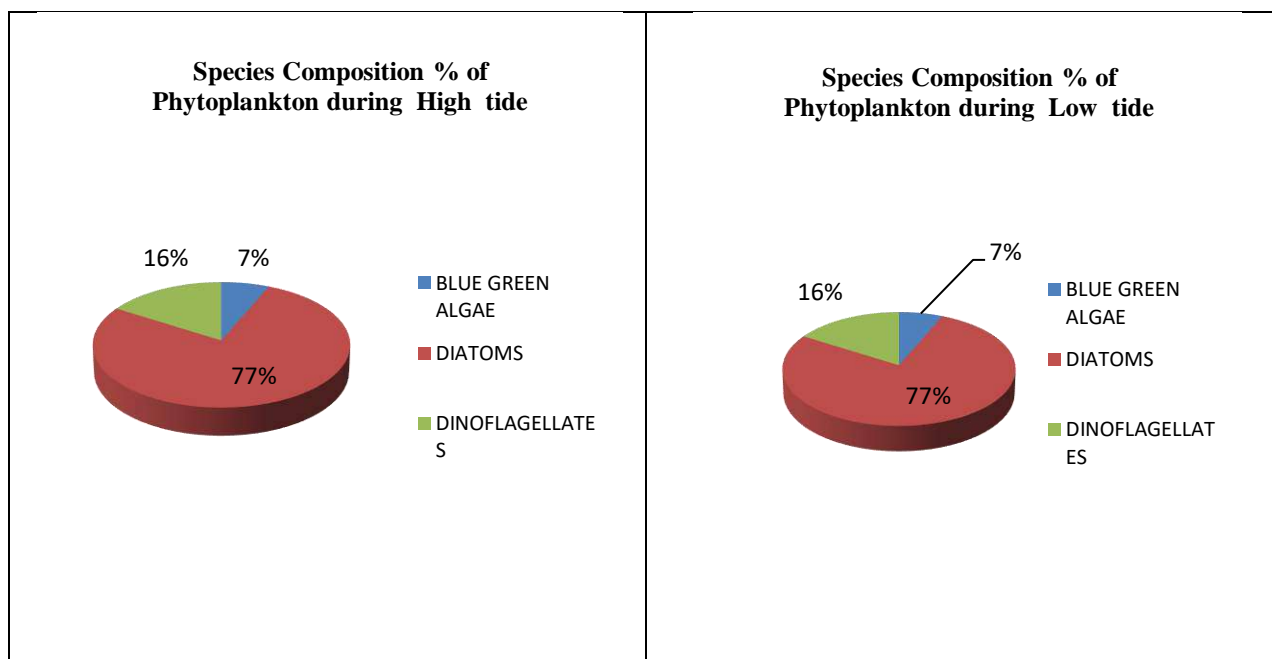
**Table:- 54 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPA OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Species Composition % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAE	5-7	4/42	9.52
			DIATOMS	238-248	32/42	76.19
			DINOFLAGELLATES	1-4	6/42	14.29
			TOTAL PHYTO PLANKTON	<b>244-259</b>		
LOW TIDE	Sub surface	2	BLUE GREEN ALGAE	4-8	4/42	9.52
			DIATOMS	194-282	32/42	76.19
			DINOFLAGELLATES	2-4	6/42	14.29
			TOTAL PHYTO PLANKTON	<b>200-294</b>		

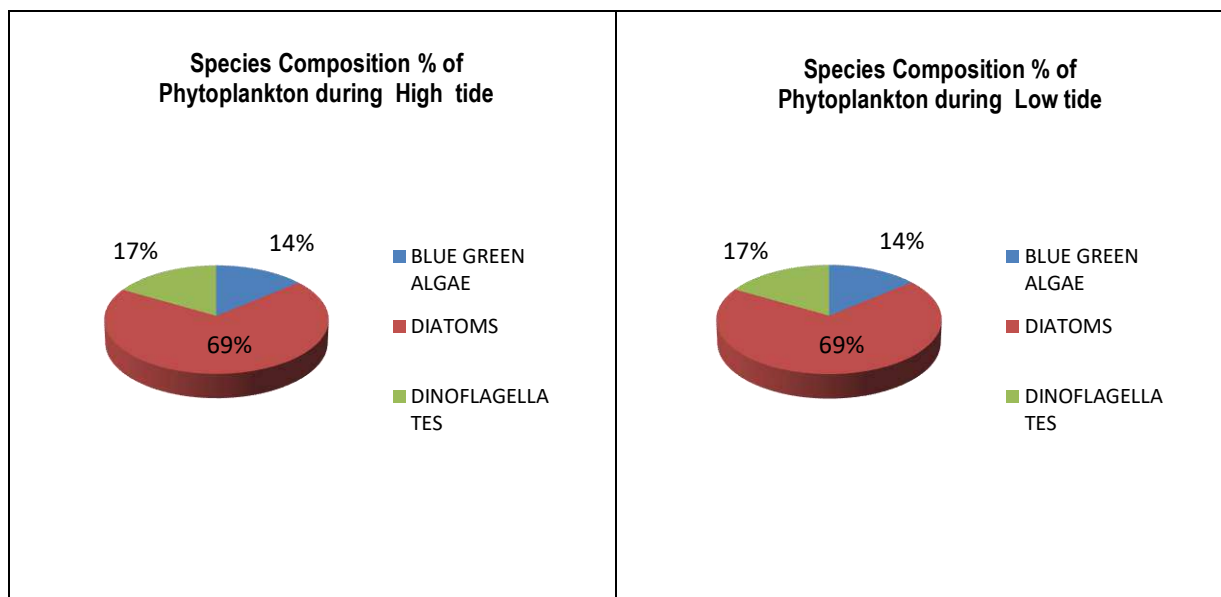
**Species Composition % of Phytoplankton during High tide and Low tide period during spring tide in Kandla creek and nearby creeks**



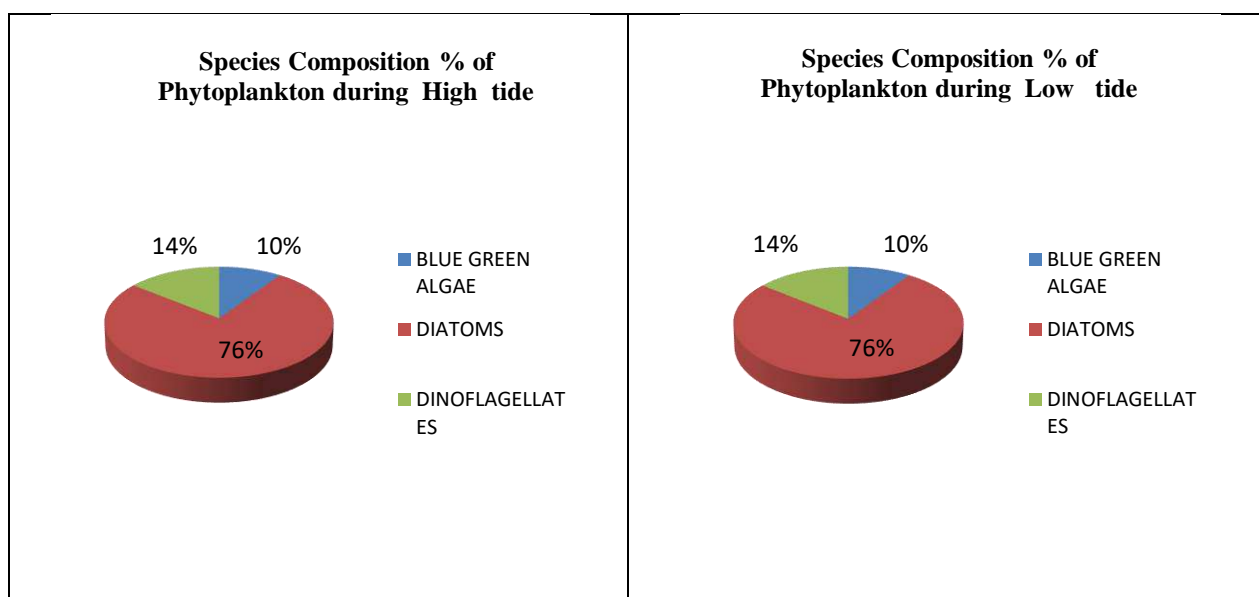
**Species Composition % of Phytoplankton during High tide and Low tide period during Neap tide in Kandla creek and nearby creeks**



**Species Composition % of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**



**Species Composition % of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar**



### **ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPA harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khoricreek) during high tide period and low tide period of spring tide and Neap tide in November, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly six groups; Tintinnids, Copepods, Arrow worms, Mysids, Urochordata, Ciliates and 8 larval forms. The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly six groups; Tintinnids, Copepods, Arrow worms, Mysids, Urochordata, Ciliates and 6 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $25-128 \times 10^3 \text{ N/m}^3$  during high tide and  $103-144 \times 10^3 \text{ N/m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA harbour area and nearby creek was varying from  $19-114 \times 10^3 \text{ N/m}^3$  during high tide and  $76-106 \times 10^3 \text{ N/m}^3$  during low tide of Neap Tide period.

For the evaluation of the Zooplankton population in DPA OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (1 in jetty area and one near SPM).

During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly four groups Tintinnids, Copepods, Urochordata, Ciliates and 4 larval forms. While the Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by four groups, Tintinnids, Copepods, Arrow worms, Urochordata and 5 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT Jetty area of path finder creek was  $91 \times 10^3 \text{ N/m}^3$  during high tide and  $86 \times 10^3 \text{ N/m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPA SPM area of path finder creek was  $101 \times 10^3 \text{ N/m}^3$  during high tide and  $70 \times 10^3 \text{ N/m}^3$  during low tide of spring Tide period.

Zooplankton of the sampling stations at sub surface layer in the DPA OOT jetty area in path finder creek was recorded  $87 \times 10^3 \text{ N/m}^3$  during high tide and  $65 \times 10^3 \text{ N/m}^3$  during consecutive low tide period of Neap tide. Zooplankton of the sampling stations at sub surface layer in the DPASPM area in path finder creek was recorded  $64 \times 10^3 \text{ N/m}^3$  during high tide and  $87 \times 10^3 \text{ N/m}^3$  during consecutive low tide period of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness)**

Margalef's diversity index (Species Richness) of Zooplankton communities in the stations Kandla creek region and nearby creeks was varying from 2.175- 5.186 with an average of 3.450 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) of Zooplankton communities varying from 2.373-3.823 with an average of 3.261 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations were varying from 1.358-3.858 with an average of 2.930 during the sampling conducted in high tide and varying from 2.289- 4.618 with an average of 3.513 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive high tide period and low tide of spring tide was recorded as 1.995 and 1.796 respectively. Margalef's diversity index (Species Richness) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive high tide period and low tide of spring tide was recorded as 2.600 and 2.118 respectively.

Margalef's diversity index (Species Richness) of Zooplankton communities near Jetty at Path finder creek were varying from 3.807 and 2.396 respectively during the sampling conducted in consecutive high tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) of Zooplankton communities near SPM at Path finder creek were varying from 2.645-3.135 respectively during the consecutive high tide and low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.778-1.164 between selected sampling stations with an average value of 0.939 during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.795-1.015 between selected sampling stations with an average value of 0.938 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.490-0.914 between selected sampling stations with an average value of 0.805 during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 0.797-1.041 of between selected sampling stations with an average value of 0.928 during consecutive low tide period.



Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.816-0.793 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.834-0.808 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.956-0.755 respectively during the sampling conducted consecutive high tide period and low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 0.775-0.751 during the consecutive high tide and low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

**Simpson's diversity index:**

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.780-0.909 between selected sampling stations with an average of 0.837 during high tide period and was varying from 0.785- 0.864 with an average value of 0.837 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of Neap tide except few, which was varying from 0.591-0.827 between selected sampling stations with an average of 0.753 during high tide period and was varying from 0.793-0.852 with an average value of 0.820 between selected sampling stations during consecutive low tide. This species diversity suggests a relatively few successful species in this habitat during November, 2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.821 and 0.815 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.812 and 0.828 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of Neap tide was recorded as 0.836- 0.766 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.768 and 0.719 respectively.

**TABLE:-55 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	124	26/33	78.79	5.186	1.164	0.9089
	2	114	18/33	54.55	3.589	0.8655	0.7802
	3	102	16/33	48.48	3.243	0.9207	0.8189
	4	128	17/33	51.52	3.298	0.9062	0.8124
	5	107	16/33	48.48	3.21	0.997	0.8686
	6	25	8/33	24.24	2.175	0.7777	0.83
LOW TIDE	1	117	16/33	48.48	3.15	0.9709	0.8609
	2	144	20/33	60.61	3.823	0.9468	0.8238
	3	121	19/33	57.58	3.753	1.015	0.8639
	4	108	16/33	48.48	3.204	0.9609	0.8505
	5	103	12/33	36.36	2.373	0.7949	0.7853

**TABLE:-56 ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In $No \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	82	18/32	56.25	3.858	0.9017	0.7814
	2	99	16/32	50.00	3.264	0.9138	0.8273
	3	89	13/32	40.63	2.673	0.8264	0.7763
	4	114	18/32	56.25	3.589	0.8478	0.7645
	5	98	14/32	43.75	2.835	0.8503	0.7766
	6	19	5/32	15.63	1.358	0.4901	0.5906
LOW TIDE	1	79	11/32	34.38	2.289	0.797	0.7932
	2	76	21/32	65.63	4.618	1.041	0.8516
	3	106	21/32	65.63	4.289	1.026	0.8446
	4	90	15/32	46.88	3.111	0.9087	0.8177
	5	100	16/32	50.00	3.257	0.865	0.7939

**Table:-57 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS  
IN DPA HARBOUR AREAATKANDLA CREEK AND NEAR BY CREEKS DURING  
SPRING TIDE IN NOVEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> / m <sup>3</sup> Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	tintinnids	9-26	11/33	33.33
			Copepods	11-51	9/33	27.27
			Arrow worms	0-1	1/33	3.03
			Mysids	0-2	1/33	3.03
			Urochordata	1-6	2/33	6.06
			Ciliates	0-2	1/33	3.03
			Larval forms	4-50	8/33	24.25
			TOTAL ZOOPLANKTON N/ M <sup>3</sup>	<b>25-128</b>	<b>33</b>	
LOW TIDE	Sub surface	5	Tintinnids	18-33	11/33	33.33
			Copepods	37-49	9/33	27.27
			Arrow worms	0-4	1/33	3.03
			Mysids	0-2	1/33	3.03
			Urochordata	0-2	2/33	6.06
			Ciliates	0-2	1/33	3.03
			Larval forms	41-65	8/33	24.25
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>103-144</b>	<b>33</b>	

**TABLE:-58 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinnids	0-14	10/32	31.25
			Copepods	6-49	10/32	31.25
			Arrow worms	0	1/32	3.13
			Mysids	0-6	2/32	6.25
			Urochordata	0-4	2/32	6.25
			Ciliates	0-2	1/32	3.13
			Larval forms	13-50	6/32	18.74
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>19-114</b>	<b>32</b>	
LOW TIDE	Sub surface	5	tintinnids	4-17	10/32	31.25
			Copepods	25-45	10/32	31.25
			Arrow worms	0-2	1/32	3.13
			Mysids	0-6	2/32	6.25
			Urochordata	0-5	2/32	6.25
			Ciliates	0-1	1/32	3.13
			Larval forms	27-47	6/32	18.74
			TOTAL ZOOPLANKTON N/M <sup>3</sup>	<b>76-106</b>	<b>32</b>	

**Table:-59 ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In $\times 10^3 N / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	91	10/20	50.00	1.995	0.816	0.821
	SPM	101	13/20	65.00	2.6	0.834	0.812
LOW TIDE	Jetty	86	9/20	45.00	1.796	0.793	0.815
	SPM	70	10/20	50.00	2.118	0.808	0.828

**TABLE:-60 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	87	18/21	85.71	3.807	0.956	0.836
	SPM	64	12/21	57.14	2.645	0.775	0.768
LOW TIDE	Jetty	65	11/21	52.38	2.396	0.755	0.766
	SPM	87	15/21	71.43	3.135	0.751	0.719

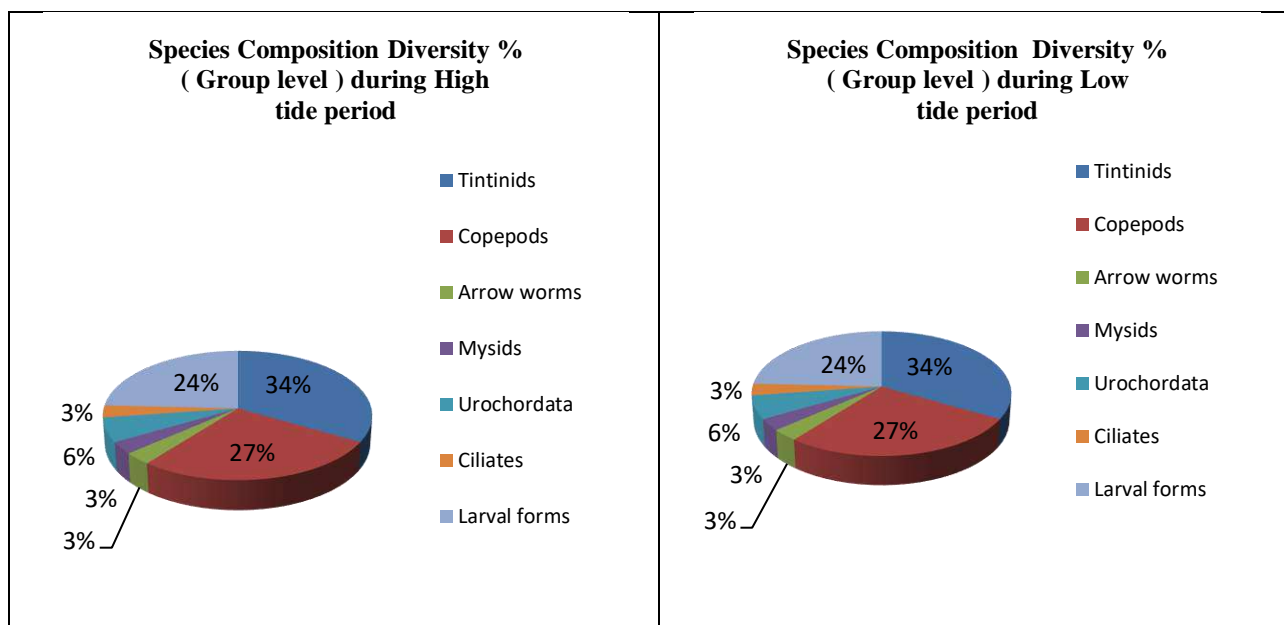
**Table:-61 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AND PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN NOVEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinnids	24-32	5/20	25.00
			Copepods	28-38	8/20	40.00
			Urochordata	1-2	2/20	10.00
			Ciliates	0-1	1/20	5.00
			Larval forms	30-36	4/20	20.00
			TOTAL ZOOPLANKTON	<b>91-101</b>	<b>20</b>	
LOW TIDE	Sub surface	2	Tintinnids	17-21	5/20	25.00
			Copepods	30-37	8/20	40.00
			Urochordata	0	2/20	10.00
			Ciliates	0	1/20	5.00
			Larval forms	19-32	4/20	20.00
			TOTAL ZOOPLANKTON	<b>70-86</b>	<b>20</b>	

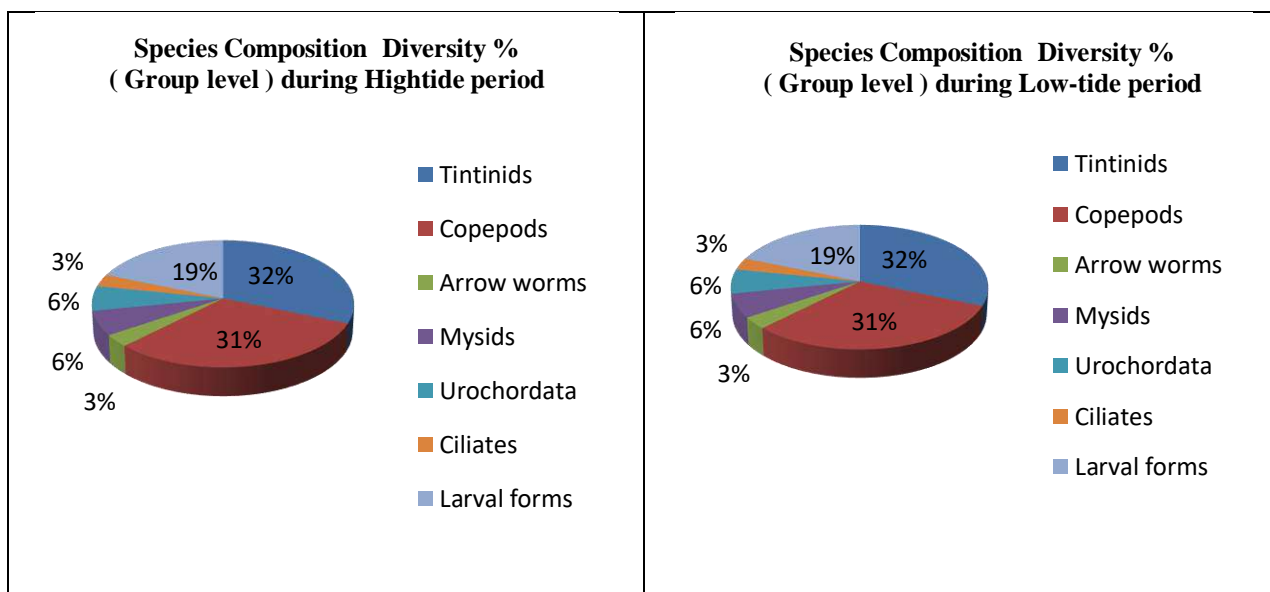
**TABLE:-62 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPA OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN NOVEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	tintinnids	9-16	7/21	33.33
			Copepods	23-34	6/21	28.57
			Arrow worms	0	1/21	4.76
			Urochordata	0-2	2/21	9.52
			Larval forms	32-35	5/21	23.82
			TOTAL ZOOPLANKTON	<b>64-87</b>	<b>21</b>	
LOW TIDE	Sub surface	2	tintinnids	6-9	7/21	33.33
			Copepods	29	6/21	28.57
			Arrow worms	0-1	1/21	4.76
			Urochordata	0-3	2/21	9.52
			Larval forms	27-48	5/21	23.82
			TOTAL ZOOPLANKTON	<b>65-87</b>	<b>21</b>	

**Species Composition % of Zooplankton during High tide and Low tide period of spring tide In  
Kandla Creek and nearby Creeks**

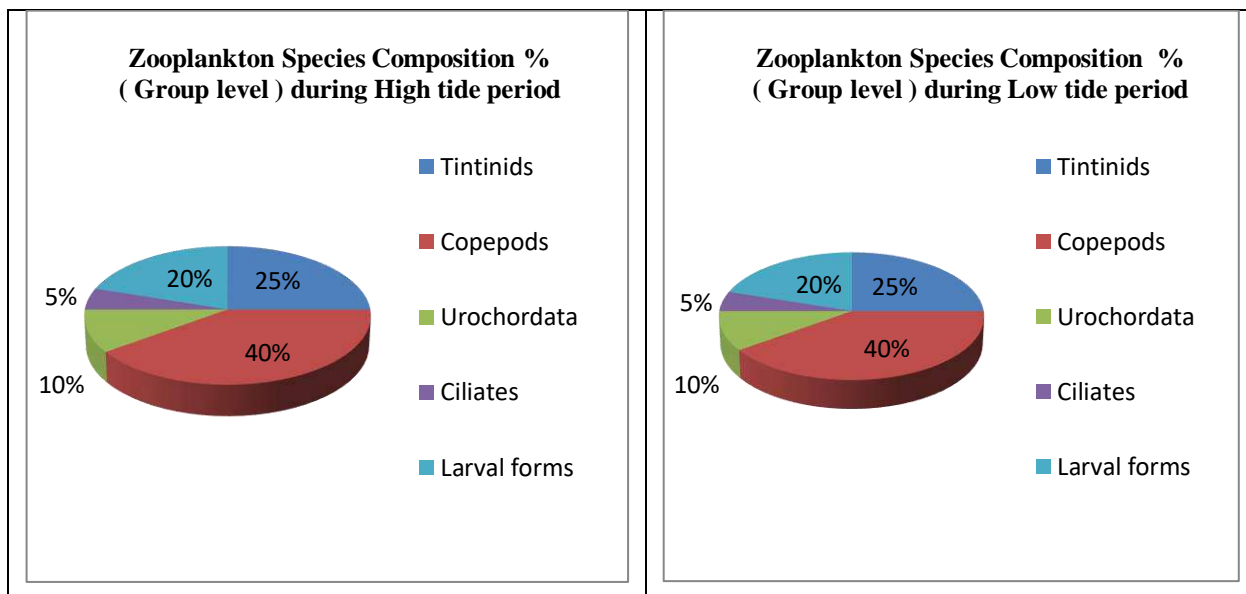


**Species Composition % of Zooplankton during High tide and Low tide period of Neap tide In  
Kandla Creek and nearby Creeks**

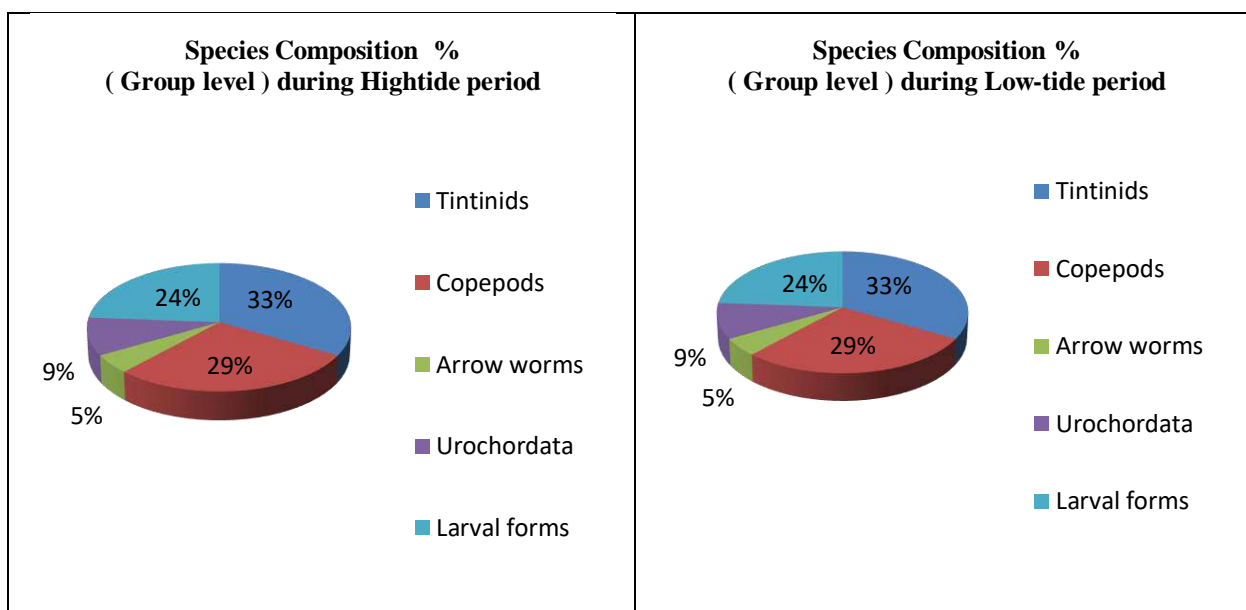




**Species Composition % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty**



**Species Composition % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM**



**TABLE:-63 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF NOVEMBER 2022**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B2	Very sparse
Coccinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphiasp</i>	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	<i>Bacteriastrum sp</i>	D2	Very sparse
			<i>Chaetoceros sp.</i>	D3	Scattered
	Corethrales	Corethraceae	<i>Corethron sp</i>	D4	Very sparse
	Coccinodiscales	Coccinodiscaceae	<i>Coccinodiscus sp.</i>	D5	Dominant
	Hemiaulales	Bellerocheaceae	<i>Bellerochea sp</i>	D6	Very sparse
		Streptothecaceae	<i>Helicotheca sp</i>	D7	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D8	Sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D9	Dominant
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniellasp</i>	D10	Very sparse
		Skeletonemataceae	<i>Skeletonemas sp</i>	D11	Abundant
	Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D12	Very sparse
			<i>Triceratium sp.</i>	D13	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D14	Very sparse
			<i>Nitzschia sp</i>	D15	Sparse
			<i>Pseudo-nitzschia sp.</i>	D16	Very sparse
	Naviculales	<u>Pleurosigmataceae</u>	<i>Pleurosigma sp.</i>	D17	Very sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D18	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp</i>	D19	Scattered
			<i>Fragilariasp</i>	D20	Very sparse
			<i>Synedrassp</i>	D21	Very sparse

	Striatellales	Striatellaceae	<i>Grammatophora sp</i>	D22	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D23	Sparse
			<i>Thalassiothrix sp.</i>	D24	Very sparse
Noctiluca / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca sp.</i>	DF1	Sparse
Dinophyceae	Peridinales	Protopteridiniaceae	<i>Protopteridinium sp.</i>	DF2	Very sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF3	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF4	Very sparse
			<i>Ceratium tripos</i>	DF5	Very sparse

**TABLE:-64 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF NOVEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria</i> sp.	B1	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix</i> sp.	B2	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp.	D1	Sparse
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp.	D2	Abundant
	Corethrales	Corethraceae	<i>Corethron</i> sp.	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus</i> sp.	D4	Abundant
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia</i> sp.	D5	Sparse
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus</i> sp.	D6	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum</i> sp.	D7	Scattered
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp.	D8	Very sparse
		Lauderiaceae	<i>Lauderia</i> sp.	D9	Very sparse
		Skeletonemataceae	<i>Skeletonemas</i> sp.	D10	Dominant
	Triceratiales	Triceratiaceae	<i>Odontella</i> sp.	D11	Very sparse
			<i>Triceratium</i> sp.	D12	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D13	Very sparse
			<i>Nitzschia</i> sp.	D14	Very sparse
			<i>Pseudo-nitzschia</i> sp.	D15	Very sparse
	Naviculales	Naviculaceae	<i>Navicula</i> sp.	D16	Very sparse
		Plagiotropidaceae	<i>Plagiotropis</i> sp.	D17	Very sparse
		<u>Pleurosigmataceae</u>	<i>Pleurosigma</i> sp.	D18	Sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis</i> sp.	D19	Very sparse
		Surirellaceae	<i>Surirella</i> sp.	D20	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp.	D21	Sparse

			<i>Fragilariasp</i>	D22	Very sparse
			<i>Synedrasp</i>	D23	Sparse
	Striatellales	Striatellaceae	<i>Grammatophora sp</i>	D24	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D25	Scattered
			<i>Thalassiothrix sp.</i>	D26	Sparse
Noctiluca / Noctiluciphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca sp.</i>	DF1	Sparse
Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF2	Very sparse
	Gonyaulacales	Ceratiaceae	<i>Ceratium breve</i>	DF3	Very sparse
			<i>Ceratium furca</i>	DF4	Very sparse
			<i>Ceratium fusus</i>	DF5	Very sparse
			<i>Ceratium tripos</i>	DF6	Very sparse

**TABLE:-65 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINARDURING NEAP TIDE OF NOVEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B1	Very sparse
			<i>Oscillatoria sp.</i>	B2	Very sparse
			<i>Spirulina sp.</i>	B3	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B4	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp	D1	Scattered
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp	D2	Scattered
	Corethrales	Corethraceae	<i>Corethron sp</i>	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D4	Dominant
	Hemiaulales	Bellerocheaceae	<i>Belleroche</i> sp	D5	Very sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Very sparse
			<i>Eucampia sp</i>	D7	Very sparse
		Streptothecaceae	<i>Helicotheca sp</i>	D8	Very sparse
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp</i>	D9	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum</i> sp	D10	Abundant
	Rhizosoleniales	Rhizosoleniaceae	<i>Dactyliosolen sp.</i>	D11	Very sparse
			<i>Rhizosolenia sp.</i>	D12	Sparse
	Thalassiosirales	Skeletonemataceae	<i>Skeletonema sp.</i>	D13	Abundant
		Lauderiaceae	<i>Lauderia sp</i>	D14	Very sparse
		Thalassiosiraceae	<i>Planktoniella</i> sp	D15	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontella</i> sp	D16	Very sparse
			<i>Triceratium</i> sp	D17	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D18	Abundant
			<i>Nitzschia sp</i>	D19	Very sparse

			<i>Pseudo-nitzschiasp</i>	D20	Scattered
	Naviculales	Naviculaceae	<i>Meuniera sp.</i>	D21	Very sparse
			<i>Navicula sp</i>	D22	Very sparse
		Pinnulariaceae	<i>Pinnulariasp</i>	D23	Very sparse
		<u>Pleurosigmataceae</u>	<i>Pleurosigma sp</i>	D24	Very sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D25	Very sparse
		Surirellaceae	<i>Surirellasp</i>	D26	Very sparse
Fragilariophyceae	Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D27	Very sparse
	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp.</i>	D28	Very sparse
			<i>Synedra sp.</i>	D29	Very sparse
	Striatellales	Striatellaceae	<i>Striatellasp</i>	D30	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D31	Sparse
			<i>Thalassiothrix sp.</i>	D32	Sparse
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
	Dinophysales	Dinophysaceae	<i>Dinophysis sp.</i>	DF2	Very sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF3	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF4	Very sparse
			<i>Ceratium fusus</i>	DF5	Very sparse
			<i>Ceratium tripos</i>	DF6	Very sparse

**TABLE:-66 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPAOOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND SPRING TIDE OF NOVEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Chroococcales	Chroococcaceae	<i>Merismopedia</i> sp.	B1	Very sparse
	Nostocales	Oscillatoriaceae	<i>Lyngbya</i> sp.	B2	Very sparse
			<i>Oscillatoria</i> sp.	B3	Sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix</i> sp.	B4	Very sparse
	Stigonematales	Stigonemataceae	<i>Stigonema</i> sp.	B5	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp.	D1	Sparse
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp.	D2	Dominant
	Corethrales	Corethraceae	<i>Corethron</i> sp.	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus</i> sp.	D4	Abundant
	Hemiaulales	Belleracheaceae	<i>Bellerachea</i> sp.	D5	Very sparse
		Hemiaulaceae	<i>Cerataulina</i> sp.	D6	Very sparse
		Streptothecaceae	<i>Helicotheca</i> sp.	D7	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia</i> sp.	D8	Scattered
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus</i> sp.	D9	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum</i> sp.	D10	Abundant
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp.	D11	Very sparse
		Lauderiaceae	<i>Lauderia</i> sp.	D12	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontella</i> sp.	D13	Sparse
			<i>Triceratium</i> sp.	D14	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D15	Scattered
			<i>Nitzschia</i> sp.	D16	Very sparse
			<i>Pseudo-nitzschia</i> sp.	D17	Sparse
	Naviculales	Pinnulariaceae	<i>Pinnularia</i> sp.	D18	Very sparse



		<u>Pleurosigmataceae</u>	<i>Pleurosigma</i> sp.	D19	Very sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis</i> sp.	D20	Very sparse
		Surirellaceae	<i>Surirella</i> sp.	D21	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp	D22	Sparse
			<i>Synedrassp</i>	D23	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema</i> sp.	D24	Sparse
			<i>Thalassiothrix</i> sp.	D25	Very sparse
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF1	Very sparse
	Dinophysales	Dinophysaceae	<i>Dinophysis</i> sp.	DF2	Very sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus</i> sp.	DF3	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF4	Very sparse
			<i>Ceratium fusus</i>	DF5	Very sparse
			<i>Ceratium tripos</i>	DF6	Very sparse

**TABLE:-67 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF NOVEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus</i> sp.	T1	Very sparse
		Codonellidae	<i>Tintinnopsis dadayi</i>	T2	Very sparse
			<i>Tintinnopsis failakkaensis</i>	T3	Very sparse
			<i>Tintinnopsis gracilis</i>	T4	Very sparse
			<i>Tintinnopsis mortensenii</i>	T5	Very sparse
			<i>Tintinnopsis radix</i>	T6	Very sparse
			<i>Tintinnopsis tocaninensis</i>	T7	Very sparse
		Tintinnidae	<i>Amphorellopsis</i> sp.	T8	Very sparse
			<i>Eutintinnus</i> sp.	T9	Very sparse
		Xystonellidae	<i>Favella</i> sp.	T10	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus</i> sp.	C1	Sparse
			<i>Parvocalanus</i> sp.	C2	Very sparse
		Acartiidae	<i>Acartia</i> sp.	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus</i> sp.	C4	Very sparse
		Centropagidae	<i>Centropages</i> sp.	C5	Very sparse
		Temoridae	<i>Temora</i> sp.	C6	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona</i> sp.	C7	Abundant
	Harpacticoida	Ectinosomatidae	<i>Microsetella</i> sp.	C8	Scattered
		Euterpinae	<i>Euterpina</i> sp.	C9	Sparse
	Poecilostomatoida	Oncaeidae	<i>Oncaea</i> sp.	C10	Very sparse
Sagittioidea	Aphragmophora	Sagittidae	<i>Sagitta</i> sp.	A1	Very sparse
Malacostraca	Mysida,	Penaeidae	<i>Metapenaeus</i> sp.	M1	Very sparse
	Decapoda	Solenoceridae	<i>Solenocera</i> sp.	M2	Very sparse

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Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca			Brachyuran zoea	L2	Very sparse
Decapoda					
Maxillopoda			Cirripede larvae	L3	Very sparse
Thecostraca					
			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Polychaeta			Trochophore larvae	L6	Very sparse

**TABLE:-68 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPA HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF NOVEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus</i> sp.	T1	Scattered
		Codonellidae	<i>Tintinnopsis dadayi</i>	T2	Very sparse
			<i>Tintinnopsis failakkaensis</i>	T3	Very sparse
			<i>Tintinnopsis gracilis</i>	T4	Very sparse
			<i>Tintinnopsis mortensenii</i>	T5	Very sparse
			<i>Tintinnopsis radix</i>	T6	Sparse
			<i>Tintinnopsis tocanensis</i>	T7	Very sparse
		Metacyclidae	<i>Metacyclis</i> sp.	T8	Very sparse
		Tintinnidae	<i>Amphorellopsis</i> sp.	T9	Very sparse
			<i>Eutintinnus</i> sp.	T10	Very sparse
		Xystonellidae	<i>Favella</i> sp.	T11	Sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus</i> sp.	C1	Scattered
			<i>Parvocalanus</i> sp.	C2	Very sparse
		Acartiidae	<i>Acartia</i> sp.	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus</i> sp.	C4	Very sparse
		Centropagidae	<i>Centropages</i> sp.	C5	Very sparse
		Eucalanidae	<i>Subeucalanus</i> sp.	C6	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona</i> sp.	C7	Abundant
	Harpacticoida	Ectinosomatidae	<i>Microsetella</i> sp.	C8	Sparse
		Euterpinae	<i>Euterpina</i> sp.	C9	Sparse
Sagittioidea	Aphragmophora	Sagittidae	<i>Sagitta</i> sp.	A1	Very sparse
Malacostraca	Mysida, Decapoda	Solenoceridae	<i>Solenocera</i> sp.	M1	Very sparse

Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca			Brachyuran zoea	L2	Sparse
Decapoda					
Maxillopoda			Cirripede larvae	L3	Very sparse
Thecostraca					
			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Gastropoda			Opisthobranchia larvae	L6	Very sparse
Streptoneura					
Polychaeta			Trochophore larvae	L7	Sparse
Pelecypoda			Veliger larvae of bivalves	L8	Very sparse

**TABLE:-69 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF NOVEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leptotintinnus</i> sp.	T1	Sparse
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Very sparse
			<i>Tintinnopsis tocanensis</i>	T5	Very sparse
		Tintinnidae	<i>Amphorellopsis</i> sp.	T6	Very sparse
		Xystonellidae	<i>Favella</i> sp.	T7	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus</i> sp.	C1	Scattered
			<i>Parvocalanus</i> sp.	C2	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona</i> sp.	C3	Abundant
	Harpacticoida	Euterpinae	<i>Euterpina</i> sp.	C4	Very sparse
		Ectinosomatidae	<i>Microsetella</i> sp.	C5	Very sparse
	Poecilostomatoida	Oncaeidae	<i>Oncaea</i> sp.	C6	Very sparse
Sagittoida	Aphragmophora	Sagittidae	<i>Sagitta</i> sp.	A1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria</i> sp.	U1	Very sparse
		Oikopleuridae	<i>Oikopleura</i> sp.	U2	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Maxillopoda Thecostraca			Cirripede larvae	L2	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L3	Very sparse
Polychaeta			Trochophore larvae	L4	Very sparse
Pelecypoda			Veliger larvae of bivalves	L5	Very sparse

**TABLE:-70 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPA OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF NOVEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnussp.</i>	T1	Abundant
		Codonellidae	<i>Tintinnopsisgracilis</i>	T2	Very sparse
			<i>Tintinnopsis mortensenii</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T5	Scattered
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
		Tortanidae	<i>Tortanus sp.</i>	C4	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C5	Abundant
		Euterpinae	<i>Euterpina sp.</i>	C6	Very sparse
	Harpacticoida	Ectinosomatidae	<i>Microsetellasp.</i>	C7	Scattered
	Poecilostomatatoida	Corycaidae	<i>Corycaeus sp.</i>	C8	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea	L2	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L3	Very sparse
Pelecypoda			Veliger larvae of bivalves	L4	Very sparse

**BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-Veen grabs during the sampling conducted during spring tide period and Neap tide period from DPA harbour region and nearby creek. The Meio-benthic organisms during spring tide were represented by Polychaetes *Tharyx sp.* and *Nereis sp.*, during Neap tide by *Nereis sp.* and few Amphipods. Population of benthic fauna was varying from 10-60- N/m<sup>2</sup> during spring tide and 0-80 N/m<sup>2</sup> during Neap tide. The benthic communities at path finder Creek were represented by Polychaetes *Glycera sp.* *Cirratulus sp.* *Nereis sp.* and few Amphipods. Their population was varying as 60 N/m<sup>2</sup> at OOT jetty premises and 80 N/m<sup>2</sup> near the SPM area during spring tide and 50 N/m<sup>2</sup> at OOT jetty premises and 50 N/m<sup>2</sup> near the SPM area during Neap tide period.

**Table:-71 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING SPRING TIDE IN NOVEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family : CIRRATULIDAE <i>Tharyxsp.</i>	20	10	10	0	0	NS
Family :NEREIDAE <i>Nereis sp.</i>	0	0	0	20	40	NS
<b>AMPHIPODA</b>	0	0	0		20	NS
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	10	10	20	60	NS

NS: No sample

**Table:-72 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA HARBOUR AREA CREEKS DURING NEAP TIDE IN NOVEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPA HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family :NEREIDAE <i>Nereis sp.</i>	0	0	0	40	60	NS
<i>Amphipoda</i>	0	20	10	10	20	NS
TOTAL Benthic Fauna NUMBER/M <sup>2</sup>	0	20	10	50	80	NS



**Table:-73 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA,  
VADINAR DURING SPRING TIDE IN NOVEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family : Glyceride <i>Glycerasp.</i>	20	40
Family : CIRRATULIDAE <i>Cirratulussp.</i>	0	20
Family: <i>NEREIDAE</i> <i>Nereis sp.</i>	30	10
<i>Amphipoda</i>	10	20
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	60	80

**Table:-74 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPA OOT JETTY AREA,  
VADINAR DURING NEAP TIDE IN NOVEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family : Glyceridase <i>Glycera sp.</i>	20	40
Family: <i>NEREIDAE</i> <i>Nereis sp.</i>	30	10
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	50	50

## **CHAPTER-11**

### **CONCLUSIVE SUMMARY & REMEDIAL MEASURES**

### 11.0 Conclusive Summary and Remedial measures Suggested

- The AAQ monitoring of six locations at Deendayal Port Authority indicates that the mean  $PM_{10}$  and  $PM_{2.5}$  values for four locations viz. Marine Bhavan, Oil Jetty, Estate Office and Coal storage area were found higher than the permissible limit (standards  $100 \mu\text{g}/\text{m}^3$ ,  $60 \mu\text{g}/\text{m}^3$ ). The higher concentration of Particulate matter at Marine Bhavan may be due to vehicles emissions during loading-unloading of food grains and timbers; at Estate office due to construction work, vehicles emission produced from trucks, heavy duty vehicles that pass through the road outside Kandla port and Oil jetty area; while at Coal Storage area lifting of coal from grab yard and other coal handling processes. Moreover, the transportation of coal produces pollution from heavy vehicles. At Tuna Port location, concentration of  $PM_{10}$  varied from  $88-175 \mu\text{g}/\text{m}^3$  and mean value was observed  $145 \mu\text{g}/\text{m}^3$  which was exceed the prescribed standard limit ( $100 \mu\text{g}/\text{m}^3$ ), concentration of  $PM_{2.5}$  was ranged from  $47-87 \mu\text{g}/\text{m}^3$  and mean was found  $71 \mu\text{g}/\text{m}^3$  which was exceed the standard limit ( $60 \mu\text{g}/\text{m}^3$ ). At Gopalpuri  $PM_{10}$  concentration ranged from  $67-168 \mu\text{g}/\text{m}^3$  and mean was  $127 \mu\text{g}/\text{m}^3$  while  $PM_{2.5}$  concentration ranged from  $34-94 \mu\text{g}/\text{m}^3$  and mean was  $66 \mu\text{g}/\text{m}^3$  were found exceed standard limit prescribed by NAAQS.
- At Vadinar, the average concentration of  $PM_{10}$  was  $114 \mu\text{g}/\text{m}^3$  and  $PM_{2.5}$  was  $74 \mu\text{g}/\text{m}^3$  at Admin Colony which was slightly exceed the standard limit while at Signal building the mean concentration  $PM_{10}$  was  $100 \mu\text{g}/\text{m}^3$  and  $PM_{2.5}$  was  $61 \mu\text{g}/\text{m}^3$  which were very close to standard limit.
- During winter, the concentration of  $PM_{10}$  and  $PM_{2.5}$  has been slowly augmented and reached a peak in the evening due to surface inversion of temperature after sunset. Thus, the pollutants are subsequently trapped in the lower layer of the atmosphere due to high atmospheric air pressure.
- Further, precautionary measures and management strategies to minimize the effect of particulate as well as gaseous pollutants have also been suggested for achieving its ambient levels in and around Kandla Port and Vadinar Port, Gujarat, India.
- Drinking water at all the twenty locations was found potable and it was found within in line of BIS standards (IS: 10500-2012).
- Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading

containers and ships. All sampling location were within the permissible limit day time 75 dB (A) and night time 70 dB (A) for the industrial area.

- The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) STP and Vadinar were in line with the standards set by the Central Pollution Control Board.
- It was suggested to monitor the STP performance on regular basis to avoid flow of contamination / Polluted water into the sea.
- Good species diversity suggests a relatively successful species in this habitat. A greater number of successful species and a more stable ecosystem. More ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole.
- The results obtained from the study for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.
- The mean day time temperature at Deendayal Port was 27.92 °C. The day-time maximum temperature was 32.9°C and minimum was 21.1 °C. The mean night time temperature recorded was 25.47 °C. The night-time maximum temperature was 29.7°C and minimum was 20.0 °C. The mean Solar Radiation in November month was 167.27 w/m<sup>2</sup>. The maximum solar radiation was recorded 759 w/m<sup>2</sup> in 4<sup>th</sup> November, 2022 and the minimum solar radiation was recorded 1.80 w/m<sup>2</sup> in 30<sup>th</sup> November, 2022. The mean Relative humidity was 69.00 % for the month of November. Maximum Relative humidity was recorded 99.0 % and minimum Relative humidity was recorded 34.0 %. The average wind velocity for the entire month of November was 1.21 m/s. Maximum wind velocity was recorded 10.19 m/s. The wind direction was mostly North-East.
- The results obtained from the study for the month of November 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

#### **Reasons for higher Values of PM<sub>10</sub>**

- The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.

- Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

### **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the month of November, 2022 were beyond the standard limit at all locations (Coal Storage, Marine Bhavan, Oil Jetty and Estate office, Tuna Port) except Gopalpuri the concentration of particulate matter was slightly exceed. Given below are the remedial measures suggest to minimize the Air pollution.

- During November, 2022 overall ambient air quality of the DPA was within CPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, Marine Bhavan, Oil Jetty and Estate Office. To improve air quality the port was using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

### **Solution towards the Green port:**

Today, it is increasingly recognized that air pollution hurts human health. Consequently, efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits.

The guidelines can be considered a basis for governments for the implementation of a strategic plan focused on the reduction of multi pollutant emission, as well as of the overall air pollution related risk.

- The plantation should be all along the periphery of the port and inside and outside the port along with the road. Trees having high dust trapping efficiency (*Azadirachta indica*, *Cassia fistula*, *Delonix regia*, *Ficus religiosa*, *Pterocarpus marsupium*) are to be grown alongside the roads.
- The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.

- The vehicles should be covered during transportation and the vehicle carrying the coal should not be overloaded by raising the height of carriage.
- The water sprinklers should be use during transportation of loaded heavy vehicles on raw road.
- It should be ensure that regular sweeping of coal internal, main road and space a free circulation.
- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle- Mask advised in sensitive areas.
- Department for use maintenance should have a routine checkup noise level by replacing bearings, tights of all loose parts that can vibrate.
- Speed control is also an effective way to mitigate noise pollution, the lowest sound emission arise from vehicles moving smoothly.
- Use of renewable energy like solar energy should be optimal and ensure to work continuously.
- Keep neat and clean public transport and all basic items at public interaction places as much as possible.
- Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.
- Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.
- Initiate Natural Gas (CNG) as fuel by all buses and trucks.

### **Green Ports Initiative**

- Deendayal Port is committed to sustainable development and adequate measures are being taken to maintain the Environmental well-being of the Port and its surrounding environs. Weighing in the environmental perspective for sustained growth, the Ministry of Shipping had started “Project Green Ports” which will help in making the Major Ports across India cleaner and greener. “Project Green Ports” will have two verticals - one is “Green Ports Initiatives” related to environmental issues and second is “Swachh Bharat Abhiyaan”.
- The Green Port Initiatives include twelve initiatives such as preparation and monitoring plan, acquiring equipments required for monitoring environmental pollution, acquiring dust suppression system, setting up of waste water treatment plants/ garbage disposal plant, setting up Green Cover area, projects for energy generation from renewable

energy sources, completion of shortfalls of Oil Spill Response (OSR) facilities (Tier-I), prohibition of disposal of almost all kind of garbage at sea, improving the quality of harbour wastes etc.

- Deendayal port has also appointed GEMI as an Advisor for “Making Deendayal Port a Green Port - Intended Sustainable Development under the Green Port Initiatives.
- Deendayal Port has also signed MOU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Trust. The plantation is being carried out by the Social Forestry division of Kachchh.

## **CHAPTER-12**

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## ENVIRONMENTAL MONITORING REPORT FOR DEENDAYAL PORT AUTHORITY



**REPORT : DCPL/DPA/21-22/32**

**Mont Issue : December 01**

**Revision : 00**  
**: 00**

**Prepare : DETOX CORPORATION PVT. LTD., SURAT**

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## **EXECUTIVE SUMMARY**

## ENVIRONMENTAL MONITORING PLAN FOR DEENDAYAL PORT ENVIRONMENTAL MONITORING REPORT- DECEMBER, 2022

### 1. EXECUTIVE SUMMARY

Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the national standards and any other relevant standards by GBCB/CPCB/MoEF & CC to withstand status of various parameters in the Environment of the Deendayal Port. The results shall address the identified impacts and suggest measures to minimize the environmental impact due to various operations at Deendayal Port.

#### A) Ambient Air

The monitoring of Ambient Air quality at 6-locations at Deendayal Port Authority Kandla and 2- location at Vadinar Port on 24 hourly basis for TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> and NMHC in twice a week 24 hourly at uniform intervals (as per NAAQS) at Gopalpuri, Tuna Port, Marine Bhavan Building, Coal storage area, Estate building, Oil jetty and at Vadinar port, Vadinar Jetty and Vadinar colony area using respirable dust sampler, Fine particulate sampler and gaseous sampler.

The Maximum TSPM values in 1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 were found 552.0 µg/m<sup>3</sup> at Coal Storage area on 09.12.2022 and minimum 100.0 µg/m<sup>3</sup> at Tuna port on 06.12.2022. The Maximum PM<sub>10</sub> values were 399.0 µg/m<sup>3</sup> at Coal Storage area on 09.12.2022 and minimum was 59.0 µg/m<sup>3</sup> at Tuna port on 06.12.2022. Maximum PM<sub>2.5</sub> values were 144.0 µg/m<sup>3</sup> at Coal Storage area on 09.12.2022 and minimum was 26.0 µg/m<sup>3</sup> at Tuna port on 06.12.2022. The average PM<sub>10</sub> values were found for monitoring locations (Marine Bhavan Building, Coal Storage Area to exceed the Standard limit (NAAQS) while Gopalpuri and Tuna port to within the Standard limit (NAAQS). PM<sub>2.5</sub> values were found for monitoring locations (Marine Bhavan Building, Coal Storage Area) to exceed the Standard limit (NAAQS) while Oil Jetty, Estate Office, Gopalpuri, Tuna port to within the Standard limit (NAAQS).

The AAQ monitoring for Vadinar at Admin building the mean TSPM, PM<sub>10</sub> and PM<sub>2.5</sub> were 153.0 µg/m<sup>3</sup>, 108.0 µg/m<sup>3</sup> and 40.0 µg/m<sup>3</sup> respectively. The PM<sub>2.5</sub> concentration was within the Standard limit (NAAQS), whereas PM<sub>10</sub> slightly exceed the Standard limit (NAAQS). The Concentration at Signal Building the mean TSPM, PM<sub>10</sub> and PM<sub>2.5</sub> were 149 µg/m<sup>3</sup>, 99.0 µg/m<sup>3</sup> and 38 µg/m<sup>3</sup> respectively which was within the Standard limit (NAAQS). The overall values

of December for Gaseous SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> concentration were within the permissible limit at all location and NMHC were found BQL (Below Quantification Limit).

#### **B) Weather**

The mean day time temperature at Deendayal Port was 25.20 °C. The day-time maximum temperature was 28.30°C and minimum was 21.70 °C. The mean night time temperature recorded was 24.33 °C. The night-time maximum temperature was 26.60°C and minimum was 22.15 °C. The mean Solar Radiation in December 1st December 2022 to 15th December 2022 was 89.76 w/m<sup>2</sup>. The maximum solar radiation was recorded 606.1 w/m<sup>2</sup> in 4<sup>th</sup> December, 2022 and the minimum solar radiation was recorded 0.0 w/m<sup>2</sup>. The mean Relative humidity was 60.25 % for the 1st December 2022 to 15th December 2022 of December. Maximum Relative humidity was recorded 79.0 % and minimum Relative humidity was recorded 38.0 %. The average wind velocity for the entire 1st December 2022 to 15th December 2022 of December was 3.07 m/s. Maximum wind velocity was recorded 9.0 m/s. The wind direction was mostly North-East.

#### **C) Marine Ecology (Flora and Fauna) / Marine Water / Sediments:**

The results obtained from the study for the 1st December 2022 to 15th December 2022 of December 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

#### **D) Drinking Water Quality**

The drinking water being supplied to Deendayal Port Authority was safe for drinking purpose. At all drinking water monitoring stations around port area were in line with the standard limit as per the drinking water specifications given in IS 10500:2012 as per tested parameters only. The average results for 20 locations were as: pH were found Min 7.41 and maximum 7.59, TDS were found min 461.39 mg/l and Max found 544.0 mg/l, Chloride were found Min 140.31 mg/l and Max 576.28 mg/l, Total Hardness were found Min 270.0 mg/l and Max 380.0 mg/l and Calcium were found Min 34.47 mg/l and Max 43.29 mg/l, color were colorless and odor were odorless. In all water samples BOD, Heavy metal like manganese, Hexavalent chromium, Copper, Cadmium, Arsenic, Mercury, Lead, zinc all are found BQL (Below Quantification Limit). The bacterial count (E-coli & Coliform) is absent in all drinking water samples.

### **E) Monitoring Performance of Sewage Treatment Plant**

It was seen that the performance of STP at Deendayal Township Gopalpuri, DPA STP Plant Kandla and Vadinar STP plant was satisfactory by overall. The treatment plant was well maintained during [December 2022] with considerable removal efficiency achieving the standards prescribed for final disposal. At Gopalpuri STP, the pollutant removal efficiency for TSS, BOD and COD was ranged from 27.5- 79.17 %, 32.26-86.25 % and 27.52-81.25% respectively. At Kandla STP, removal efficiency for TSS, BOD and COD was ranged from 54.88-65.22%, 56.76-72.41% and 58.33-76.19% respectively & at Vadinar STP removal efficiency for TSS, BOD and COD was ranged from 38.57-51.85%, 50.0-55.56% and 33.33-50.0% respectively. At all STP location treated waste water the pH was ranged from 7.21-7.42, Total Suspended Solids were found 20.0- 58.0mg/l, Residual Chlorine were below Detection Limit (< 0.5), COD were found 30-79 mg/l and 3day BOD @ 27 °C were found 7.0-21.0 mg/l.

### **F) Noise**

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 51.7 dB(A) to 69.8 dB(A) while at Vadinar port 3 location ranged from 53.4 dB(A) to 61.2 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 44.4 dB to 60.7 dB(A) while at Vadinar port ranged from 49.0 dB (A) to 55.9 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.



# **CHAPTER-1**

## **INTRODUCTION**

### **DEENDAYAL PORT AUTHORITY**

## **1.0 Introduction**

### **About Deendayal Port**

The Deendayal Port is situated in the Kandla Creek and is 90 Kms. From the mouth of Gulf of Kachchh. Latitude: 23° 01" N Longitude: 70° 13"E. Deendayal Port's journey began in 1931 with construction of RCC Jetty by Maharao Khengarji. After partition, Deendayal Port's success story has continued and it rose to the No. 1 Port in India in the year 2007-08 and since then retained the position for the 15-consecutive year. On 31.03.2016, Deendayal Port created history by handling 100 MMT cargoes in a year, the first Major Port to achieve the milestone. Kandla, also known as the Deendayal Port Authority is a seaport in Kutch District of Gujarat state in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla was constructed in the 1950s as the chief seaport serving western India, after the partition of India from Pakistan left the port of Karachi in Pakistan. The Port of Deendayal is located on the Gulf of Kutch on the northwestern coast of India some 256 nautical miles North West of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Kandla history Deendayal Port Authority, India's busiest major port in recent years, is gearing to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 127.10 million metric tons of cargo during the FY 2021-22, as against 117.566 million metric tons in FY 2020-21. Showing a growth of 8.11 %. Incidentally, DPA is the only major Indian port of handle more than 127 MMT cargo throughout and it has also registered the highest cargo throughput in its history. While the port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in Sept. 2021. Even as much of this growth has come from handling of crude oil imports, mainly for Essar Oil's Vadinar refinery in Gujarat, the port is also taking measures to boost non-POL cargo. Last fiscal, POL traffic accounted for 63 per cent of the total cargo handled at Deendayal Port, as against 59% in 2007-08. The Deendayal Port Authority had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant. Quantum of infrastructural up-gradation has been affected & excellent maritime infrastructure been created at Vadinar for the 32 MMTPA Essar Oil Refinery in Jamnagar District. Monitoring of various environmental aspects of the Deendayal port by M/s Detox Corporation Pvt. Ltd. has been carried out through collection of samples, analysis of the same, comparing results with respect to the prescribed standards by GPCB/CPCB/MoEF& CC. The results shall address the identified impacts and suggest measures to minimize the environmental

impact due to various operations at Deendayal Port. The environmental monitoring is carried out as per the Environment Management and Monitoring Plan submitted by Detox Corporation Pvt. Ltd.

## CHAPTER-2

### AMBIENT AIR QUALITY MONITORING



## 2. Introduction

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment. The concentration of air pollutants depends not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration varies spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Air pollution occurs when harmful substances including particulates and biological molecules are introduced into earth's atmosphere. It may cause diseases, allergies or death of humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Human activity and natural processes can both generate air pollution. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty. The consequences of industrialization and the demand for improved quality of life has been increased exposure to air pollution (Vallero, 2014). An air pollutant is a substance in the air that can have adverse effects on humans and the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Any gas could qualify as pollution if it reached a high enough concentration to do harm. Theoretically, that means there are dozens of different pollution gases. In practice, about ten different substances cause most concern. Heavy metals represent a class of omnipresent pollutants, with toxic potential, in some cases even at low exposure levels. They concentrate in each trophic level because of their weak mobility, so the concentration in plants is higher than in soil, in herbivore animals higher than in plants, in carnivores' tissues higher than in herbivore, the highest concentration being reached at the end of the trophic chain, at big predators and human bodies. Globally, one of the main contributors to emissions of atmospheric pollutants and a significant user of energy is the industrial sector (Contiel, 2015). The concentration of air pollutants depends not only on the quantities that are emitted from the polluting sources, but also on the ability of the atmosphere to either absorb or disperse such emissions (USEPA, 2008). Nowadays, the shipping sector provides low-cost and reliable delivery services in the economic field

(Arunachalam et al. 2015). Nevertheless, shipping-related activities have a considerable impact on air pollution, especially in coastal areas but also globally (Buccolieri et al. 2016).

The primary air pollutants are PM, VOCs, NO<sub>x</sub>, O<sub>3</sub>, SO<sub>2</sub>, and CO (Bailey and Solomon 2004). As a consequence, a wide range of options toward “greener” seaports is needed (Bailey and Solomon 2004). Some of these measures are easy to adopt such as the regulation of fuel quality (by using low-sulfur alternative fuels), the speed reduction (Lack et al. 2011), and the use of alternative transportation equipment (Lai et al. 2011). Clean air is the basic requirement of all living organisms. In recent times, due to population growth, urban sprawl, industrial development, and vehicular boom, the quality of air is deteriorating and being polluted. Pollutants of major public health concerns include particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide, which pose serious threats to human health and hygiene. In the present study, prime particulate pollutants (PM<sub>10</sub>, PM<sub>2.5</sub>), and gaseous pollutants (SO<sub>2</sub>, and NO<sub>2</sub>) were estimated at seven stations in and around Dahej Port, Gujarat, India (Soni and Jagruti Patel, 2017). Among particulate pollutants, particulate matter (PM) is a ubiquitous entity, and is especially a grave problem due to its higher suspension rate into the atmosphere, and adverse health effects on plants, animals, humans, and materials in the form of visibility reduction, soiling of buildings, etc. (Horaginamani and Ravichandran, 2010; Chaurasia *et al.*, 2013). The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is getting adversely affected. In order to arrest the deterioration in air quality, Govt. of India has enacted Air (Prevention and Control of Pollution) Act in 1981. The responsibility has been further emphasized within Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level. The programme was later renamed as National Air Quality Monitoring Programme (NAMP).

## 2.1 Ambient Air Quality Monitoring

As per the Environmental Monitoring Plan of Deendayal Port Authority, Air monitoring was carried out at six identified locations at Deendayal Port and two locations at Vadinar Port.

**Table: 1. Ambient Air Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Marine Bhavan	AL-1	23° 0' 26.524"N	70° 13' 22.414"E	<b>DPA-Kandla</b>
2.	Oil Jetty	AL-2	23° 1' 45.613"N	70° 13' 11.052"E	
3.	Estate Office	AL-3	23° 1' 11.273"N	70° 12' 48.657"E	
4.	Gopalpuri Hospital	AL-4	23° 4' 53.551"N	70° 8' 7.047"E	
5.	Coal Storage Area	AL-5	22° 59' 31.812"N	70° 13' 9.979"E	
6.	Tuna Port	AL-6	22° 59' 15.291"N	70° 58' 57.018"E	
7.	Signal Building	AL-7	22° 26' 26.750"N	69° 40' 22.127"E	<b>DPA-Vadinar</b>
8.	Admin Building	AL-8	22° 26' 25.223"N	69° 40' 19.358"E	

### ● Air Quality Monitoring Methodology

Air quality is measured in all the stations, for 24 hours for Total Suspended Particulate Matter (TSPM), PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub> & Benzene and Grab-sampling for CO & CO<sub>2</sub> measurements. The Air samplers are operated for a period of 24 hours and after a continuous operation of 8 hours for gaseous parameters. The absorbing reagents for SO<sub>2</sub>: - Absorbing Reagent TCM (Potassium Tetrachloromercurate 0.04M): Mercuric Chloride, Potassium Chloride and EDTA used. For NO<sub>2</sub>: - Absorbing Reagent Sodium Hydroxide (NaOH): Sodium Hydroxide and Sodium Arsenite used. For NH<sub>3</sub> need Conc. Sulphuric Acid and Distilled water was used. By replacing 3 times the reagents per day for each parameter namely, SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>. The GFA filter paper and PTFE Membrane bound filter paper are used for a period of 24 hours to obtain one sample each of TSPM, PM<sub>10</sub> & PM<sub>2.5</sub>. The AAQ samples are collected two consecutive days a week as per CPCB guidelines, from all the eight locations as mentioned in the EMP.

## 2.2 Results

The ambient air quality monitoring data for six stations, viz. Marine Bhavan, Oil Jetty, Port Colony, Gopalpuri Hospital, Tuna Port and Nr. Coal Storage Area for the 1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 of December 2022 are given in Tables 2 to 7. The ambient air quality monitoring data for two stations at Vadinar (Nr. Admin Building & Nr. Signal Building) are given in Tables 8 to 9. The Movement of heavy transport with uncovered coal transportation, raw road around ambient location may be causes fugitive dust emission from dry conditions. Particulate Matter then enters the atmosphere through the action of wind, vehicular movement, or other activities. The dust produces tends to float in air and spread all around the vicinity. Direction and speed of wind affect the dispersion of the dust particulate matter. Humidity of air also has strong effect on the spreading of particulate matter. With increasing humidity, moisture particles eventually grow in size to a point where 'dry deposition' occurs, reducing PM<sub>10</sub> concentrations in the atmosphere.

**Location 1: Marine Bhavan (AL1)**

**Table 2: Results of Air Pollutant Concentration at Marine Bhavan**

	Date	TSPM [µg/ m³]	PM <sub>10</sub> [µg/ m³]	PM <sub>2.5</sub> [µg/ m³]	SO <sub>2</sub> [µg/m³]		NO <sub>x</sub> [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m³	60 µg/m³		80 µg/m³		80 µg/ m³		400 µg/m³
AL1 – 1	02.12.2022	321	206	98	4.84	4.33	17.89	16.54	2.42	4.34
					3.63		18.47		5.41	
					4.53		13.27		5.18	
AL1 – 2	06.12.2022	377	241	106	5.74	5.14	14.43	16.16	5.87	5.56
					4.23		15.58		4.26	
					5.44		18.47		6.56	
AL1 – 3	09.12.2022	404	273	110	6.65	4.58	21.93	19.24	4.95	3.53
					3.93		16.16		2.53	
					3.17		19.62		3.11	
AL1 – 4	12.12.2022	372	233	96	3.02	4.33	17.89	19.43	6.22	6.37
					5.74		18.47		7.83	
					4.23		21.93		5.06	
AL1 – 5	15.12.2022	290	192	80	5.74	5.14	16.74	15.58	6.56	7.07
					4.23		14.43		7.98	
					5.44		15.58		6.68	
1 <sup>st</sup> December 2022 to 15 <sup>th</sup> December 2022 Average		353	229	98		4.7		17.4		5.4
Standard Deviation		46	32	12		0		2		1

<b>Table 2 : Results of Air Pollutant Concentration at Marine Bhavan</b>					
	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>HC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
<b>Sampling Period</b>		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>	<b>ppm</b>	<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL1 – 1</b>	02.12.2022	1.1	BQL	1.67	1005
<b>AL1 – 2</b>	06.12.2022	1.21	BQL	1.46	1160
<b>AL1 – 3</b>	09.12.2022	1.16	BQL	1.71	938
<b>AL1 – 4</b>	12.12.2022	1.06	BQL	2.31	853
<b>AL1 – 5</b>	15.12.2022	1.12	BQL	1.96	598
<b>1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 Average</b>		<b>1.13</b>	<b>-</b>	<b>1.82</b>	<b>910.80</b>
<b>Standard Deviation</b>		<b>0.06</b>	<b>-</b>	<b>0.33</b>	<b>207.91</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Marine Bhavan, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> is attributed mainly by motor vehicle emission produced from various types of automobiles (both diesel and petrol driven). Moreover, the loading and unloading of Food Grains and Timber at Jetty no. 1 and 2 also contributes to the high levels of TSPM and PM<sub>10</sub>. The mean TSPM value at Marine Bhavan was 353.0 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 229 µg/m<sup>3</sup> which was above the standard limit and PM<sub>2.5</sub> value was 98.0 µg/m<sup>3</sup> which is within the standard limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.7 µg/m<sup>3</sup>, 17.4 µg/m<sup>3</sup> & 5.4 µg/m<sup>3</sup> respectively; these values were within the standard limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Marine Bhavan. The mean Benzene concentration was 1.13 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.82 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup> prescribed by NAAQS.

Location 2: Oil Jetty (AL2)

Table 3 : Results of Air Pollutant Concentration at Oil Jetty

Table 3 : Results of Air Pollutant Concentration at Oil Jetty										
	Date	TSPM [µg/ m <sup>3</sup> ]	PM <sub>10</sub> [µg/ m <sup>3</sup> ]	PM <sub>2.5</sub> [µg/ m <sup>3</sup> ]	SO <sub>2</sub> [µg/m <sup>3</sup> ]		NO <sub>x</sub> [µg/m3]		NH <sub>3</sub> [µg/m <sup>3</sup> ]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)	8 hr	24hr (Avg.)
NAAQMS Limit			100 µg/m <sup>3</sup>	60 µg/m3		80 µg/ m <sup>3</sup>		80 µg/m <sup>3</sup>		400 µg/m <sup>3</sup>
AL2 – 1	02.12.2022	198	111	52	5.44	4.39	13.85	13.66	6.10	6.52
					5.14		11.54		7.83	
					2.59		15.58		5.64	
AL2 – 2	06.12.2022	211	132	62	3.63	3.73	10.97	11.16	3.34	4.91
					4.23		9.81		5.29	
					3.32		12.70		6.10	
AL2 – 3	09.12.2022	239	141	71	2.88	2.98	23.66	20.97	3.80	4.91
					3.46		17.31		3.11	
					2.59		21.93		7.83	
AL2 – 4	12.12.2022	224	137	68	3.32	3.93	16.16	14.24	3.22	4.72
					3.93		12.70		4.83	
					4.53		13.85		6.10	
AL2 – 5	15.12.2022	210	119	49	3.32	4.03	15.58	16.35	4.37	4.60
					4.23		14.43		7.98	
					5.44		15.58		6.68	
1 <sup>st</sup> December 2022 to 15 <sup>th</sup> December 2022 Average		216	128	60		4		15		5
Standard Deviation		16	13	10		1		4		1

**Table 3 : Results of Air Pollutant Concentration at Oil Jetty**

	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
Sampling Period		8 hr		Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL2-1	02.12.2022	1.07	BQL	1.16	768
AL2-2	06.12.2022	1.12	BQL	1.91	1208
AL2-3	09.12.2022	1.16	BQL	1.49	1056
AL2-4	12.12.2022	1.21	BQL	1.1	855
AL2 -5	15.12.2022	1.3	BQL	1.46	511
<b>1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 Average</b>		<b>1.17</b>	-	<b>1.42</b>	<b>879.60</b>
<b>Standard Deviation</b>		<b>0.09</b>	-	<b>0.32</b>	<b>268.28</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

Oil Jetty Area, the overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> was mainly by motor vehicle emission produced from various types of vehicles at Oil Jetty Area. The mean TSPM value at Oil Jetty was 216.0 µg/m<sup>3</sup>. The mean PM<sub>10</sub> value was 128.0 µg/m<sup>3</sup> which was above the permissible limit mean, the mean PM<sub>2.5</sub> value was 60.0 µg/m<sup>3</sup> which was within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were within the permissible limit prescribed by NAAQS. The mean concentration of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.0 µg/m<sup>3</sup>, 15.00 µg/m<sup>3</sup> and 5.0 µg/m<sup>3</sup> respectively.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Oil Jetty. The mean Benzene concentration was 1.17 µg/m<sup>3</sup> which was well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.42 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



Location 3: Kandla Colony – Estate Office (AL-3)

Table 4 : Results of Air Pollutant Concentration at Estate Office

Table 4 : Results of Air Pollutant Concentration at Estate Office										
	Date	TSPM [µg/ m³]	PM <sub>10</sub> [µg/ m³]	PM <sub>2.5</sub> [µg/ m³]	SO2 [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr	24hr	24hr
NAAQMS Limit			100 µg/m³	60 µg/m³		80 µg/m³			100 µg/m³	60 µg/m³
AL3 – 1	02.12.2022	192	98	39	6.95	5.24	18.47	15.00	6.33	7.52
					5.74		16.74		7.83	
					3.02		9.81		8.40	
AL3 – 2	06.12.2022	201	110	42	4.84	4.64	11.54	11.93	6.45	4.18
					5.74		9.81		3.22	
					3.32		14.43		2.88	
AL3 – 3	09.12.2022	240	152	61	3.75	3.65	14.43	12.31	3.80	2.92
					4.32		11.54		3.22	
					2.88		10.97		1.73	
AL3 – 4	12.12.2022	222	126	59	3.93	4.63	19.04	16.74	5.76	4.34
					4.84		14.43		4.37	
					5.14		16.74		2.88	
AL3 – 5	15.12.2022	210	120	49	3.32	4.43	21.93	22.51	4.37	4.10
					3.02		31.16		4.72	
					6.95		14.43		3.22	
1 <sup>st</sup> December 2022 to 15 <sup>th</sup> December 2022 Average		213	121	50		4.5		15.7		4.6
Standard Deviation		19	20	10		1		4		2

**Table 4 : Results of Air Pollutant Concentration at Estate Office**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm ]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
<b>NAAQMS limit</b>					
<b>AL3 -1</b>	02.12.2022	1.13	BQL	1.58	895
<b>AL3 -2</b>	06.12.2022	1.22	BQL	1.38	996
<b>AL3 -3</b>	09.12.2022	1.14	BQL	1.87	859
<b>AL3 -4</b>	12.12.2022	1.16	BQL	1.88	932
<b>AL3 – 5</b>	15.12.2022	1.05	BQL	1.34	523
<b>1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 Average</b>		<b>1.14</b>	-	<b>1.61</b>	<b>841.00</b>
<b>Standard Deviation</b>		<b>0.06</b>	-	<b>0.26</b>	<b>184.84</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Kandla Port Colony (Estate Office) was attributed by vehicle emission produced from trucks and heavy-duty vehicles that pass through the road outside Kandla Port Colony. The mean TSPM values at Estate Office were 213.0 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 121.0 µg/m<sup>3</sup> was above the permissible limit prescribed by NAAQS and PM<sub>2.5</sub> value was 50.0 µg/m<sup>3</sup> which was within the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 4.5 µg/m<sup>3</sup>, 15.7 µg/m<sup>3</sup> and 4.6 µg/m<sup>3</sup> respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Kandla Port Colony. The mean Benzene concentration was 1.14 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide was 1.61 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

Location 4: Gopalpuri Hospital (AL-4)

Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital

	Date	TSPM [µg/ m³]	PM <sub>10</sub> [µg/ m³]	PM <sub>2.5</sub> [µg/ m³]	SO2 [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr	24hr	24hr
NAAQMS Limit			100 µg/m³	60 µg/m³		80 µg/m³			100 µg/m³	60 µg/m³
AL4 -1	02.12.2022	140	92	35	5.14	4.53	10.39	8.27	4.37	3.57
					3.02		7.50		3.45	
					5.44		6.93		2.88	
AL4 -2	06.12.2022	162	109	40	4.84	4.03	5.77	9.23	2.42	3.53
					3.02		10.39		3.68	
					4.23		11.54		4.49	
AL4 -3	09.12.2022	173	100	56	4.61	3.36	6.93	8.46	1.96	2.19
					2.88		10.97		2.42	
					2.59		7.50		2.19	
AL4 -4	12.12.2022	155	93	49	1.21	1.71	9.23	9.04	3.22	2.53
					2.12		11.54		1.84	
					1.81		6.35		2.53	
AL4 – 5	15.12.2022	169	98	51	2.42	2.42	14.43	13.27	2.42	3.11
					1.81		8.08		4.03	
					3.02		17.31		2.88	
1 <sup>st</sup> December 2022 to 15 <sup>th</sup> December 2022 Average		160	98	46		3.21		9.66		2.99
Standard Deviation		13	7	9		1		2		1

<b>Table 5 : Results of Air Pollutant Concentration at Gopalpuri Hospital</b>					
<b>Sampling Period</b>	<b>Date</b>	<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>	<b>*NMHC</b>	<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm ]</b>
		<b>8 hr</b>		<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL4 -1</b>	02.12.2022	1.04	BQL	1.64	890
<b>AL4 -2</b>	06.12.2022	1.25	BQL	2.05	1314
<b>AL4 -3</b>	09.12.2022	1.13	BQL	1.21	924
<b>AL4 -4</b>	12.12.2022	1.22	BQL	1.55	1275
<b>AL4 – 5</b>	15.12.2022	1.1	BQL	1.35	405
<b>1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 Average</b>		<b>1.15</b>	<b>-</b>	<b>1.56</b>	<b>961.60</b>
<b>Standard Deviation</b>		<b>0.09</b>	<b>-</b>	<b>0.32</b>	<b>367.00</b>

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Gopalpuri Hospital was attributed by vehicle emission produced from light motor vehicles of the colony residents. The mean TSPM values at Gopalpuri Hospital were 160.0 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value 98.0 µg/m<sup>3</sup> and PM<sub>2.5</sub> 46.0 µg/m<sup>3</sup> within the standard limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 3.21 µg/m<sup>3</sup>, 9.66 µg/m<sup>3</sup> and 2.99 µg/m<sup>3</sup> respectively and were within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Gopalpuri Hospital. The mean Benzene concentration was 1.15 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon monoxide concentration was 1.56 mg/m<sup>3</sup> which is well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 5: Coal Storage Area (AL-5)**

**Table 6 : Results of Air Pollutant Concentration at Coal Storage Area**

Table 6 : Results of Air Pollutant Concentration at Coal Storage Area										
	Date	TSPM [µg/ m³]	PM <sub>10</sub> [µg/ m³]	PM <sub>2.5</sub> [µg/ m³]	SO2 [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr	24hr	24hr
NAAQMS Limit			100 µg/m³	60 µg/m³		80 µg/m³			100 µg/m³	60 µg/m³
AL5 – 1	02.12.2022	392	310	129	7.25	6.04	13.85	18.85	4.95	6.56
					6.04		21.93		6.91	
					4.84		20.78		7.83	
AL5 – 2	06.12.2022	488	342	136	6.95	5.34	13.27	16.16	7.48	7.67
					5.14		22.51		8.06	
					3.93		12.70		7.48	
AL5 – 3	09.12.2022	552	399	144	5.77	4.52	21.93	23.85	3.80	3.49
					4.32		19.04		3.22	
					3.46		30.59		3.45	
AL5 – 4	12.12.2022	510	364	124	6.04	6.04	16.16	15.97	5.87	5.76
					7.55		12.70		4.03	
					4.53		19.04		7.37	
AL5 – 5	15.12.2022	472	290	110	6.35	4.94	19.62	20.01	7.71	6.56
					4.84		17.31		6.33	
					3.63		23.08		5.64	
1st December 2022 to 15th December 2022 Average		483	341	129		5.38		18.97		6.01
Standard Deviation		59	43	13		1		3		2

**Table 6: Results of Air Pollutant Concentration at Coal Storage Area**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]	*NMHC	CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
NAAQMS limit					
AL5 – 1	02.12.2022	1.11	BQL	1.66	1289
AL5 – 2	06.12.2022	1.16	BQL	1.97	1427
AL5 – 3	09.12.2022	1.22	BQL	2.19	718
AL5 – 4	12.12.2022	1.13	BQL	1.48	1222
AL5 – 5	15.12.2022	1.19	BQL	1.43	481
1st December 2022 to 15th December 2022 Average		1.16	-	1.75	1027.40
Standard Deviation		0.04	-	0.33	406.28

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The overall values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> at Coal Storage Area was comparatively highest among all the locations of Air Quality monitoring in Kandla Port. High values of TSPM, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, NO<sub>2</sub> at this location was due to lifting of coal with grab and other coal handling processes near Berth no. 6 & 7. Moreover, the traffic was also heavy around this place for transport of coal thus emissions produced from heavy vehicles. The mean TSPM values at Coal storage were 483.0 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 341.0 µg/m<sup>3</sup>, and the PM<sub>2.5</sub> value was 129.0 µg/m<sup>3</sup> which was above the permissible limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 5.38 µg/m<sup>3</sup>, 18.97 µg/m<sup>3</sup> and 6.01 µg/m<sup>3</sup> respectively and were within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Coal Storage Area. The mean Benzene concentration was 1.16 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.75 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.

**Location 6: Tuna Port (AL-6)**

**Table 7: Results of Air Pollutant Concentration at Tuna Port**

Table 7: Results of Air Pollutant Concentration at Tuna Port										
	Date	TSPM [µg/ m³]	PM <sub>10</sub> [µg/ m³]	PM <sub>2.5</sub> [µg/ m³]	SO2 [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr	24hr	24hr
NAAQMS Limit			100 µg/m³	60 µg/m³		80 µg/m³			100 µg/m³	60 µg/m³
AL5 -1	02.12.2022	106	66	30	4.53	3.42	11.54	9.62	4.49	3.57
					3.02		9.81		3.91	
					2.72		7.50		2.30	
AL5 – 2	06.12.2022	100	59	26	2.42	1.91	7.50	8.27	2.65	3.61
					1.81		9.23		3.45	
					1.51		8.08		4.72	
AL5 – 3	09.12.2022	110	61	32	2.59	2.11	6.35	10.39	3.11	2.92
					1.73		11.54		2.07	
					2.02		13.27		3.57	
AL5 – 4	12.12.2022	126	78	40	1.21	1.31	8.66	10.97	2.42	2.95
					0.91		11.54		3.57	
					1.81		12.70		2.88	
AL5 – 5	15.12.2022	108	70	36	1.81	2.82	13.27	11.73	5.76	5.45
					3.63		11.54		5.53	
					3.02		10.39		5.06	
1st December 2022 to 15th December 2022 Average		110	67	33		2.32		10.2		3.70
Standard Deviation		10	8	5		1		1		1

**Table 7: Results of Air Pollutant Concentration at Tuna Port**

		C <sub>6</sub> H <sub>6</sub> [µg/m <sup>3</sup> ]		CO [mg/m <sup>3</sup> ]	CO <sub>2</sub> [ppm]
Sampling Period	Date	8 hr	*NMHC	Grab Sampling	Grab Sampling
NAAQMS limit		5.0 µg/m <sup>3</sup>		4.0 mg/m <sup>3</sup>	-
AL6 -1	02.12.2022	1.1	BQL	1.78	1459
AL6 – 2	06.12.2022	1.27	BQL	1.55	1067
AL6 – 3	09.12.2022	1.1	BQL	2.1	651
AL6 – 4	12.12.2022	1.23	BQL	1.81	391
AL6 – 5	15.12.2022	1.12	BQL	1.29	471
AL6 – 6	02.12.2022	1.1	BQL	1.78	1459
1st December 2022 to 15th December 2022 Average		1.16	-	1.71	807.80
Standard Deviation		0.08	-	0.30	448.05

\* NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

The mean TSPM values at Tuna Port was 110.0 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 67.0 µg/m<sup>3</sup> and PM<sub>2.5</sub> value was 33.0 µg/m<sup>3</sup> which were within the standard limit prescribed by NAAQS. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> were 2.32 µg/m<sup>3</sup>, 10.2 µg/m<sup>3</sup> and 3.70 µg/m<sup>3</sup> respectively and were all within the standard limit prescribed by NAAQS.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Tuna Port. The mean Benzene concentration was 1.16 µg/m<sup>3</sup>, well below the permissible limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.71 mg/m<sup>3</sup>, well below the permissible limit of 4.0 mg/m<sup>3</sup>.



**Location 7: Admin Building (Vadinar) (AL-7)**

**Table 8: Results of Air Pollutant Concentration at Admin Building**

Table 8: Results of Air Pollutant Concentration at Admin Building										
	Date	TSPM [µg/ m³]	PM <sub>10</sub> [µg/ m³]	PM <sub>2.5</sub> [µg/ m³]	SO2 [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr	24hr	24hr
NAAQMS Limit			100 µg/m³	60 µg/m³		80 µg/m³			100 µg/m³	60 µg/m³
AL7 -1	02.12.2022	160	106	44	3.93	3.93	11.54	12.12	8.17	8.52
					4.84		15.00		9.44	
					3.02		9.81		7.94	
AL7 -2	06.12.2022	163	114	48	3.52	5.13	10.39	12.12	7.25	8.40
					5.28		14.43		8.52	
					6.59		11.54		9.44	
AL7 -3	09.12.2022	155	109	39	3.32	3.93	10.97	9.62	7.02	6.10
					3.63		10.39		4.83	
					4.84		7.50		6.45	
AL7 -4	12.12.2022	159	112	41	5.14	5.24	13.27	13.08	7.94	7.60
					6.65		10.97		6.79	
					3.93		15.00		8.06	
AL7 -5	15.12.2022	130	99	29	3.02	3.73	16.16	15.97	6.79	7.52
					5.44		18.47		7.60	
					2.72		13.27		8.17	
1st December 2022 to 15th December 2022 Average		153	108	40		4.39		12.58		7.63
Standard Deviation		13	6	7		0.73		2.29		0.97

**Table 8: Results of Air Pollutant Concentration at Admin Building Vadinar**

Sampling Period	Date	C <sub>6</sub> H <sub>6</sub> [ $\mu\text{g}/\text{m}^3$ ]	*NMHC	CO [ $\text{mg}/\text{m}^3$ ]	CO <sub>2</sub> [ppm]
		8 hr		Grab Sampling	Grab Sampling
		5.0 $\mu\text{g}/\text{m}^3$		4.0 $\text{mg}/\text{m}^3$	-
AL7 -1	02.12.2022	1.08	BQL	1.65	566
AL7 -2	06.12.2022	1.13	BQL	1.6	523
AL7 -3	09.12.2022	1.17	1.81	1.39	406
AL7 -4	12.12.2022	1.14	BQL	1.46	414
AL7 -5	15.12.2022	1.03	BQL	1.2	400
<b>1st December 2022 to 15th December 2022 Average</b>		<b>1.11</b>	-	<b>1.46</b>	<b>462</b>
<b>Standard Deviation</b>		<b>0.06</b>	-	<b>0.18</b>	<b>77</b>

\*NMHC- Non- Methane Hydrocarbons

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

At Admin Building, Vadinar the mean TSPM value was  $153.0 \mu\text{g}/\text{m}^3$ , the mean PM<sub>10</sub> value was  $108.0 \mu\text{g}/\text{m}^3$  which was slightly exceed the standard limit, mean PM<sub>2.5</sub> value was  $40.0 \mu\text{g}/\text{m}^3$  within the standard limit The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were  $4.39 \mu\text{g}/\text{m}^3$ ,  $12.58 \mu\text{g}/\text{m}^3$  and  $7.63 \mu\text{g}/\text{m}^3$  respectively and were all within the permissible limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was  $1.11 \mu\text{g}/\text{m}^3$ , well below the permissible limit of  $5.0 \mu\text{g}/\text{m}^3$ . NMHC's were below the detectable limit and Carbon Monoxide concentration was  $1.46 \text{ mg}/\text{m}^3$ , well below the permissible limit of  $4.0 \text{ mg}/\text{m}^3$ .

**Location 8: Signal Building (Vadinar) (AL-8)**

**Table 9 : Results of Air Pollutant Concentration at Signal Building, Vadinar**

Table 9 : Results of Air Pollutant Concentration at Signal Building, Vadinar										
	Date	TSPM [µg/ m³]	PM <sub>10</sub> [µg/ m³]	PM <sub>2.5</sub> [µg/ m³]	SO2 [µg/m³]		NOx [µg/m³]		NH <sub>3</sub> [µg/m³]	
Sampling Period		24hr	24hr	24hr	8 hr	24hr (Avg.)	8 hr	24hr	24hr	24hr
NAAQMS Limit			100 µg/m³	60 µg/m³		80 µg/m³			100 µg/m³	60 µg/m³
AL8 -1	02.12.2022	130	96	35	5.44	4.84	9.23	10.97	5.29	6.94
					3.93		11.54		6.56	
					5.14		12.12		8.98	
AL8 -2	03.12.2022	146	106	42	4.84	4.73	15.00	12.70	7.14	7.33
					5.44		12.70		8.06	
					3.93		10.39		6.79	
AL8 -3	06.12.2022	152	90	37	5.44	3.83	13.27	13.66	5.76	5.72
					3.32		16.16		4.95	
					2.72		11.54		6.45	
AL8 -4	09.12.2022	149	94	30	4.23	5.24	10.97	13.08	6.33	5.68
					5.14		15.00		5.64	
					6.35		13.27		5.06	
AL8 -5	15.12.2022	150	108	48	5.44	5.44	12.12	15.00	5.29	5.64
					6.04		15.58		7.14	
					4.84		17.31		4.49	
1st December 2022 to 15th December 2022 Average		145	99	38		4.82		13.08		6.26
Standard Deviation		8.88	7.82	6.88		0.62		1.47		0.81

**Table 9 : Results of Air Pollutant Concentration at Signal Building Vadinar**

		<b>C<sub>6</sub>H<sub>6</sub> [µg/m<sup>3</sup>]</b>		<b>CO [mg/m<sup>3</sup>]</b>	<b>CO<sub>2</sub> [ppm]</b>
<b>Sampling Period</b>	<b>Date</b>	<b>8 hr</b>	<b>*NMHC</b>	<b>Grab Sampling</b>	<b>Grab Sampling</b>
<b>NAAQMS limit</b>		<b>5.0 µg/m<sup>3</sup></b>		<b>4.0 mg/m<sup>3</sup></b>	<b>-</b>
<b>AL8 -1</b>	02.12.2022	1.19	BQL	0.98	576
<b>AL8 -2</b>	06.12.2022	1.2	BQL	1.38	510
<b>AL8 -3</b>	09.12.2022	1.14	BQL	1.97	378
<b>AL8 -4</b>	12.12.2022	1.1	BQL	1.94	403
<b>AL8 -5</b>	15.12.2022	1.19	BQL	1.41	393
<b>1st December 2022 to 15th December 2022 Average</b>		<b>1.16</b>	<b>-</b>	<b>1.54</b>	<b>452</b>
<b>Standard Deviation</b>		<b>0.04</b>	<b>-</b>	<b>0.42</b>	<b>87</b>

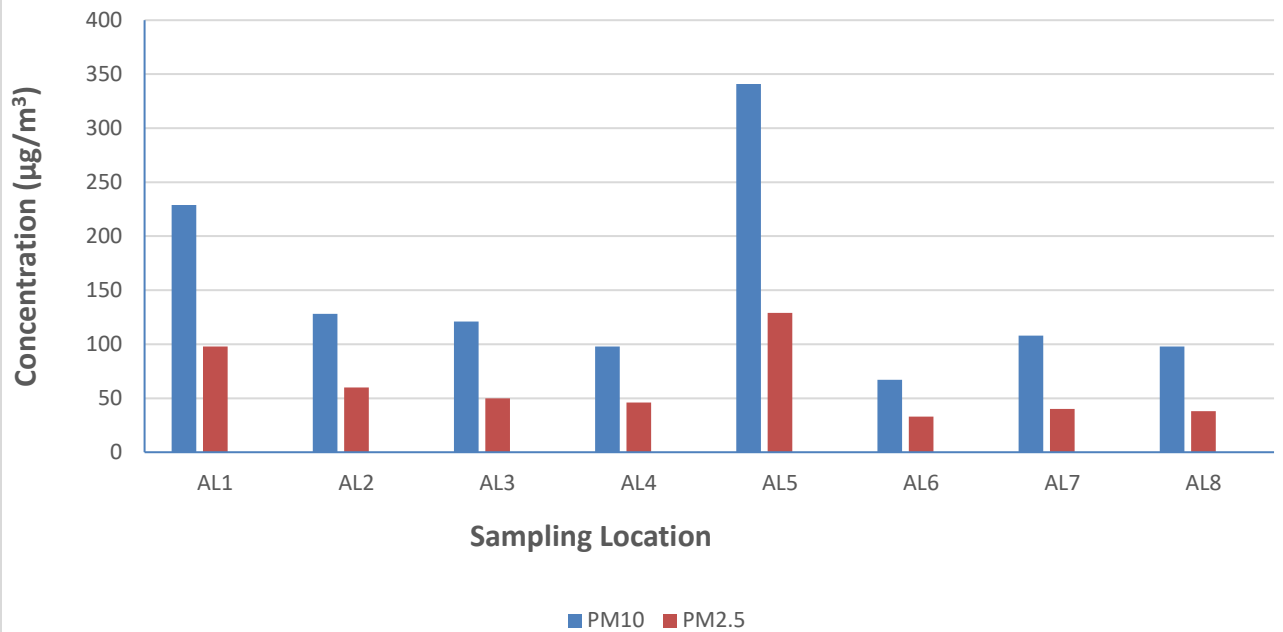
\* NMHC- Non- Methane Hydrocarbon

BQL- Below Quantification Limit (Quantification Limit – NMHC: 0.5 ppm)

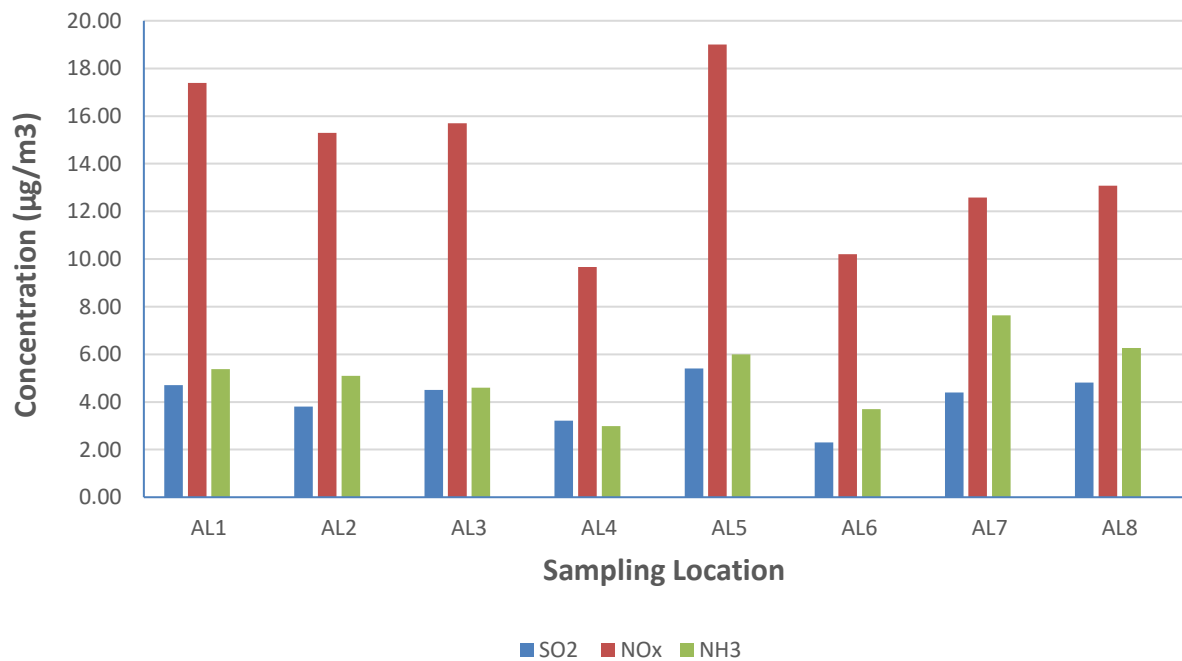
At Signal Building, Vadinar the mean TSPM value was 145 µg/m<sup>3</sup>, the mean PM<sub>10</sub> value was 99 µg/m<sup>3</sup> and PM<sub>2.5</sub> value was 38 µg/m<sup>3</sup> which were within the permissible limit. The average values of SO<sub>2</sub>, NO<sub>2</sub> and NH<sub>3</sub> concentrations were 4.82 µg/m<sup>3</sup>, 13.08 µg/m<sup>3</sup> and 6.26 µg/m<sup>3</sup> respectively and were all within the standard limit.

The levels of Benzene, Hydrocarbons (HC) and CO were within the permissible limit at Vadinar Port. The mean Benzene concentration was 1.16 µg/m<sup>3</sup>, well below the standard limit of 5.0 µg/m<sup>3</sup>. NMHC's were below the detectable limit and Carbon Monoxide concentration was 1.54 mg/m<sup>3</sup>, well below the standard limit of 4.0 mg/m<sup>3</sup>.

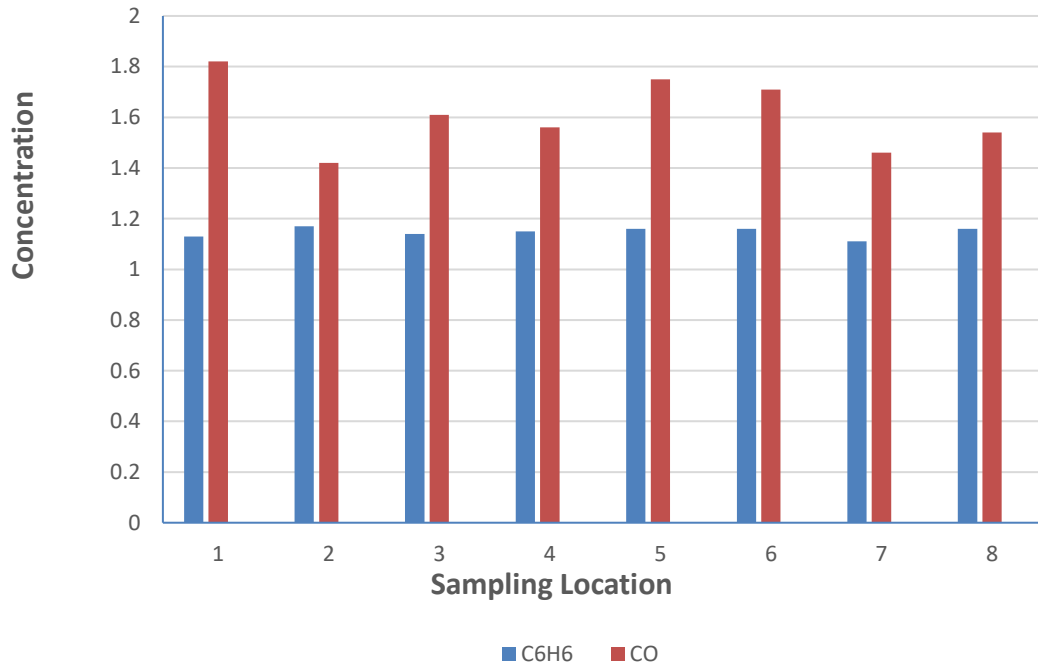
**Fig. No:-1 Average ambient air quality (PM) month of December-2022 at DPA and Vadinar Sampling Station**



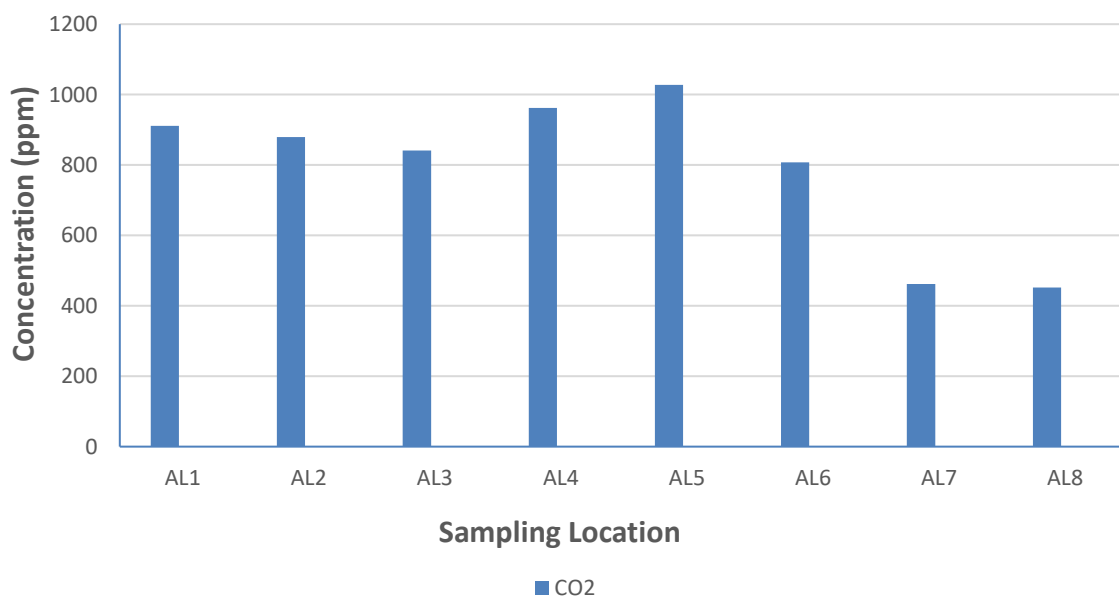
**Fig. No:-2. Average ambient air quality (Gaseous) month of December-2022 at DPA and Vadinar sampling location**



**Fig. No:-3. Average ambient air quality (Gaseous) month of December-2022 at DPA and Vadinar sampling location**



**Fig. No:-4. Average ambient air quality (Gaseous) month of December-2022 at DPA and Vadinar sampling location**



### 2.3 Observations and Conclusion

During the monitoring period, the overall Ambient Air Quality of the port area was found within permissible levels for various gaseous pollutants. However, Particulate matter as PM<sub>10</sub> and PM<sub>2.5</sub> was found to exceed the limits at Marine Bhavan, Oil Jetty, Estate Office and Coal Storage ambient air monitoring sampling locations.

The mean concentration of PM<sub>10</sub> was slightly exceed the standard limit at admin building Vadinar while PM<sub>2.5</sub> was within standard limit and at Signal building Vadinar the concentration of PM<sub>10</sub> & PM<sub>2.5</sub> within the standard limit.

The overall values of December for Gaseous SO<sub>2</sub>, NO<sub>2</sub>, NH<sub>3</sub>, CO<sub>2</sub>, CO, C<sub>6</sub>H<sub>6</sub> concentration were within the permissible limit at all location and NMHC were found BQL (Below Quantification Limit).

## **CHAPTER-3**

### **METEOROLOGICAL OBSERVATIONS**



#### **4.1 Meteorological Data**

Automatic Weather station (ID KAZPHOEN424) have been installed in Seva Sadan-3 at the Deendayal Port which records the data on Temperature (°C), Relative Humidity (%), Wind speed (m/s), Wind Direction (°), Solar radiation (w/m<sup>2</sup>) and Rainfall mm.

Meteorological factors play an important role in environmental pollution studies particularly in pollutant transport irrespective of their entry into the environment. The wind speed and direction play a major role in dispersion of environment pollutants. Effects of pollution on receptors animate and inanimate depends on atmospheric condition.

##### **Temperature**

At Deendayal Port, the day time temperature was found range 21.70-28.30<sup>0</sup>C. The average day time temperature was 25.20<sup>0</sup>C. The night time temperature was range from 22.15-26.60<sup>0</sup>C. The mean night time temperature recorded was 24.33 °C.

##### **Solar Radiation**

The mean Solar Radiation in December 1st December 2022 to 15th December 2022 was 89.76 w/m<sup>2</sup>. The maximum solar radiation was recorded 606.1 w/m<sup>2</sup> in 4<sup>th</sup> December, 2022 and the minimum solar radiation was recorded 0.00 w/m<sup>2</sup> in December, 2022.

##### **Rainfall**

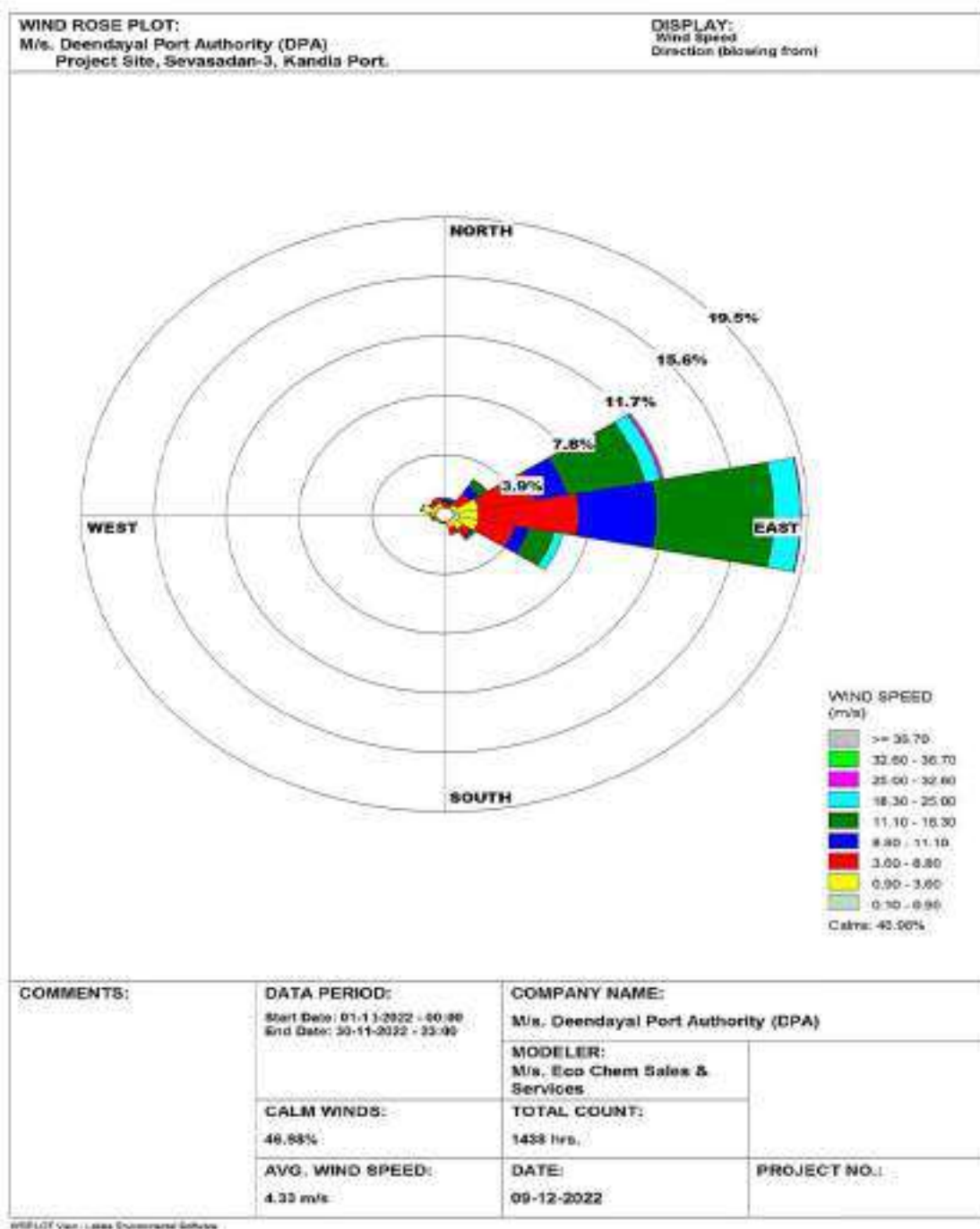
Rain fall of December 1st December 2022 to 15th December 2022 was recorded 0.00 mm.

##### **Relative Humidity**

The mean Relative humidity was 60.25 % for the 1st December 2022 to 15th December 2022 of December. Maximum Relative humidity was recorded 79.0 % and minimum Relative humidity was recorded 38.0 %.

##### **Wind Velocity and Wind Direction**

Velocity and direction of wind have a significant role in the dispersion of air borne materials and therefore determines the air quality of the area. The average wind velocity for the entire 1st December 2022 to 15th December 2022 of December was 4.33 m/s. Maximum wind velocity was recorded 9.0 m/s. The wind direction was mostly North-East.



## **CHAPTER-4**

### **DRINKING WATER QUALITY MONITORING**

#### 4.0 Drinking Water Quality Monitoring

Drinking Water Quality Monitoring was carried out at twenty stations at Kandla, Vadinar & Township Area of Deendayal Port.

**Table No: -10. Drinking Water Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude
1.	Nirman Building	DL-1	23° 0' 27"N	70° 13' 21"E
2.	P & C Building	DL-2	23° 0' 33"N	70° 13' 20"E
3.	North Gate	DL-3	23° 0' 26.97"N	70° 13' 21.87"E
4.	DPA-Canteen	DL-4	23° 2' 17.2674"N	70° 13' 18.2814"E
5.	West Gate	DL-5	23° 59' 40.48"N	70° 12' 50.96"E
6.	Wharf Area	DL-6	22° 59' 52.2"N	70° 13' 22.95"E
7.	Sevasadan-3	DL-7	23° 0' 22.55"N	70° 13' 15.34"E
8.	Workshop	DL-8	23° 0' 33.74"N	70° 13' 20.05"E
9.	Custom Building	DL-9	23° 1' 8.70"N	70° 12' 52.0"E
10.	Kandla Colony	DL-10	23° 11' 14.9"N	70° 12' 48.4"E
11.	DPA Hospital	DL-11	23° 1' 5.02"N	70° 12' 44.38"E
12.	A.O. Building	DL-12	23° 3' 42.89"N	70° 8' 41.5"E
13.	Gopalpuri School	DL-13	23° 5' 1.03"N	70° 7' 55.42"E
14.	Gopalpuri Guest House	DL-14	23° 4' 43.14"N	70° 7' 51.92"E
15.	E-Type Quarters	DL-15	23° 4' 59.90"N	70° 7' 56.72"E
16.	F-Type Quarters	DL-16	23° 4' 38.45"N	70° 8' 8.63"E
17.	Gopalpuri Hospital	DL-17	23° 4' 54.09"N	70° 8' 7.5"E
18.	Tuna Port	DL-18	23° 58' 23.06"N	70° 5' 35.6"E
19.	Vadinar Jetty	DL-19	22° 25' 51.73"N	69° 41' 36.62"E
20.	Vadinar Colony	DL-20	22° 30' 26.25"N	69° 39' 45.03"E

#### **4.1 Drinking Water Monitoring Methodology**

Samples for physico-chemical analysis were collected in 2 Carboys and samples for microbiological parameters were collected in sterilized bottles. These samples were then analyzed in laboratory for various drinking water parameters at Kandla Lab/Surat.

The Sampling was done as per IS: 3025 Part-1, analysis was done as per IS: 3025/APHA standard methods and, the analysis results compare with IS 10500:2012. The water samples were analyzed for various parameters, viz. Color, Odor, Turbidity, Conductivity, pH, Chlorides, TDS, Total Hardness, Iron, Sulphate, Salinity, DO, BOD, Na, K, Ca, Mg, F, NO<sub>3</sub>, NO<sub>2</sub>, Mn, Cr-6, Cu, Cd, As, Hg, Pb, Zn, Bacterial Count (CFU).

#### **4.2 Results**

The Drinking Water Quality monitoring data for 20 stations are given in below from table No. 11 to Table No. 17

**Table 11: Drinking Water Quality Monitoring Parameters for Nirman Building, P & C Building and Main Gate (North) at Kandla.**

Sr. No.	Parameter	Unit	Nirman Building 1	P & C Building	Main Gate North	Acceptable Limits as per IS 10500 :2012	Permissible Limits in the absence of Alternate Source as
1	pH	-	7.42	7.40	7.27	7.35	6.5 to 8.5
2	Total Dissolved Solids	mg/l	490	455	471	690	2000
3	Turbidity	NTU	1	0	0	0	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	980	910	942	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	170.38	155.35	130.29	250	1000
9	Ca as Ca	mg/l	47.29	33.67	39.28	75	200
10	Mg as Mg	mg/l	58.81	57.35	73.39	30	100
11	Total Hardness	mg/l	360	320	400	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.25	0.39	0.31	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	45.23	49.11	52.62	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	3.18	2.62	2.49	45	No Relaxation
17	Salinity	‰	0.31	0.28	0.24	NS*	NS*
18	Sodium as Na	mg/l	190.0	207.60	198.50	NS*	NS*
19	Potassium as K	mg/l	5.64	3.89	3.95	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/ 100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified BQL- Below Quantification Limit, (BOD-2.0 mg/l, Fe- 0.009 mg/l, Mn- 0.01 mg/l, Cr<sup>+6</sup>- 0.03 mg/l, Cu- 0.004 mg/l, Cd- 0.003 mg/l, As- 0.003mg/l, Hg- 0.001 mg/l, Pb- 0.006mg/l, Zinc- 0.021 mg/l).

**Table 12: Drinking Water Quality Monitoring Parameters for Canteen, West Gate – I & Wharf Area at Kandla**

Sr. No.	Parameter	Unit	Canteen	West Gate – I	Wharf Area	Acceptable Limits as per IS 10500: 2012	Permissible Limits in the absence of Alternate Source as per IS 10500: 2012
1	pH	-	7.38	7.40	7.55	7.48	6.5 to 8.5
2	Total Dissolved Solids	mg/l	489	449	474	640	2000
3	Turbidity	NTU	1	0	1	0	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	978	898	948	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	175.39	140.31	160.36	250	1000
9	Ca as Ca	mg/l	40.08	36.87	40.08	75	200
10	Mg as Mg	mg/l	43.74	55.40	34.02	30	100
11	Total Hardness	mg/l	280	320	240	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.33	0.24	0.35	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	48.36	54.87	51.11	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	3.31	3.87	3.59	45	No Relaxation
17	Salinity	‰	0.32	0.25	0.29	NS*	NS*
18	Sodium as Na	mg/l	199.10	278.50	144.50	NS*	NS*
19	Potassium as K	mg/l	3.98	4.38	3.91	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 13: Drinking Water Quality Monitoring Parameters for Sewa sadan-3, Workshop I and Custom Building at Kandla**

Sr. No.	Parameter	Unit	Sewa Sadan – 3	Workshop	Custom Building	Acceptable Limits as per IS 10500: 2012	Permissible Limits in the absence of Alternate Source as per IS 10500: 2012
1	pH	-	7.29	7.30	7.29	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	483	469	400	500	2000
3	Turbidity	NTU	1	1	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	966	937	800	NS*	NS*
7	Biochemical	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	155.35	180.40	165.37	250	1000
9	Ca as Ca	mg/l	41.68	39.28	40.88	75	200
10	Mg as Mg	mg/l	62.21	73.39	23.81	30	100
11	Total Hardness	mg/l	360	400	200	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.27	0.28	0.23	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	52.62	57.00	50.61	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	4.69	5.39	5.66	45	No Relaxation
17	Salinity	‰	0.28	0.33	0.30	NS*	NS*
18	Sodium as Na	mg/l	210.40	210.90	171.40	NS*	NS*
19	Potassium as K	mg/l	3.99	3.84	3.34	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).



**Table 14: Drinking Water Quality Monitoring Parameters for Port Colony Kandla, Hospital Kandla and A.O. Building at Gandhidham.**

Sr. No.	Parameter	Unit	Port Colony Kandla	Hospital Kandla	A.O. Building	Acceptable Limits as per IS 10500: 2012	Permissible Limits in the absence of Alternate Source as per IS 10500: 2012
1	pH	-	7.31	7.36	7.4	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	455	423	444	500	2000
3	Turbidity	NTU	1	0	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	910	846	888	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	180.40	145.32	155.35	250	1000
9	Ca as Ca	mg/l	44.89	42.48	37.68	75	200
10	Mg as Mg	mg/l	35.96	42.28	54.92	30	100
11	Total Hardness	mg/l	260	280	320	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.27	0.27	0.38	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	53.24	50.61	55.62	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	4.90	3.31	3.59	45	No Relaxation
17	Salinity	‰	0.33	0.26	0.28	NS*	NS*
18	Sodium as Na	mg/l	198.50	190.00	200.00	NS*	NS*
19	Potassium as K	mg/l	3.96	4.14	4.29	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

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**Table 15: Drinking Water Quality Monitoring Parameters for School Gopalpuri, Guest House and E-Type Quarter at Gopalpuri, Gandhidham**

Sr. No.	Parameter	Unit	Gopalpuri School	Guest House	E - Type Quarter	Acceptable Limits as per IS 10500: 2012	Permissible Limits in the absence of Alternate Source as per IS 10500: 2012
1	pH	-	7.5	7.59	7.42	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	448	450	455	500	2000
3	Turbidity	NTU	0	1	0	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	895	900	910	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	135.30	150.33	145.32	250	1000
9	Ca as Ca	mg/l	40.08	41.68	38.48	75	200
10	Mg as Mg	mg/l	63.18	71.93	44.71	30	100
11	Total Hardness	mg/l	360	400	280	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.25	0.25	0.11	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	35.08	48.23	51.62	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	5.59	3.04	3.73	45	No Relaxation
17	Salinity	‰	0.24	0.27	0.26	NS*	NS*
18	Sodium as Na	mg/l	201.00	200.00	192.00	NS*	NS*
19	Potassium as K	mg/l	3.80	3.70	3.65	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100 ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 16: Drinking Water Quality Monitoring Parameters for F-Type Quarter, Hospital Gopalpuri and Tuna Port.**

Sr. No.	Parameter	Unit	F - Type Quarter	Hospital Gopalpuri	Tuna Port	Acceptable Limits as per IS 10500: 2012	Permissible Limits in the absence of Alternate Source as per IS 10500: 2012
1	pH	-	7.44	7.49	7.48	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	460	446	544	500	2000
3	Turbidity	NTU	1	0	1	1	5
4	Odor	-	Odorless	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	Colorless	5	15
6	Conductivity	µs/cm	920	892	1000	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	115.26	180.40	210.47	250	1000
9	Ca as Ca	mg/l	44.89	41.68	49.70	75	200
10	Mg as Mg	mg/l	60.26	33.05	67.07	30	100
11	Total Hardness	mg/l	360	240	400	200	600
12	Iron as Fe	mg/l	BQL	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.27	0.30	0.40	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	52.62	53.12	62.64	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	4.28	5.39	4.28	45	No Relaxation
17	Salinity	‰	0.21	0.33	0.38	NS*	NS*
18	Sodium as Na	mg/l	200.00	204.00	122.30	NS*	NS*
19	Potassium as K	mg/l	3.58	3.83	BQL	NS*	NS*
20	Manganese	mg/l	BQL	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent	Absent

\*NS: Not Specified, BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

**Table 17: Drinking Water Quality Monitoring Parameters for Vadinar Jetty and Port Colony at Vadinar.**

Sr. No.	Parameter	Unit	Vadinar Jetty	Port Colony Vadinar	Acceptable Limits as per IS 10500: 2012	Permissible Limits in the absence of Alternate Source as per IS 10500: 2012
1	pH	-	7.42	7.38	6.5 to 8.5	6.5 to 8.5
2	Total Dissolved Solids	mg/l	249	250	500	2000
3	Turbidity	NTU	0.00	1.00	1	5
4	Odor	-	Odorless	Odorless	Agreeable	Agreeable
5	Color	-	Colorless	Colorless	5	15
6	Conductivity	µs/cm	498	500	NS*	NS*
7	Biochemical Oxygen Demand	mg/l	BQL	BQL	NS*	NS*
8	Chloride as Cl	mg/l	150.33	141.30	250	1000
9	Ca as Ca	mg/l	39.28	40.88	75	200
10	Mg as Mg	mg/l	44.23	62.69	30	100
11	Total Hardness	mg/l	280	360	200	600
12	Iron as Fe	mg/l	BQL	BQL	0.3	No Relaxation
13	Fluorides as F	mg/l	0.62	0.58	1	1.5
14	Sulphate as SO <sub>4</sub>	mg/l	25.06	24.05	200	400
15	Nitrite as NO <sub>2</sub>	mg/l	BQL	BQL	NS*	NS*
16	Nitrate as NO <sub>3</sub>	mg/l	2.00	1.38	45	No Relaxation
17	Salinity	‰	0.27	0.25	NS*	NS*
18	Sodium as Na	mg/l	199.1	210.9	NS*	NS*
19	Potassium as K	mg/l	3.98	3.84	NS*	NS*
20	Manganese	mg/l	BQL	BQL	0.1	0.3
21	Hexavalent Chromium	mg/l	BQL	BQL	NS*	NS*
22	Copper	mg/l	BQL	BQL	0.05	1.5
23	Cadmium	mg/l	BQL	BQL	0.003	NS*
24	Arsenic	mg/l	BQL	BQL	0.01	0.05
25	Mercury	mg/l	BQL	BQL	0.001	NS*
26	Lead	mg/l	BQL	BQL	0.01	NS*
27	Zinc	mg/l	BQL	BQL	5	15
28	Bacterial Count	CFU/100ml	Absent	Absent	Absent	Absent

\*NS: Not Specified,

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Fe-0.009 mg/l, Mn- 0.01 mg/l, Cr+6- 0.03 mg/l, Cu-0.004 mg/l, Cd-0.003 mg/l, As-0.003mg/l, Hg-0.001 mg/l, Pb-0.006mg/l, Zinc-0.021 mg/l).

### **4.3 Results & Discussion**

The colour of all drinking water samples was found Colourless and odour of the samples also agreeable. All parameters were found within the specified limit as per the Drinking water Standard.

#### **pH**

The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. At DPA Site the pH values for drinking water samples ranged from 7.27-7.59 and mean value was 7.41 while at Vadinar pH ranged from 7.38-7.42 and mean value was 7.40. All the sampling points showed pH values within the prescribed limit by Indian Standards.

#### **Turbidity**

The selected drinking water sample location turbidity range from 0-1NTU at all location of DPA and Vadinar in 1st December 2022 to 15th December 2022 of December. The Turbidity values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Total Dissolved Solids (TDS)**

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc.

TDS values at DPA varied between 400-544 mg/l. The average TDS value was found 462.90 mg/l. The minimum value for TDS was 400 mg/l at Custom Building and maximum was 544.0 mg/l at Tuna Port while at Vadinar TDS ranged from 249-250 mg/l and mean was 249.5 mg/l. The TDS values were within the permissible limit at all sampling location prescribed limit by Indian standards.

#### **Conductivity**

Electrical Conductivity is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected during the 1st December 2022 to 15th December 2022 of December DPA ranged from 800.0  $\mu\text{S}/\text{cm}$  at Custom Building to 1000.0  $\mu\text{S}/\text{cm}$  at Tuna Port and mean value was 921.52  $\mu\text{S}/\text{cm}$  while at Vadinar ranged from 498-500  $\mu\text{S}/\text{cm}$  and mean was 499.0  $\mu\text{S}/\text{cm}$ .

## **BOD**

BOD value in the studied area of DPA and Vadinar was found Below Quantification Limit (<2.0 mg/l). IS 10500:2012 does not show any standard values for BOD in drinking water.

## **Chlorides**

Excessive chloride concentration increase rates of corrosion of metals in the distribution system. This can lead to increased concentration of metals in the supply. The Chloride value in the studied area of DPA ranged from 115.26-210.47 mg/l. The mean value was 157.49 mg/l. The minimum chloride was 115.26 mg/l at F-Type colony and maximum was 210.47 mg/l at Tuna port while at Vadinar location chloride ranged from 115.26-210.47mg/l and mean was 157.49 mg/l. The Chloride was found within the Permissible limit of the Drinking Water Standard.

## **Calcium**

Calcium is most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases.

The Calcium value in the studied area of DPA ranged from 33.67-49.7 mg/l. The mean value was 41.00 mg/l. The minimum calcium was 33.67 mg/l at P&C building and maximum was 49.7 mg/l at Tuna Port while at Vadinar location Calcium ranged from 33.67-49.7 and mean was 41.15 mg/l. All the locations had calcium within the prescribed limits of 75-200 mg/L.

## **Magnesium**

The magnesium value in the studied area of DPA ranged from 23.81-73.39 mg/l. The mean value was 53.08 mg/l. The minimum magnesium was 23.81 mg/l at Custom Building and maximum was 73.39 mg/l at main gate north and workshop while at Vadinar location magnesium ranged from 44.23- 62.69 and mean was 53.46 mg/l. All the locations had magnesium within the prescribed limits of 30-100 mg/L.

## **Total Hardness**

Total Hardness value in the studied area of DPA ranged from 200.0 mg/l at Port Colony to 400.0 mg/l at Main Gate, Guest House, Tuna Port & workshop and mean value was 326.67 mg/l while at Vadinar location total hardness ranged from 280.0-360.00 mg/l and mean was

320.0 mg/l. The values of total hardness were found within the Permissible limit of the Drinking Water Standard (200-600 mg/L). These results clear, that hardness of water is according to the IS standards and it is not harmful for local inhabitants.

### **Iron**

Iron values in the studied area of DPA & Vadinar were Below Quantification Limit (0.009 mg/l) and hence well below the permissible limit as per Indian Standards are 0.3 mg/L.

### **Fluoride**

Fluoride value in the studied area of DPA varied between 0.11-0.40 mg/l and mean was 0.29 mg/l. The minimum value was 0.11 mg/ at E-Type Quarter and maximum was 0.40 mg/l at Tuna port while at Vadinar location fluoride ranged from 0.58-0.62 mg/l and mean was 0.60 mg/l. The Fluoride values were well below the permissible limit as per Indian Standards is 1.0-1.5 mg/L. Moderate amounts lead to dental effects, but long-term ingestion of large amounts can lead to potentially severe skeletal problems.

### **Sulphate**

Sulphate value in the studied area of DPA varied between 35.08- 62.64 mg/l and mean was 51.35 mg/l. The minimum value was 35.08 mg/ at School gopalpuri and maximum was 62.64 mg/l at Tuna port while at Vadinar location Sulphate ranged from 24.05- 25.06 mg/l and mean was 24.56 mg/l. All the sampling points showed Sulphate values within the prescribed limits by Indian Standards (200-400 mg/L). Sulphate content in drinking water exceeding the 400 mg/L imparts bitter taste.

### **Nitrites (NO<sub>2</sub>) and Nitrates (NO<sub>3</sub>)**

The all values of Nitrite were found BQL (<0.05 mg/l) and Nitrate were well within the permissible limit of the Drinking water Standard.

### **Salinity**

Salinity in drinking water in the present samples collected at DPA ranged from 0.21 ‰ F-type Quarter to 0.38 ‰ at Tuna port and average salinity was 0.29 ‰ while at Vadinar sampling location salinity ranged from 0.25-0.27 ‰. There are no prescribed Indian standards for salinity in Drinking water.

### **Sodium and Potassium Salts**

Sodium values in the samples collected at DPA ranged from 122.3-278.5 mg/l and average was 196.04 mg/l while at Vadinar sodium ranged from 199.10- 210.9 mg/l and average was 205.0 mg/l . Potassium salts ranged at DPA ranged from 3.34-5.64 mg/l while average was 3.99 mg/l while at Vadinar sampling locations potassium were BQL (<2.0 mg/l). There are no prescribed limits of Sodium and Potassium in Indian standards for Drinking water.

### **Heavy Metals in Drinking Water**

In the present study period drinking water samples were analyzed for Mn, Cr, Cu, Cd, As, Hg, Pb and Zn. All these heavy metals were well Below the Quantification limits prescribed by the Indian Standards.

### **Bacteriological Study**

Analysis of the bacteriological parameter (E-coli and total coliform) at all location shows that Bacteria were not detectable. This shows that drinking water samples were safe for human consumption as per tested parameters.

### **4.4 Conclusions**

These results were compared with permissible limits as prescribed in IS 10500:2012 – Drinking Water Specification. It was seen from the analysis data that during the study period at selected sampling location the water was safe for human consumption as per analyzed parameters at all drinking water monitoring stations.



## CHAPTER-5

### NOISE MONITORING

## 5.0 Noise Level Monitoring

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise Monitoring was done at 13 stations at Kandla, Vadinar and Township area.

### 5.1 Method of Monitoring

Sampling was done at all stations for 24-hour period. Data was recorded using automated sound level meter. The intensity of sound was measured in sound pressure level (SPL) and common unit of measurement is decibel (dB).

### 5.2 Results

**Table 18: Noise Monitoring data for ten locations of Deendayal Port and three locations of Vadinar Port**

Sr. No.	Location	Day Time Average Noise Level (SPL) in dB(A)	Night Time Average Noise Level (SPL) in dB(A)
	<b>Sampling Time</b>	<b>6:00 am to 10:00 PM pm</b>	<b>10:00PM to 6:00 AM</b>
1	Marine Bhavan	59.7	49.9
2	Nirman Building 1	68.5	50.0
3	Tuna Port	51.7	44.4
4	Main Gate North	61.4	48.8
5	West Gate I	68.1	54.2
6	Canteen Area	67.3	49.2
7	Main Road	68.6	51.4
8	ATM Building	65.8	47.1
9	Wharf Area /Jetty Area	69.8	60.7
10	Port & Custom Office	51.8	48.9
<b>Vadinar Port</b>			
11	Entrance Gate of Vadinar Port	54.0	49.5
12	Nr. Port Colony, Vadinar	61.2	55.9
13	Nr. Vadinar Jetty	53.4	49.0

### 5.3 Conclusions

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships.

Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level (SPL) in all 10 locations at Deendayal Port Authority ranged from 51.7 dB(A) to 69.8 dB(A) while at Vadinar port 3 location ranged from 53.4 dB(A) to 61.2 dB(A) which was within the permissible limits of 75 dB(A) for the industrial area for the daytime. The Night Time Average Noise Level (SPL) in all locations of Deendayal Port Authority ranged from 44.4 dB to 60.7 dB(A) while at Vadinar port ranged from 49.0 dB (A) to 55.9 dB(A) which was within the permissible limits of 70 dB(A) for the industrial area for the night time.

## CHAPTER-6

### SOIL MONITORING

## 6.0 Soil Monitoring

Sampling and analysis of soil samples were withintaken at six locations within the study area (Deendayal Port and Vadinar Port) as a part of EMP. The soil sampling locations are initially decided based on the locations as provided in the tender document of the Deendayal Port.

**Table No.:-19. Soil Sampling Location**

Sr. No.	Name of Location	Location Code	Latitude	Longitude	Remarks
1.	Tuna Port	SL-1	22° 58' 10.18"N	70° 6' 3.7"E	Near main gate of Port
2.	IFFCO Plant	SL-2	23° 26' 8.37"N	70° 13' 4.4"E	10 m away from main gate
3.	Khori creek	SL-3	22° 58' 10.18"N	70° 6' 3.7"E	Sand from creek after tide
4.	Nakti Creek	SL-4	23° 2' 1.10"N	70° 9' 33.6"E	
5.	DPA admin site	SL-5	22° 26' 30.9"N	69° 40' 37.03"E	Vadinar
6.	DPA colony	SL-6	22° 23' 57.09"N	69° 42' 49.42"E	

## 6.1 Methodology

The soil samples were collected in the 1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 of December 2022. The samples collected from the all locations are homogeneous representative of each location. At random locations were identified at each location and soil was dug from 30 cm below the surface. It was uniformly mixed before homogenizing the soil samples. The samples were filled in polythene bags, labeled in the field with number and site name and sent to laboratory for analysis.

## 6.2 Results

**Table-20: Chemical Characteristics of Soil in the Study Area for Tuna port, IFFCO, Khori Creek, Nakti Creek, DPA admin site, DPA colony.**

Sr. No.	Parameter	Unit	Station Name					
			SL1	SL2	SL3	SL4	SL5	SL6
			Tuna Port	IFFCO Plant	Khori Creek	Nakti Creek	DPA Admin Site	DPA Colony
			Near main gate of Port	10 m away from main	Sand from creek after tide		Vadinar	
1	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	pH	-	7.40	7.10	7.90	6.80	6.96	7.10
3	Electrical Conductivity	µs/cm	22700.0	10260.0	33,900.00	10,080.0	307.0	389.0
4	Phosphorus	mg/kg	8	9.2	8.60	7.40	3.20	4.10
5	Moisture	%	2.2	2.9	1.40	2.50	3.20	4.32
6	Total Organic Carbon	%	3.8	1.6	2.80	4.20	1.80	2.00
7	Alkalinity	mg/kg	900.0	700.0	800.0	400.0	400.0	600.0
8	Total Nitrogen	%	BQL	BQL	BQL	BQL	BQL	BQL
9	Sulphate	mg/kg	790.00	888.00	972.00	752.00	46.0	59.0
10	Chloride	mg/kg	10582.0	4280.0	13,200.00	3,000.00	120.00	142.00
11	Calcium	mg/kg	1,042.00	1,709.00	6,813.00	3,206.00	1,444.00	1,468.00
12	Sodium	mg/kg	1711	1255.0	2,820.00	2,451.00	30.00	36.00
13	Potassium	mg/kg	591	634	707.00	416.00	4.60	5.60
14	Copper as Cu	mg/kg	28.8	39.2	21.60	12.40	63.80	74.10
15	Lead as Pb	mg/kg	25.1	7.8	10.90	BQL	BQL	BQL
16	Nickel as Ni	mg/kg	32.70	35.20	20.50	20.90	16.20	36.00
17	Zinc as Zn	mg/kg	81.3	78.40	150.90	35.10	20.60	81.30
18	Cadmium as Cd	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, ( TN: 0.001%, Cd: 1.0mg/kg)

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### 6.3 Discussion

- DPA Kandla soil sampling data shows that value of pH ranges from 6.8 at Natki Creek to 7.90 at Khari Creek while the average value of pH was 6.96 at DPA colony and 7.10 at DPA Admin Site in Vadinar sampling location
- The Electrical Conductivity of DPA Kandla soil sample ranged from 10080.0  $\mu\text{S}/\text{cm}$  at Nakti Creek (Sand from creek after tide) to 33900.0  $\mu\text{S}/\text{cm}$  at Khari creek and mean was 19235.0  $\mu\text{S}/\text{cm}$  while Vadinar soil sampling location conductivity were 307.0  $\mu\text{S}/\text{cm}$  at DPA Admin Site and 389.0  $\mu\text{S}/\text{cm}$  at DPA Colony site.
- Total organic Carbon of DPA Kandla soil sample ranged from 1.6 % at IFFCO Plant to 4.20 % at Nakti Creek (Sand from creek after tide) and mean was 3.10 % while Vadinar soil sample were 2.0 % at DPA Colony and 1.80 % at DPA admin Site.
- The concentration of Phosphorus in the soil samples of DPA Kandla varies from 7.40 mg/kg at Nakti Creek (Sand from creek after tide) and 9.20 mg/kg at IFFCO Plant and mean was 8.30 mg/kg while the Vadinar soil sample for Phosphorus were 4.10 mg/kg at DPA Colony and 3.20 mg/kg at DPA Admin Site.
- Chloride in soil sample of DPA ranged from 3000.00 mg/kg at Nakti Creek (Sand from creek after tide) to 13200 mg/kg at Khari creek and mean was 7765.50 mg/kg while Vadinar soil sample were 140 mg/kg at DPA admin and 525 mg/kg at DPA Colony.
- The Concentration of Potassium in the soil samples of DPA Kandla ranged from 416 mg/kg at Nakti creek and 707 mg/kg at Khori Creek and mean was 587.0 mg/kg while the Vadinar soil sample for Potassium were 5.6 mg/kg at DPA Colony Site and 4.60 mg/kg at DPA Admin Site.
- The concentration of Sodium in the soil samples of DPA Kandla ranged from 1255.0 mg/kg at IFFCO plant and 2820.0 mg/kg at Khori Creek and mean was 2059.25 mg/kg while the Vadinar soil sample for Sodium were 36.00 mg/kg at DPA Admin Site and 30.0 mg/kg at DPA Colony.

These differences in NPK in soil at different locations are due to the dissimilar nature of soil at each of the locations. Samples SL# & SL4 (Khori Creek & Nakti Creek) where coastal soil; where as other locations are inland locations and have different chemical properties.

### Heavy Metals in the Soil

Traces of Copper, Lead, Nickel and Zinc were observed in the soil samples collected from all the four locations of Deendayal Port Authority Kandla and two locations of Vadinar Port. Cadmium metal was below detection limit in the Soil.

### 6.4 Conclusion

The soils of Deendayal Port Authority Kandla and Vadinar Port appears to be neutral to basic with varying levels of Chloride, Sulphate, NPK and Calcium. As the nature of soil at different locations are different with respect to its proximity to the sea, the samples showed high degree of variations in their chemical properties.

## **CHAPTER-7**

### **SEWAGE TREATMENT PLANT MONITORING**



## 7.0 Sewage Treatment Plant Monitoring

This involves safe collection of waste water (spent/used water) from wash areas, bathroom, industrial units, etc., waste from toilets of various buildings and its conveyance to the treatment plant and final disposal in conformity with the requirement and guidelines of State Pollution Control Board and other statutory bodies.

### 7.1 Methodology for STP Monitoring

To monitor the working efficiency of Sewage Treatment Plant (STP), STP Inlet and Outlet Samples were collected once a week. Locations selected are namely Gopalpuri Township, Deendayal Port and Vadinar. Samples were collected in 1 lit. Carboys and were analyzed in laboratory for various parameters.

A new STP with an improved capacity of 1 MLD is being constructed at Gopalpuri Colony.

**Table No. 21. Sewage Treatment Plant**

Sr. No.	Location of STP	Types of Treatment	STP Capacity	Treated water Utilization
1.	Gopalpuri Township	MBBR	450 KLD	Plantation and Gardening
2.	Deendayal Port, Kandla	MBBR	600 KLD	Discharge to marine through pipeline, Plantation, Gardening
3.	Vadinar Port Colony	MBBR	1.5 MLD	Plantation and Gardening

## 7.2 Results

**Table 22: Sewage Water Monitoring at Kandla STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	03.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.46	7.62	6.5 - 8.5
2	Total Suspended Solids	mg/l	92	32	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	168	40.0	100
5	BOD @ 27 °C	mg/l	34.0	13.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	88.0		
7	MLVSS	%	97.0		

**Table 23: Sewage Water Monitoring at Kandla STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	09.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.49	7.66	6.5 - 8.5
2	Total Suspended Solids	mg/l	82.0	37.0	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	120.0	50.0	100
5	BOD @ 27 °C	mg/l	37.0	16.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	56.0		
7	MLVSS	%	85.0		

**Table 24: Sewage Water Monitoring at Kandla STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	15.12.2022
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Sr. No.	Parameters	Unit	Results		CPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.14	7.09	6.5 - 8.5
2	Total Suspended Solids	mg/l	84.0	32.0	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	110.0	30	100
5	BOD @ 27 °C	mg/l	29.0	8.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	14.0		
7	MLVSS	%	92.0		

**Table 25: Sewage Water Monitoring at Gopalpuri STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	03.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.32	7.56	6.5 - 8.5
2	Total Suspended Solids	mg/l	80	58	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	109	79	100
5	BOD @ 27 °C	mg/l	31.0	21.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	56.5		
7	MLVSS	%	85.0		

**Table 26: Sewage Water Monitoring at Gopalpuri STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	09.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			DPA STP I/L	DPA STP O/L	
1	pH	-	7.49	7.66	6.5 - 8.5
2	Total Suspended Solids	mg/l	96	20	100
3	Residual Chlorine	mg/l		<0.5	-
4	COD	mg/l	120	50.0	100
5	BOD @ 27 °C	mg/l	37.0	16.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	30.0		
7	MLVSS	%	87.0		

**Table 27: Sewage Water Monitoring at Gopalpuri STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	15.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Gopalpuri STP I/L	Gopalpuri STP O/L	
1	pH	-	7.46	7.52	6.5 - 8.5
2	Total Suspended Solids	mg/l	96.0	42.0	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	109.0	50.0	100
5	BOD @ 27 °C	mg/l	33.0	16.0	30
<b>Aeration Tank</b>					
6	MLSS	mg/l	45.0		
7	MLVSS	%	87.0		

**Table 28: Sewage Water Monitoring at Vadinar STP (1<sup>st</sup> Week)**

<b>Date of Sampling</b>	03.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.49	7.30	6.5 - 8.5
2	Total Suspended Solids	mg/l	54.0	26.0	100
3	Residual Chlorine	mg/	-	<0.5	-
4	COD	mg/l	60.0	30.0	100
5	BOD @ 27 °C	mg/l	18.0	8.0	30

**Table 29: Sewage Water Monitoring at Vadinar STP (2<sup>nd</sup> Week)**

<b>Date of Sampling</b>	09.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar STP O/L	
1	pH	-	7.38	7.28	6.5 - 8.5
2	Total Suspended Solids	mg/l	39.6	20.3	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	50.0	30.0	100
5	BOD @ 27 °C	mg/l	12.0	6.0	30

**Table 30: Sewage Water Monitoring at Vadinar STP (3<sup>rd</sup> Week)**

<b>Date of Sampling</b>	15.12.2022
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Sr. No.	Parameters	Unit	Results		GPCB Prescribed Limit
			Vadinar STP I/L	Vadinar O/L	
1	pH	-	7.31	7.29	6.5 - 8.5
2	Total Suspended Solids	mg/l	58.6	36.0	100
3	Residual Chlorine	mg/l	-	<0.5	-
4	COD	mg/l	60.0	40.0	100
5	BOD @ 27 °C	mg/l	24.0	12.0	30

**Table No. 31. General Standards for discharge of Environmental Pollutant Part-A**

Sr. No.	Parameter	Inland Surface Water	Land Irrigation	Marine Coastal Areas
1.	pH	5.5-9.0	5.5-9.0	5.5-9.0
2.	Total Suspended Solids (mg/l)	100	200	100
3.	Residual Chlorine (mg/l)	1.0	-	1.0
4.	BOD (mg/l)	30	100	100
5.	COD (mg/l)	250	-	250

Source:CPCB

### 7.3 Results & Discussion

The STP Sample carried out to evaluate the efficiency and performance of the wastewater treatment plant at Gopalpuri, Kandla and Vadinar STP. The performance of these plants is an essential parameter to monitor because the treated sewage water is discharged for irrigation purposes and discharge into marine. Wastewater samples were collected from different unit operations of the plant i.e, the inlet, aeration tank and the final treated outlet. These samples were analyzed for various physico-chemical characteristics such as pH, TSS, Residual Chlorine, COD, BOD, MLSS and MLVS.

The final treated outlet observed pH values were within the allowed range at STP Gopalpuri, STP Kandla & STP Vadinar ranged from 7.32-7.63, 7.39-7.66 & 7.28-7.49 respectively. The wastewater treatment makes it suitable for irrigation. These values are below the allowed limit of the GPCB. The final treated outlet observed Total suspended solid values at Gopalpuri, DPA Kandla & Vadinar ranged from 20.0-58.0 mg/l, 32.0-57.0 mg/l & 20.30-36.0 mg/l respectively. These values are below the allowed limit of the GPCB. The final treated outlet observed Residual Chlorine values were <0.5 at Gopalpuri, DPA Kandla & Vadinar. These values are below the allowed limit of the CPCB. The final treated outlet observed COD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 30.0-79.0 mg/l, 30.0-50.0 mg/l & 30.0-40.0 mg/l respectively. These values are below the allowed limit of the CPCB. The main focus of wastewater treatment plants is supposed to reduce the BOD in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The final treated outlet observed BOD values were at Gopalpuri, DPA Kandla & Vadinar ranged from 7.01-21.0 mg/l, 8.0-16.0 mg/l & 6.0-12.0 mg/l respectively. These values are below the allowed limit of the GPCB.

**7.4 Conclusions:** All parameters for STP outlet are within limit prescribed by CPCB. After the final treatment, it is found that the treated water is satisfactory.

## **CHAPTER-8**

### **MARINE WATER MONITORING**



## **8.0 Marine Water Monitoring**

### **Marine Water Quality**

The Forty Second Amendment to the Constitution in 1976 within scored the importance of ‘green thinking’. Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the “fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”.

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making. The National Conservation Strategy and Policy Statement on Environment and Development, (1992) aimed at “integrating environmental concerns with developmental imperatives to meet the challenges by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources.” The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, (2002) contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives.

### **Sampling Stations**

The monitoring of marine environment for the study of biological and ecological parameters was carried out on 05<sup>th</sup> & 06<sup>th</sup> October-2022 in harbor regions of DPA & Vadinar during Neap tide period of New moon phase of Lunar Cycle. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 12<sup>th</sup> & 16<sup>th</sup> October-2022 in harbor regions of DPA & Vadinar during Spring tide period first quarter of Lunar Cycle.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbor area and two stations in Nakti creek and one station in Khorī creek. The same sampling schedule was repeated during consecutive spring tide and neap tide in same 1st December 2022 to 15th December 2022. Plankton samples from sub surface layer was collected both during high tide period and low tide period from 1 water quality monitoring stations near Vadinar jetty area during spring tide and neap tide in this 1st December

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2022 to 15th December 2022. Collected water samples were processed for estimation of Chlorophyll-a, Pheophytin-a, qualitative & quantitative evaluation of phytoplankton, qualitative & quantitative evaluation zooplanktons (density and their population).

#### Sampling Locations

Offshore monitoring requirement	Number of locations
Offshore Installations	3 in Kandla creek 2 in Nakti creek 1 in Khorī creek 1 near Vadinar Jetty 1 near 1 <sup>st</sup> SBM
<b>Total Number of locations</b>	<b>8</b>

#### 8.1 Marine Water Quality and Results

Marine water quality of marine waters of Deendayal Port Harbor waters, Khorī & Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each 1st December 2022 to 15th December 2022. The results of marine water quality from table no 32 to 39. During low tide DPA-6 Nakti-II location monitoring was not possible due to non-availability of marine water.

**Table 32: Marine Water Quality Monitoring Parameters for Location Near DPA Colony**

Sr. No.	Parameters	Unit	Kandla Creek Near DPA Colony (1)			
			23°0'58"N 70°13'22."E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.40	7.51	7.48	7.39
2	Color	-	agreeable	agreeable	agreeable	agreeable
3	Odor	-	agreeable	agreeable	agreeable	agreeable
4	Salinity	‰	32.1	31.7	30.7	29.8
5	Turbidity	NTU	46	39	42	46
6	Total Dissolved Solids	mg/l	52377.7	48868.0	42202.0	47413.0
7	Total Suspended Solids	mg/l	500	437	406.1	709.1
8	Total Solids	mg/l	52878	49304	42608	48122
9	DO	mg/l	5.3	5.2	5.5	5.4
10	COD	mg/l	86.0	84.0	82.0	86.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	2.53	2.01	0.99	0.91
13	Phosphate	mg/l	0.11	0.13	0.09	0.04
14	Sulphate	mg/l	3019.2	2893.9	3708.0	3658
15	Nitrate	mg/l	3.19	3.61	0.75	0.42
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	601.20	681.36	681.36	801.6
18	Magnesium	mg/l	1676.7	1555.2	1652.4	1628.1
19	Sodium	mg/l	9901.0	8291.0	8396.0	8699.0
20	Potassium	mg/l	316.2	310.2	391.0	395.0
21	Iron	mg/l	BQL	BQL	0.88	0.57
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 33: Marine Water Quality Monitoring Parameters for Location Near Passenger Jetty One at Kandla**

Sr. No.	Parameters	Unit	Near passenger Jetty One (2)			
			23° 0'18 "N 70°13'31"E			
			Spring Tide		Neap Tide	
	Tide		High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.42	7.39	7.52	7.33
2	Color	-	agreeable	agreeable	agreeable	agreeable
3	Odor	-	agreeable	agreeable	agreeable	agreeable
4	Salinity	‰	31.2	33.9	31.6	32.0
5	Turbidity	NTU	40	43	40	38
6	Total Dissolved Solids	mg/l	47345	53023	49279	47973
7	Total Suspended Solids	mg/l	351	663	860.9	976.8
8	Total Solids	mg/l	47696	53686	50140	48950
9	DO	mg/l	5	4.9	5.2	5
10	COD	mg/l	92.0	90.0	90.0	92.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.14	1.60	1.33	0.85
13	Phosphate	mg/l	0.34	0.16	0.33	0.19
14	Sulphate	mg/l	3006.7	4146.7	4072	3407
15	Nitrate	mg/l	12.18	3.52	1.17	4.36
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	641.28	601.20	641.28	601.2
18	Magnesium	mg/l	1749.6	1555.2	1725.3	1701
19	Sodium	mg/l	8871.0	7582.0	9247.0	9219.0
20	Potassium	mg/l	299.1	334.3	370.0	380.0
21	Iron	mg/l	0.47	BQL	1.76	0.30
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Nitrite: 0.05mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 34: Marine Water Quality Monitoring Parameters for location Near Coal Berth**

Sr. No.	Parameters	Unit	Near Coal Berth			
			22°59'12"N 70°13'40"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.52	7.32	7.58	7.66
2	Color	-	agreeable	agreeable	agreeable	agreeable
3	Odor	-	agreeable	agreeable	agreeable	agreeable
4	Salinity	‰	32.6	32.1	30.7	32.5
5	Turbidity	NTU	49	50	36	42
6	Total Dissolved Solids	mg/l	51431	49900	52201	47319
7	Total Suspended Solids	mg/l	469	550	624.8	821
8	Total Solids	mg/l	51900	50450	52826	48140
9	DO	mg/l	4.8	4.7	4.9	5.2
10	COD	mg/l	80.0	78.0	88.0	84.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.82	0.12	0.69	1.76
13	Phosphate	mg/l	0.31	0.64	0.12	0.61
14	Sulphate	mg/l	2731.1	1804	2981	3758
15	Nitrate	mg/l	7.64	4.70	2.68	4.70
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	721.44	561.12	761.52	561.12
18	Magnesium	mg/l	1530.9	1701	1701	1798.2
19	Sodium	mg/l	5451.0	7757.0	9245.0	9814.0
20	Potassium	mg/l	199.1	252.5	392.0	384.0
21	Iron	mg/l	BQL	BQL	BQL	1.34
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 35: Marine Water Quality Monitoring Parameters for location Khori creek at Kandla**

Sr. No.	Parameters	Unit	Khori creek			
			Near 15/16 Berth			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.39	7.36	7.53	7.42
2	Color	-	agreeable	agreeable	agreeable	agreeable
3	Odor	-	agreeable	agreeable	agreeable	agreeable
4	Salinity	‰	33.5	31.7	30.3	30.7
5	Turbidity	NTU	42	44	40	46
6	Total Dissolved Solids	mg/l	52753	43459	46336	57920
7	Total Suspended Solids	mg/l	549	687	705.5	878
8	Total Solids	mg/l	53302	44146	47042	58798
9	DO	mg/l	4.6	5.1	5	4.8
10	COD	mg/l	90.0	94.0	92.0	96.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.72	2.61	1.39	1.18
13	Phosphate	mg/l	0.45	0.47	0.35	0.42
14	Sulphate	mg/l	2092.1	2555.7	3157	3170
15	Nitrate	mg/l	3.52	5.29	1.34	5.20
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	681.36	721.44	681.36	601.2
18	Magnesium	mg/l	1530.9	1628.1	1676.7	1701
19	Sodium	mg/l	6525.0	7297.0	7966.0	8696.0
20	Potassium	mg/l	308.1	296.8	382.0	377.0
21	Iron	mg/l	0.44	BQL	0.17	0.31
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	0.02
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 36: Marine Water Quality Monitoring Parameters for location Nakti Creek near Tuna Port**

Sr. No.	Parameters	Unit	Nakti Creek Near Tuna Port			
			22°57'49."N 70° 7'0.67"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.48	7.44	7.53	7.41
2	Color	-	agreeable	agreeable	agreeable	agreeable
3	Odor	-	agreeable	agreeable	agreeable	agreeable
4	Salinity	‰	32.1	33.9	33.3	32.9
5	Turbidity	NTU	49	43	49	38
6	Total Dissolved Solids	mg/l	49694.3	56539	39315	41219
7	Total Suspended Solids	mg/l	424	421	406.8	768.7
8	Total Solids	mg/l	50118	56960	39722	41988
9	DO	mg/l	5.2	5	4.7	5.1
10	COD	mg/l	100.0	96.0	98.0	100.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	1.62	1.26	1.42	1.22
13	Phosphate	mg/l	0.41	0.11	0.46	0.12
14	Sulphate	mg/l	2718.5	3232.2	3445	3433
15	Nitrate	mg/l	2.85	2.68	5.12	1.69
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	521.04	480.96	801.6	641.28
18	Magnesium	mg/l	1798.2	1725.3	1628.1	1701
19	Sodium	mg/l	7075.0	8162.0	8655.0	7939.0
20	Potassium	mg/l	352.1	374.1	384.0	386.0
21	Iron	mg/l	BQL	0.33	0.34	0.18
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l,BOD-2.0 mg/l,Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l,Zinc-0.1 mg/l).

**Table 37: Marine Water Quality Monitoring Parameters for location Nakti Creek Near NH-8A at Kandla**

Sr. No.	Parameters	Unit	Nakti Creek Near NH-8A			
			23° 02'01"N 70° 09'31"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.58	Sampling not possible during Low Tide	7.48	Sampling not possible during Low Tide
2	Color	-	agreeable		agreeable	
3	Odor	-	agreeable		agreeable	
4	Salinity	‰	33.0		32.5	
5	Turbidity	NTU	40		42	
6	Total Dissolved Solids	mg/l	46423		57638	
7	Total Suspended Solids	mg/l	787		495.9	
8	Total Solids	mg/l	47210		58134	
9	DO	mg/l	4.8		4.8	
10	COD	mg/l	100.0		110.0	
11	BOD	mg/l	BQL		BQL	
12	Silica	mg/l	1.56		0.16	
13	Phosphate	mg/l	0.35		0.46	
14	Sulphate	mg/l	3507.8		4961	
15	Nitrate	mg/l	5.71		3.52	
16	Nitrite	mg/l	BQL		BQL	
17	Calcium	mg/l	601.20		681.36	
18	Magnesium	mg/l	1579.5		1725.3	
19	Sodium	mg/l	9287.0		8528.0	
20	Potassium	mg/l	364.5		427.0	
21	Iron	mg/l	BQL		0.54	
22	Chromium	mg/l	BQL		BQL	
23	Copper	mg/l	BQL		BQL	
24	Arsenic	mg/l	BQL		BQL	
25	Cadmium	mg/l	BQL		0.01	
26	Mercury	mg/l	BQL		BQL	
27	Lead	mg/l	BQL		BQL	
28	Zinc	mg/l	BQL		BQL	

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

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**Table 38: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar Jetty**

Sr. No.	Parameters	Unit	Nr.Vadinar Jetty			
			22°26'25.26"N 69°40'20.41"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.49	7.39	7.59	7.54
2	Color	-	agreeable	agreeable	agreeable	agreeable
3	Odor	-	agreeable	agreeable	agreeable	agreeable
4	Salinity	‰	32.6	33.5	31.2	31.6
5	Turbidity	NTU	37	45	40	39
6	Total Dissolved Solids	mg/l	53031	53126	46806	40112
7	Total Suspended Solids	mg/l	377	348	316.3	330.1
8	Total Solids	mg/l	53408	53474	47122	40442
9	DO	mg/l	4.6	4.5	4.9	5.1
10	COD	mg/l	98.0	96.0	96.0	92.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.38	0.55	0.36	0.28
13	Phosphate	mg/l	0.15	0.11	0.33	0.19
14	Sulphate	mg/l	2956.6	3232.2	3683	3645
15	Nitrate	mg/l	1.51	1.85	1.00	2.43
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	721.44	561.12	721.44	561.12
18	Magnesium	mg/l	1458	1506.6	1652.4	1798.2
19	Sodium	mg/l	7157.0	8212.0	7810.0	8912.0
20	Potassium	mg/l	318.3	317.4	452.0	456.0
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.30	BQL	0.77	0.45

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l).

**Table 39: Marine Water Quality Monitoring Parameters for locations Nr. Vadinar SPM**

Sr. No.	Parameters	Unit	Nr. Vadinar SPM			
			22°30'56.15"N 69°42'12.07"E			
			Spring Tide		Neap Tide	
			High Tide	Low Tide	High Tide	Low Tide
1	pH	-	7.30	7.22	7.56	7.44
2	Color	-	agreeable	agreeable	agreeable	agreeable
3	Odor	-	agreeable	agreeable	agreeable	agreeable
4	Salinity	‰	31.7	32.6	32.9	32.5
5	Turbidity	NTU	42	48	46	48
6	Total Dissolved Solids	mg/l	53437	51595	44012	54136
7	Total Suspended Solids	mg/l	283	281	348.1	364.1
8	Total Solids	mg/l	53720	51876	44360	54500
9	DO	mg/l	4.7	4.5	5.4	5.3
10	COD	mg/l	98.0	100.0	96.0	94.0
11	BOD	mg/l	BQL	BQL	BQL	BQL
12	Silica	mg/l	0.44	0.24	0.34	0.30
13	Phosphate	mg/l	0.10	0.12	0.46	0.28
14	Sulphate	mg/l	3094.4	3608	3745	4008
15	Nitrate	mg/l	4.70	2.77	4.95	2.10
16	Nitrite	mg/l	BQL	BQL	BQL	BQL
17	Calcium	mg/l	801.60	681.36	641.28	721.44
18	Magnesium	mg/l	1433.7	1482.3	1676.7	1603.8
19	Sodium	mg/l	6329.0	6047.0	9131.0	8526.0
20	Potassium	mg/l	329.1	307.7	413.0	441.0
21	Iron	mg/l	BQL	BQL	BQL	BQL
22	Chromium	mg/l	BQL	BQL	BQL	BQL
23	Copper	mg/l	BQL	BQL	BQL	BQL
24	Arsenic	mg/l	BQL	BQL	BQL	BQL
25	Cadmium	mg/l	BQL	BQL	BQL	BQL
26	Mercury	mg/l	BQL	BQL	BQL	BQL
27	Lead	mg/l	BQL	BQL	BQL	BQL
28	Zinc	mg/l	0.25	BQL	0.50	BQL

BQL- Below Quantification Limit, (Nitrite - 0.05 mg/l, BOD-2.0 mg/l, Cu-0.1 mg/l, As-0.1mg/l, Hg-0.01 mg/l, Zinc-0.1 mg/l)

## **8.2 Results & Discussion for Marine water samples**

Marine water quality of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each 1<sup>st</sup> December 2022 to 15th December 2022. The Heavy metal analyzed and mostly found below quantification limit.

### **pH**

During spring tide, the pH values was ranged from 7.32-7.58 at DPA Kandla and 7.22-7.49 at Vadinar while during Neap Tide pH values was ranged from 7.33-7.66 at DPA Kandla and 7.44-7.59 at Vadinar.

### **Color and Odor**

All marine samples for Odor and Color were found agreeable at all sampling locations.

### **Turbidity**

During spring tide, the Turbidity values was ranged from 39-50 NTU at DPA Kandla and 37-48 NTU at Vadinar while during Neap Tide Turbidity values was ranged from 36-49 NTU at DPA Kandla and 39-48 NTU at Vadinar. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity (Yap et al, 2011). Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and microscopic organisms (Lawler, 2004). The turbidity affects the amount of light penetrating to the plants for photosynthesis.

### **Total Dissolved Solids (TDS)**

TDS values in the studied area during Spring Tide varied between 43458.90–56539.50 mg/l at DPA Kandla and 51594.70–53436.70 mg/l at Vadinar while during Neap Tide TDS values was varied 39315.0-57920.0 mg/l at DPA Kandla and 40111.90–54135.90 mg/l at Near Vadinar.

### **Calcium**

Calcium value in the studied area during Spring Tide varied between 480.96-721.44mg/l at DPA Kandla and 561.12-801.60 mg/l at Vadinar while during Neap Tide calcium values between 561.12-801.60 mg/l at DPA Kandla and 561.12-721.44mg/l at Vadinar.

### **Magnesium**

Magnesium value in the studied area during Spring Tide varied between 1530.90-1798.20 mg/l at DPA Kandla and 1433.70-1506.60 mg/l at Vadinar while during Neap Tide magnesium values between 1628.10-1798.20 mg/l at DPA Kandla and 1603.80-1798.20 at Vadinar. Calcium and magnesium both play an important role in antagonizing the toxic effects of various ions and neutralizing the excess acid produced (Narayan R. et. al., 2007)

### **Nitrate**

Nitrate value in the studied area during Spring Tide varied between 2.68-12.18 mg/l at DPA Kandla and 1.51-4.70 mg/l at Vadinar while during Neap Tide Nitrate values between 0.42-5.2 mg/l at DPA Kandla and 1.0-4.95 at Vadinar.

The variations were observed due to variation in phytoplankton excretion, oxidation of ammonia, reduction of nitrate and by recycling of nitrogen and bacterial decomposition of planktonic detritus (Asha and Diwakar, 2007).

### **Iron**

Iron values in the studied area during Spring Tide ranged from 0.33-0.47 mg/l at DPA Kandla and at Vadinar were BQL (<0.10) while during Neap Tide Iron values ranged from 0.17-1.76 mg/l at DPA Kandla and 0.24-0.31 mg/l at Vadinar.

### **Sulphates**

Sulphate values in the studied area during Spring Tide ranged from 1804-4146.70 mg/l at DPA Kandla and 2956-3608.0 mg/l at Vadinar while during Neap Tide the Sulphate values was varied 2981-4961 mg/l at DPA Kandla and 3645-4008mg/l at Vadinar.

### **Salinity**

Salinity values in the studied area during Spring Tide varied ranged 31.23-33.95 ‰ at DPA Kandla and 31.69 to 33.50 ‰ at Vadinar while during Neap Tide the Salinity values was varied 29.84 to 33.35 ‰ at DPA Kandla and 31.15 to 32.91 ‰ at Vadinar.

### **Sodium and Potassium Salts**

During Spring Tide the Sodium values ranged from 5451-9901.0 mg/l at DPA Kandla & 6047.0-8212.0 mg/l at Vadinar and Potassium salts ranged from 199-374.10mg/l at DPA Kandla & 307.70-329.10mg/l at Vadinar while during Neap Tide the Sodium values was

ranges from 7939-9814 mg/l at DPA Kandla & 7810-9131 mg/l at Vadinar and Potassium salts ranged from 370-427 mg/l at DPA Kandla & 413-456 mg/l at Vadinar.

## **DO**

The DO refers to the amount of oxygen dissolved in the water and it is particularly important in limnology {(aquatic ecology) (Weiss 1970)}. The fate and behavior of DO is of critical importance to marine organisms in determining the severity of adverse impacts (Best et al. 2007). The major factor controlling dissolved oxygen concentration is biological activity: photosynthesis producing oxygen while respiration and nitrification consume oxygen (Best et al. 2007). From the studied samples, DO in marine water during Spring Tide was found in ranges from 4.6-5.30 mg/l at DPA Kandla and 4.50-4.70 mg/l at Vadinar while during Neap Tide 4.70-5.50 mg/l at DPA Kandla and 4.90-5.40 mg/l at Vadinar.

## **BOD**

BOD in marine water at all sampling location in the studied samples were found BQL (<2.0 mg/l).

## **Heavy Metals in Marine Water**

In the present study period marine water samples were analyzed for Cr, Cu, Cd, As, Hg, Pb and Zn. Maximum heavy metals parameters were well Below the Quantification limits.

## **9.3 Conclusion**

In the present study period marine water samples were analyzed and found inline as per Primary Water Quality criteria for class-IV WATERS (For Harbour Waters).

## CHAPTER-9

### MARINE SEDIMENT MONITORING

## 9.0 Marine Sediments

The deep-sea ocean floor is made up of sediment. This sediment is composed of tiny particles such as fine sand, silt, clay, or animal skeletons that have settled on the ocean bottom. Over long periods of time, some of these particles become compressed and form stratified layers. Scientists that study these layers look at particle size, particle composition, and origin to help them create historical records of the deep ocean floor. This process is called weathering. Weathering can be either mechanical or chemical. Mechanical weathering can occur as ice, wind, or water wears away the rock's surface. Chemical weathering can occur as rocks are dissolved by a chemical such as acid rain. The particles created as a result of weathering are called terrigenous sediments. These particles are transported to the ocean by wind and by rivers and streams. Once the particles enter the ocean, they are dispersed by waves, currents, and tides. The heaviest and largest particles that reach the oceans, such as sand, settle very quickly to the bottom as a result of gravity. Sand is deposited near the coast whereas the smaller silt and clay particles are transported farther distances offshore before they settle to the bottom. Sediments are an important component of aquatic ecosystems because they provide nutrients and habitat for aquatic organisms (Benhamed et al. 2016). However, human activities result in accumulation of toxic substances such as heavy metals in marine sediments. Heavy metals are well-known environmental pollutants due to their toxicity, persistence in the environment, and bioaccumulation. Metals affect the ecosystem because they are not removed from water by self-purification, but accumulate in sediments and enter the food chain (Astakhov et al. 2015).

Sediment samples were collected with Van Veen Grab from the six locations in Kandla Port Waters and two locations in Vadinar Port. Benthic surface grab samplers look like giant metal jaws. They dig into the bottom and take a bite of the sediment. These samplers are good for collecting softer, sandy or silty sediments that do not contain rocks. A box corer is a cross between a surface sampler and a sediment corer. It is a special device that is used to collect an undisturbed sample of the very top surface layers and the sediment withineath. Samples were collected and preserved in silver foil in ice box to prevent the contamination/decaying of the samples.





## 10.1 Results

The Sediment Quality results are given in below from table no. 40 & 41.

**Table 40: Results of Analysis of Sediment of Kandla & Vadinar Port (Neap Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	0.93	0.70	0.86	0.73	0.40	0.64	0.76
3	Organic Carbon	mg/kg	0.37	0.44	0.54	0.40	0.50	0.37	0.44
4	Inorganic Phosphate	mg/kg	98.00	101.00	80.00	86.00	100.00	90.00	94.00
5	Moisture	%	22.80	12.40	16.00	18.80	20.24	21.10	24.50
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	6.80	7.20	6.40	7.10	6.20	7.00	8.20
8	Phosphate	mg/kg	11.23	14.49	18.16	10.07	10.45	100.00	197.00
9	Sulphate	mg/kg	740.00	823.00	590.00	463.00	496.00	800.00	390.00
10	Nitrite	mg/kg	0.12	0.10	0.11	0.12	0.11	0.11	0.11
11	Nitrate	mg/kg	1.11	3.8	19.01	26.6	36.1	BQL	BQL
12	Calcium	mg/kg	1442.00	2125.00	1844.00	1783.00	1623.00	1783.00	2204.00
13	Magnesium	mg/kg	1178.00	1968.00	1628.00	1603.00	874.00	1530.00	1931.00
14	Sodium	mg/kg	3434.00	4319.00	1656.00	2860.00	2525.00	3493.00	3231.00
15	Potassium	mg/kg	486.0	520.0	436.0	520.0	102.0	595.00	701.00
16	Chromium	mg/kg	56.30	44.30	42.60	52.00	41.40	64.00	43.10
17	Nickel	mg/kg	25.00	20.90	18.30	24.30	19.20	31.10	18.30
18	Copper	mg/kg	14.20	11.90	11.50	13.30	11.40	26.20	14.30
19	Zinc	mg/kg	40.30	38.40	29.10	37.50	36.40	44.10	30.10
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Lead	mg/kg	4.70	4.20	3.80	5.80	3.90	4.60	4.80
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0mg/kg, Cd: 1.0mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg).

**Table 41 : Results of Analysis of Sediment of Kandla & Vadinar Port (Spring Tide)**

Sr. No.	Parameters	Unit	DPA – 1	DPA - 2	DPA - 3	DPA - 4	DPA - 5	Jetty	SPM
1	Texture	-	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
2	Organic Matter	mg/kg	1.13	0.66	0.76	0.76	1.13	1.33	1.04
3	Organic Carbon	mg/kg	0.65	0.38	0.44	0.4	0.65	0.77	0.60
4	Inorganic Phosphate	mg/kg	92.00	80.00	100.00	89.00	106.00	96.00	100.00
5	Moisture	%	4.20	6.00	3.20	1.80	2.60	3.30	4.20
6	Aluminum	mg/kg	ND	ND	ND	ND	ND	ND	ND
7	Silica	mg/kg	7.00	6.80	7.20	6.40	8.80	9.60	10.00
8	Phosphate	mg/kg	620.00	542.00	444.00	682.00	481.00	510.00	600.00
9	Sulphate	mg/kg	810.00	648.00	498.00	333.00	421.00	658.00	398.00
10	Nitrite	mg/kg	0.11	0.12	0.10	0.11	0.11	0.10	0.11
11	Nitrate	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12	Calcium	mg/kg	2104.00	2184.00	2364.00	1783.00	2184.00	1783.00	1663.00
13	Magnesium	mg/kg	1798.00	2320.00	1652.00	2876.00	1931.00	1530.00	1615.00
14	Sodium	mg/kg	1711.00	1255.00	2820.00	2451.00	1430.00	309.00	258.00
15	Potassium	mg/kg	41.30	414.20	55.70	518.70	165.20	143.0	110.0
16	Chromium	mg/kg	52.30	34.20	75.50	60.00	42.30	62.90	54.50
17	Nickel	mg/kg	26.80	17.70	41.10	31.50	21.70	31.50	28.30
18	Copper	mg/kg	11.90	9.30	19.00	14.50	10.40	18.30	15.20
19	Zinc	mg/kg	36.90	32.90	58.50	49.00	29.10	45.40	56.20
20	Cadmium	mg/kg	BQL	BQL	BQL	BQL	BQL	0.30	BQL
21	Lead	mg/kg	4.80	3.70	9.60	7.00	5.50	6.40	6.10
22	Mercury	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Arsenic	mg/kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL

\*ND - Not Detected, BQL: Below Quantification Limit (NO<sub>3</sub>:10.0 mg/kg, Cd: 1.0 mg/kg, Hg: 1.0mg/kg, As: 1.0mg/kg)

## **9.2 Discussion of Marine Sediment samples**

Marine Sediments of Deendayal Port Harbor waters, Khorī and Nakti Creeks and two locations of Vadinar are monitored for various physico-chemical parameters during spring and neap tide of each 1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022. The Heavy metal analyzed and found below quantification limit.

## **9.3 Conclusion**

The sediment types are majority Sandy loamy. Also, maximum heavy metals parameters found below Quantification limit wise, Pb, Cd, Hg, As, Nitrate and Al was not Detected.

## CHAPTER-11

### MARINE ECOLOGICAL MONITORING

## 10.0 INTRODUCTION:

**10.1 Sampling Stations:** The monitoring of marine environment for the study of biological and ecological Parameters was carried out on 01<sup>st</sup> December 2022 in harbour region of DPT at Kandla Creek, and on 02<sup>nd</sup> December 2022 in creeks near by the port during Neap tide. The monitoring of marine environment for the study of biological and ecological parameters was repeated again on 08<sup>th</sup> December, 2022 in harbour region of DPT at Kandla Creek and on 09<sup>th</sup> December, 2022 in creeks near by the port during spring tidal condition.

Plankton samples from sub surface layer was collected both during high tide period and low tide period from 3 water quality monitoring stations of DPA harbour area and two stations in Nakti creek and one station in Khori creek. Sampling at second sampling station of Nakti creek was possible only during high tide period.

Plankton samples from sub surface layer were collected during high tide period and low tide period from monitoring station near Vadinar jetty at Path Finder Creek during Neap tide on 01/12/2022 and Spring tide period on 08/12/2022. Collected water samples were processed for estimation of Chlorophyll- a, Pheophytin- a, qualitative and quantitative evaluation of phytoplankton, qualitative and quantitative evaluation of zooplankton density and their population.

**TABLE 42. SAMPLING LOCATIONS**

monitoring requirement	Number of locations
Kandla creek	3 in Kandla creek
Nakti creek	2 in Nakti creek
Khori Creek	1 in Khori creek
Vadinar jetty	1 near Vadinar Jetty
SPM	1 near I <sup>st</sup> SPM
<b>Total Number of locations</b>	<b>8</b>

### Sampling methodology adopted:

A marine sampling is an estimation of the body of information in the population. The theory of the sampling design is depending upon the within lying frequency distribution of the population of interest. The requirement for useful water sampling is to collect a representative sample of suitable volume from the specified depth and retain it free from contamination during retrieval.

50 litres of the water sample were collected from Sub surface by using bucket. From the collected water sample 1 litres of water sample was taken in an opaque plastic bottle for chlorophyll estimation, thereafter plankton samples were collected by using filtration assembly with Nylobolt cloth of 20µm mesh size.

### **Samples Processing for chlorophyll estimation:**

Samples for chlorophyll estimation were preserved in ice box on board in darkness to avoid degradation in opaque container covered with aluminum foil. Immediately after reaching the shore after sampling, 1 litre of collected water sample was filtered through GF/F filters (pore size 0.45 µm) by using vacuum filtration assembly. After vacuum filtration the glass micro fiber filter paper was grunted in tissue grinder, macerating of glass fiber filter paper along with the filtrate was done in 90% aqueous Acetone in the glass tissue grinder with glass grinding tube. Glass fiber filter paper will assist breaking the cell during grinding and chlorophyll content was extracted with 10 ml of 90% Acetone, within cold dark conditions along with saturated magnesium carbonate solution in glass screw cap tubes. After an extraction period of 24 hours, the samples were transferred to calibrated centrifuge tubes and adjusted the volume to original volume with 90% aqueous acetone solution to make up the evaporation loss. The extract was clarified by using centrifuge in closed tubes. The clarified extracts were then decanted in clean cuvette and optical density was observed at wavelength 664, 665 nm. By using corrected optical density, Chlorophyll-a value was calculated as given in (APHA, 1998).

### **PLANKTON:**

The entire area open water in the sea is the pelagic realm. Pelagic organisms live in the open sea. In contrast to the pelagic realm, the benthic realm comprises organisms and zone of the bottom of the sea. Vertically the pelagic realm can be dividing into two zones based on light penetration; upper photic or euphotic zone and lower dark water mass, aphotic zone below the photic zone.

The term plankton is a general term for organisms which have such limited powers of locomotion that they are at the mercy of the prevailing water movement. Plankton is subdivided to phytoplankton and zooplankton. Phytoplankton are free floating organisms that are capable of photosynthesis and zooplankton are the various free-floating animals. Pelagic zone, represents the entire ocean water column from the surface to the deepest depths, is home to a diverse community of organisms. Differences in their locomotive ability categorize the organisms in the pelagic realm into two, *plankton* and *nekton* (Lalli and Parsons, 1997). *Plankton* consists of all organisms drifting in the water and is unable to swim against water currents, whereas *Nekton* includes organisms having strong locomotive power. Ecological studies on the plankton community, which form the base of the aquatic food chain, help in the better withstanding of the dynamics and functioning of the marine ecosystem. The term 'Plankton' first coined by Victor Hensen (1887), Plankton, (Greek word: *planktos* meaning "passively drifting or wandering") is defined as drifting or free-floating organisms that inhabit the pelagic zone of water. Based on their mode of nutrition planktonic organisms are categorised into phytoplankton (organisms having an autotrophic mode of nutrition) and zooplankton (organisms having a heterotrophic mode of nutrition).

### **Phytoplankton in the marine environment:**

Phytoplankton are free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio-purifier and bio-indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem.

The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (Bacillariophyceae) and Dinoflagellates (Dinophyceae). The phytoplankton those normally captured in the net from the Gulf of Kutch is normally dominated by these two major groups; Diatoms and Dinoflagellates. Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro flagellates (naked flagellates) as well as and Cyanophytes (Blue-green algae).

Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts.

Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

#### **Zooplankton in the marine environment:**

Zooplankton includes a taxonomically and morphologically diverse community of heterotrophic organisms that drift in the waters of the world's oceans. Qualitative and quantitative studies on zooplankton community are a prerequisite to delineate the ecological processes active in the marine ecosystem. Zooplankton community plays a pivotal role in the pelagic food web as the primary consumers of phytoplankton and act as the food source for organisms in the higher trophic levels, particularly the economically essential groups such as fish larvae and fishes. They also function in the cycling of elements in the marine ecosystem. The dynamics of the zooplankton community, their reproduction, and growth and survival rate are all significant factors determining the recruitment and abundance of fish stocks as they form an essential food for larval, juvenile and adult fishes (Beaugrand et al., 2004). Zooplankton grazing in the marine environment controls the primary Production and helps in determining the pelagic ecosystem (Banse, 1995). Through grazing in surface waters and following the production of sinking faecal matters and also by the active transportation of dissolved and particulate matter to deeper waters via vertical migration, they help in the transport of

organic carbon to deep ocean layers and thus act as key drivers of 'biological pump' in the marine ecosystem. Zooplankton grazing and metabolism also, transform particulate organic matter into dissolved forms, promoting primary producer community, microbial demineralization, and particle export to the ocean's interior.

The categorization of zooplankton into various ecological groups is based on several factors such as duration of planktonic life, size, food preferences and habitat. As they vary significantly in size from microscopic to metazoic forms, the classification of zooplankton based on size has paramount importance in the field of quantitative plankton research.

Based on the duration of planktonic life, zooplankton are categorized into Holoplankton (organisms which complete their entire lifecycle as plankton) and Meroplankton (organisms which are planktonic during the early part of their lives such as the larval stages of benthic and nektonic organisms). Tychoplankton are organisms which live a brief planktonic life, such as the benthic crustaceans (Cumaceans, mysids, isopods) which ascend to the water column at night for feeding and certain ectoparasitic copepods, they leave the host and spend their life as plankton during their breeding cycle.

Zooplankton can be subdivided into holoplankton, i.e., permanent members of the plankton (e.g., Calanoid copepods), and meroplankton, i.e., temporary members in the plankton e.g., larvae of fish, shrimp, and crab). The meroplankton group consists of larval and young stages of animals that will adopt a different lifestyle once they mature. In contrast to phytoplankton which consist of a relatively smaller variety of organisms, Zooplankton are extremely divers, consist of a host of larval and adult forms representing many animal phylum.

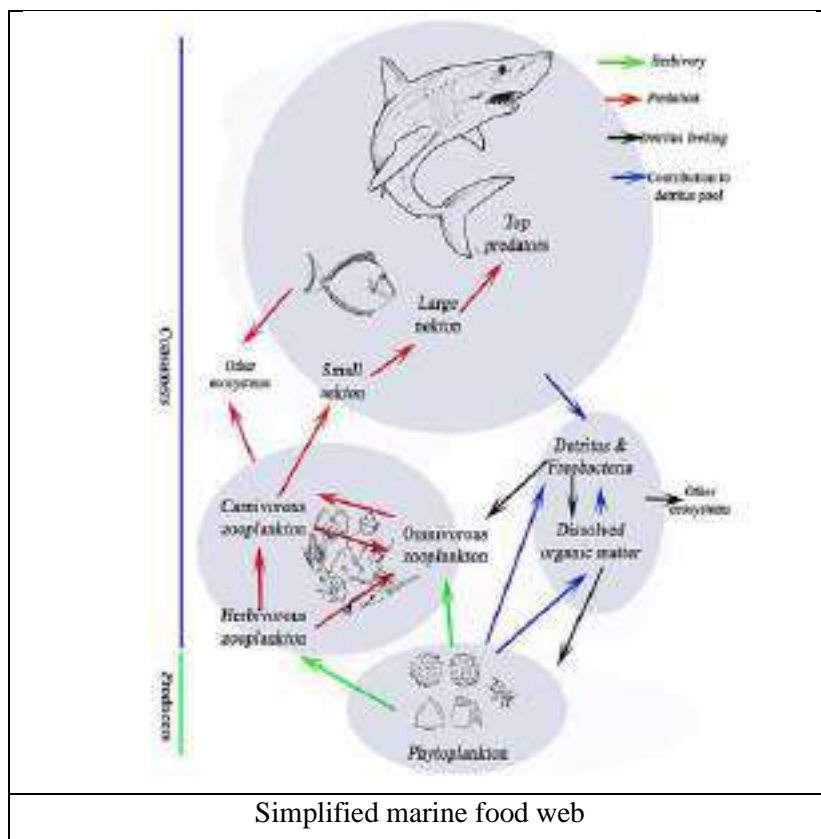
Among the zooplankton one group always dominate than others; members of sub class copepods (Phylum Arthropoda) and Tintinnids (Phylum Protozoa) among the net planktons. These small animals are of vital importance in marine ecosystem as one of the primary herbivores animals in the sea, and it is they provide vital link between primary producer (autotrophs) and numerous small and large marine consumers.

As their community structure and function are highly susceptible to changes in the environmental conditions regular monitoring of their distribution as well as their interactions with various physicochemical parameters is inevitable for the sustainable management of the ecosystem (Kusum et al., 2014). Of all the marine zooplankton groups, copepods mainly Calanoid copepods are the dominant groups in marine subtropical and tropical waters and exhibit considerable diversity in morphology and habitats they occupy (Madhupratap, 1991 ;)

It has been well established that potential of pelagic fishes viz. finfishes, crustaceans, molluscs and marine mammals either directly or indirectly depend on zooplankton. The herbivorous zooplanktons are efficient grazers of the phytoplankton and are referred to as living machines transforming plant



material into animal tissue. Hence, they play an essential role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter lifespan, drifting nature, high group/species diversity and different tolerance to the stress, they are used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem (Ghajibhiye, 2002).



### Spatial distribution of Plankton:

A characteristic of plankton population is that they tend to occur in patches, which are varying spatially on a scale of few meters to far as few kilometres in distance. They also vary in time scale, season as well as vertically in the water column. It is this patchiness and its constant changes in time and spot, that has made it so difficult for plankton biologist to learn about the ecology of plankton. The biological factors that causes this patchiness is due to the ability of zooplankton to migrate vertically and graze out the phytoplankton at a rapid rate that can create patchiness. Similarly, the active swimming ability by certain zooplankton organisms can cause to aggregate in dense group.

At its most extreme, because the water in which plankton is suspended is constantly moving, each sample taken by the plankton biologists remain a different volume of water, so each sample is unique and replicate does not exist. Physical factors contribute to this type of patchiness include light intensity, nutrients and density gradients in the water column.

Phytoplankton in particular tends to be unequally distributed vertically, which leads to the existence of different concentration of a chlorophyll value between photic zone and below the photic zone.

**Methodology adopted for Plankton sampling:**

Mixed plankton sample were obtained from the sub surface layer at each sampling locations by towing the net horizontally with the weight. After a tow of about 15-30 minutes, plankton net was pulled up and washed down to the tail and the plankton adhered to plankton net is collected in the collection bucket at the bottom by springing outer and inner surface of the net with sea water, while the net was hanging with the mouth upward. For quantitative evaluation 50 L water samples were collected from subsurface layer and filtered through 20 µm mesh size net by using bucket and filtration assembly.

**Preservation and storage:**

Both filtered plankton and those collected from the plankton net were preserved with 5% buffered formalin and stored in 1L plastic container for further processing in the laboratory.

**Sample concentration:**

The collected plankton samples were concentrated by using centrifuge and made up to 50 ml with 5% formalin -Glycerine mixture.

**Taxonomic evaluation:**

Before processing, the sample was mixed carefully and a subsample was taken with a calibrated Stempel-pipette. 1 ml of the concentrated plankton samples were transferred on a glass slide with automatic pipette. The plankton sample on the glass slides were stained by using Lugol's iodine and added glycerine to avoid drying while observation. The plankton samples were identified by using Labex triangular Research microscope with photographic attachment. Microphotographs of the plankton samples were taken for record as well as for confirming the identification. The bigger sized zooplankton was observed through dissecting stereomicroscope with magnification of 20-30 x. Plankton organisms in the whole slide were identified to the lowest taxon possible. A thorough literature search was conducted for the identification of the different groups of phytoplankton and zooplankton that were encountered.

**Cell counts by drop count method:**

The common glass slide mounted with a 1ml of concentrated phytoplankton/zooplankton sample in glycerol and covered with cover slip 22 mm x 60 mm was placed within the compound microscope provided with a mechanical stage. The plankton was then counted from the microscopic field of the left top corner of the slide. Then slide is moved horizontally along the right side and plankton in each microscopic field was thus counted. When first microscopic field row was finished the next consecutive row was adjusted using the mechanical device of the stage. In this way all the plankton present in entire microscopic field are counted. From this total number in 1ml of the concentrated

plankton, total amount of phytoplankton in the original volume of sample filtered was calculated as units/L and Zooplankton as N/m<sup>3</sup>

#### **BENTHIC ORGANISMS:**

Benthos is those organisms that are associated with the sea bed or benthic habitats. Epi- benthic organisms live attached to a hard substratum or rooted to a shallow depth below the surface. In fauna organisms live below the sediment–water interface. Interstitial organisms live and move in pore water among sedimentary grains.

Because the benthic organisms are often collected and separated on sieves, a classification based on the overall size is used. Macro benthos include organisms whose shortest dimension is greater than or equal to 0.5 mm. Meio benthos are smaller than 0.5mm but larger than 42μ in size.

The terms such as macro fauna and Meio fauna generally have little relevance with taxonomic classification. The terms Meio fauna and macro fauna depend on the size. Meio fauna were considered as good bioassay of community health and rather sensitive indicators of environmental changes.

#### **SAMPLING METHODOLOGY ADOPTED FOR SUB TIDAL REGION:**

Van veen sampler (0.09m<sup>2</sup>) was used for sampling bottom sediments. Two sets of sediments were sampled from each location, one for macro fauna and other for Meio fauna. The macro fauna in the sediments were sieved on board to separate out the organisms. The fixation of Meio fauna is normally done by bulk fixation of the sediment sample. The bulk fixation is done by using 10% formalin (Buffered with borate). The organisms were preserved with seawater as diluting agent.

#### **Sample sieving:**

Sediments samples were sieved to extract the organisms. Sieving was performed carefully as possible to avoid any damage to the animals. The large portion of the sediment was split in to smaller portions and mixed with sea water in a bucket. The cohesive lumps were broken down by continuous stirring. The disaggregated sediments were then passed through the sieves.

#### **Sample staining:**

Sorting of the Meio fauna from the sieve is difficult task especially in the preserved material, because organisms are not easily detectable. To facilitate the animal detection the entire sample retained on the sieve after sieving operation were stained by immersing the sieve in a flat bottom tub with 1% Rose Bengal stain; a protein stain. A staining period of 10-30 minutes is sufficient for sample detection.

#### **DIVERSITY INDICES:**

On the whole, diversity indices provide more information about community composition than simply species richness (number of species present); they also, take the relative abundances of different species into account. Based on this fact, diversity indices therefore depend not only on species

richness but on the evenness, or equitability, with which individuals are distributed among the different species (Magurram, A. E. (1988)

A diversity index is a measure of species diversity within a community that consists of co-occurring populations of several (two or more) different species. It includes two components: richness and evenness. Richness is the measure of the number of different species within a sample, more the types of species in a community, the higher is the diversity or greater is the richness. Evenness is the measure of relative abundance of the different species with in a community.

The basic idea of diversity index is to obtain a quantitative estimate of biological variability that can be used to compare biological entities composed of discrete components in space and time (Carol H.R. *etal.* 1998). Biodiversity is commonly expressed through indices based on species richness and species abundances (Whittaker 1972, Lande 1996, Purvis and Hector 2000). Biodiversity indices are a non-parametric tool used to describe the relationship between species number and abundance. The most widely used bio diversity indices are Shannon Weiner index and Simpson's index.

A diversity Index is a single statistic that incorporates information on richness and evenness. Any study intended to interpret causes and effect of adverse impact on Biodiversity of communities require suitable measures to evaluate specie richness and Diversity. The former is number of species in community, while latter is a function of relative frequency of different species. Species richness is the iconic measure of biological diversity (Magurran, 2004). Several indices have been created to measure the diversity of species; however, the most widely used in the last decades are the Shannon (1948) and Simpson (1949) (Buzas and Hayek 1996; Gorelick 2006), with the components of diversity: richness (*S*) and evenness (*J*)

#### **Simpson's diversity index**

Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and evenness of abundance among the species present. The Simpson index is one of the meaningful and robust biodiversity measures available. (Magurran ,2004).

The formula for calculating D is presented as:

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

Where  $n_i$  = the total number of organisms of each individual species

$N$  = the total number of organisms of all species

The value of D ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. When D increases diversity decreases. Simpson's index is therefore usually expressed as 1-D or 1/D. (Magurran, 2004)

Low species diversity suggests:relatively few successful species in the habitat the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted

to that environment food webs which are relatively simple change in the environment would probably have quite serious effects High species diversity suggests: a greater number of successful species and a more stable ecosystem more ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole

### **Species richness indices**

The species richness(*S*) is simply the number of species present in an ecosystem. Species richness Indices of species richness are widely used to quantify or monitor the effects of anthropogenic disturbance. A decline in species richness in may be concomitant with severe or chronic human-induced perturbation (Fair weather 1990,) Species richness measures have traditionally been the mainstay in assessing the effects of environmental degradation on the biodiversity of natural assemblages of organisms (Clarke & Warwick, 2001). Species richness is the iconic measure of biological diversity (Magurran, 2004). The species richness (*S*) is simply the number of species present in an ecosystem. This index makes no use of relative abundances. The term species richness was coined by McIntosh (1967) and oldest and most intuitive measure of biological diversity (Magurran, 2004).

Margalef's diversity index is a species richness index. Margalef's Species richness index (*d*), or indices that describe the evenness of the distribution of the numbers of individuals among species, were derived.

The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of diversity index is maximized when all types are equally abundant [Rosenzweig, M. L. (1995)]

### **Shannon-Wiener's index:**

An index of diversity commonly used in plankton community analyses is the Shannon-Wiener's index (**H**), which emphasizes not only the number of species (richness or variety), but also the apportionment of the numbers of individuals among the species (Odum 1971 and Reish 1984). Shannon-Wiener's index (**H**) reproduces community parameters to a single number by using an equation.

$$H' = - \sum_{j=1}^s \frac{n_j}{N} \ln \left( \frac{n_j}{N} \right)$$

Shannon and Weiner index represents entropy. It is a diversity index taking into account the number of individuals as well as the number of taxa. It varies from 0 for communities with only single taxa to high values for community with many taxa each with few individuals. This index can also determine the pollution status of a water body. Normal values range from 0 to 4. This index is a combination of species present and the evenness of the species. Examining the diversity in the range of polluted and

unpolluted ecosystems, Wilham and Dorris (1968) concluded that the values of the index greater than 3 indicate clean water, values in the range of 1 to 3 are characterized by moderate pollution and values less than 1 are characterized as heavily polluted

## RESULTS:

### CHLOROPHYLL-a:

In the sub surface water chlorophyll-a was varying from 0.511-0.883 mg/m<sup>3</sup> with an average value 0.734 mg/m<sup>3</sup> in harbour region of DPT in Kandla Creek during sampling done in spring tide period of December 2022. In the nearby creeks chlorophyll-a was varying from 0.322- 0.679 mg/m<sup>3</sup>. with an average value 0.555 mg/m<sup>3</sup>. Pheophytin-a level was below detectable limit- the all the sampling stations during spring tide. Even though the plankton diversity and abundance were more during the spring tide sampling, the chlorophyll -content was detected lesser than expected because, the phytoplankton communities were mainly represented by diatoms *Thalassiothrix sp.* *Biddulphia* sp and *Chaetoceros* sp.

In the sub surface water chlorophyll-a was varying from 0.44- 0.764 mg/m<sup>3</sup> with an average value 0.622 mg/m<sup>3</sup> in harbour region of DPT in Kandla Creek during sampling done in Neap tide period of December 2022. In the nearby creeks chlorophyll-a was varying from 0.204- 0.646 mg/m<sup>3</sup> with an average value 0.507 mg/m<sup>3</sup>. Pheophytin -a level was below detectable limit at all the sampling stations. During neap tide sampling phytoplankton communities were mainly represented by *Thalassiothrix sp.* *Coscinodiscus sp.* and *Biddulphia sp*

In the sub surface water chlorophyll-a was varying from 0.424- 0.866 mg/m<sup>3</sup> in harbour region of DPT OOT in path finder Creek during sampling done in spring tide period of December 2022. In the sub surface water chlorophyll-a was varying from 0.509- 0.661 mg/m<sup>3</sup> in harbour region of DPT OOT in path finder Creek during sampling done in Neap Tide period of December 2022

**TABLE 43 VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK, NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING SPRING TIDE IN DECEMBER 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPT HARBOUR AREA KANDLA CREEK					
1	DPA1	High tide	0.883	BDL	59.161
		Low tide	0.527	BDL	35.309
2	DPA 2	High tide	0.866	BDL	58.022
		Low tide	0.511	BDL	34.237
3	DPA 3	High tide	0.765	BDL	51.255
		Low tide	0.851	BDL	57.017
CREEKS					
4	DPA-4 Khor-I	High tide	0.631	BDL	42.277
		Low tide	0.629	BDL	42.143
5	DPA-5 Nakti-I	High tide	0.679	BDL	45.493
		Low tide	0.513	BDL	34.371
6	DPA-6 Nakti-II	High tide	0.322	BDL	21.574
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.866	BDL	58.022
8		Low tide	0.747	BDL	50.049
9	SPM	High tide	0.424	BDL	28.408
10		Low tide	0.528	BDL	35.376

BDL: Below Detectable Limit., ND: Not detected

**TABLE 44 VARIATIONS IN CHLOROPHYLL –a PHEOPHYTIN- a AND ALGAL BIOMASS FROM SAMPLING STATIONS IN DPT HARBOUR AREA, NEAR BY CREEKS AND DPT OOT JETTY IN PATH FINDER CREEK AND SPM NEAR VADINAR DURING NEAP TIDE IN DECEMBER 2022**

Sr. No.	Station	Tide	Chlorophyll-a (mg/m <sup>3</sup> )	Pheophytin- a (mg/m <sup>3</sup> )	Algal Biomass (Chlorophyll method) mg/m <sup>3</sup>
DPT HARBOUR AREA KANDLA CREEK					
1	DPA1	High tide	0.764	BDL	51.188
		Low tide	0.748	BDL	50.116
2	DPA 2	High tide	0.440	BDL	29.480
		Low tide	0.630	BDL	42.210
3	DPA 3	High tide	0.527	BDL	35.309
		Low tide	-	-	-
CREEKS					
4	DPA-4 Khor-I	High tide	0.629	BDL	42.143
		Low tide	0.646	BDL	43.282
5	DPA-5 Nakti-I	High tide	0.543	BDL	36.381
		Low tide	0.511	BDL	34.237
6	DPA-6 Nakti-II	High tide	0.204	BDL	13.668
PATHFINDER CREEK VADINAR					
7	VADINAR-I jetty	High tide	0.614	BDL	41.138
8		Low tide	0.509	BDL	34.103
9	SPM	High tide	0.661	BDL	44.287
10		Low tide	0.517	BDL	34.639

BDL: Below Detectable Limit. ND: Not detected

#### PHYTOPLANKTON POPULATION:

For the evaluation of the Phytoplankton population in DPT harbour area and within the immediate surroundings of the port, sampling was conducted from 5 sampling locations (3 in harbour area and two in Nakti creek) during high tide period and low tide period of spring tide and neap tide.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 25 genera, Blue green algae were represented by 2 genera and Dinoflagellates were



represented by 4 genera during the sampling conducted in spring tide in December, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 48-312 units/ L during high tide period and 158-229 units/ L during low tide of Spring Tide. During spring tide sampling phytoplankton communities were dominated by *Thalassiothrix sp.* almost forming a bloom in the Kandla creek and other nearby creek area and abundant population of *Biddulphia sp* and *Chaetoceros sp* were also observed during spring tide in December, 2022.

The phytoplankton community of the sub surface water in the harbour and nearby creeks was represented by Diatoms, Blue green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 26 genera, Blue green algae were represented single genera and Dinoflagellates with 4 genera during the sampling conducted in Neap tide in December, 2022. Phytoplankton of the sampling stations at sub surface layer in the harbour area and nearby creeks was varying from 28-261 units/ L during high tide period and 113-161 units/ L during low tide of Neap Tide. During Neap tide sampling phytoplankton communities were dominated by, *Thalassiothrix sp.*, *Coscinodiscus sp.* and *Biddulphia sp.*

For the evaluation of the Phytoplankton population in DPT OOT jetty area in Path Finder creek sampling was conducted from two sampling locations; Jetty area and SPM area during high tide period and low tide of spring tide and Neap tide period.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algae and Dinoflagellates during spring tide period. Diatoms were represented by 30 genera, Blue Green algae by 5 genera and Dinoflagellates by 4 genera during the sampling conducted in spring tide in December, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty area was 343 units/ L during high tide period and 204 units/ L during low tide of Spring Tide. Phytoplankton of the sampling stations at sub surface layer in the SPM area was varying from 287 units/ L during high tide period and 180 units/ L during low tide of Spring Tide.

The phytoplankton community of the sub surface water in the path finder creeks was represented by Diatoms, Blue green algae, Green algae and Dinoflagellates during Neap tide period. Diatoms were represented by 28 genera and Blue green algae by 5 genera, Green algae by single genera and Dinoflagellates by 4 genera during the sampling conducted in Neap tide in December, 2022. Phytoplankton of the sampling stations at sub surface path finder creek near OOT Jetty was varying from 246 units/ L during high tide period and 198 units/ L during low tide of Neap Tide. Phytoplankton of the sampling stations at sub surface path finder creek near SPM area was varying from 273 units/ L during high tide period and 212 units/ L during low tide of Neap Tide.

### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

At the organismal level, the most widely used biodiversity measures are those based on the number of species present, perhaps adjusted for the number of individuals sampled, Here Margalef's Species richness index (d), or indices that describe the evenness of the distribution of the numbers of individuals among species, are derived.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek and nearby creeks sampling stations was varying from 1.808- 4.325 with an average of 3.472 during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.345- 3.313 with an average of 2.712 during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations in Kandla creek and nearby creeks was varying from 2.345- 3.651 with an average of 3.007 during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the Kandla creek region and nearby creeks was varying from 2.327- 2.895 with an average of 2.680 during consecutive low tide.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the sampling station was 5.139 at OOT jetty area and 4.064 at SPM area during the sampling conducted in High tide period of spring tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 3.385 and 3.851 at SPM during the consecutive low tide period.

Margalef's diversity index (Species Richness) S of phytoplankton communities in the stations was 4.359 at OOT jetty area and 3.922 at SPM area during the sampling conducted in High tide period of Neap tide. While Margalef's diversity index (Species Richness) S of phytoplankton communities in the path finder creek near OOT jetty was 4.727 and SPM area was 3.36 during the consecutive low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.808- 0.967 between selected sampling stations with an average value of 0.925 during high tide period of spring tide at Kandla creek and nearby creeks. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.813-0.900 ( $H'(\log_{10})$ ) between selected sampling stations with an average value of 0.874 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 0.782– 0.905 between selected sampling stations with an average value of 0.840 during high tide

period of neap tide at Kandla creek and nearby creeks. Shannon-Wiener's Index of phytoplankton communities in the sampling stations was in the range of 0.850- 0.888 between selected sampling stations with an average value of 0.864 during consecutive low tide at Kandla creek and nearby creeks.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.018 at OOT jetty area and 0.987 at SPM area during the sampling conducted in High tide period of spring tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 0.913 and 0.989 at SPM during the consecutive low tide period of spring tide.

Shannon-Wiener's Index (H) of phytoplankton communities in the stations was 1.033 at OOT jetty area and 0.977 at SPM area during the sampling conducted in High tide period of Neap tide. While Shannon-Wiener's Index (H) of phytoplankton communities in the path finder creek near OOT jetty was 1.044 and at SPM area was 0.926 during the consecutive low tide period.

Typical values are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of phytoplankton of Kandla Harbour region and nearby creeks is less but with abundant population of few, with relatively few ecological niches and only very few opportunist organisms are really well adapted to this environment and thrive better than other species.

#### **Simpson's diversity index:**

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.831- 0.855 between selected sampling stations with an average of 0.844 during high tide period of spring tide. Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks, which was varying from 0.782 - 0.834 between selected sampling stations with an average of 0.821 during consecutive low tide.

Simpson diversity index (1-D) of phytoplankton communities was below 0.9 at all sampling stations except few in Kandla Harbour region and nearby creeks, during high tide period and low tide period during Neap tide also, which was varying from 0.757- 0.857 with an average value of 0.803 between selected sampling stations during high tide period and 0.823- 0.834 varying from with an average value of 0.830 between selected sampling stations during consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.867 at OOT jetty area and 0.866 at SPM area during the sampling conducted in High tide period of spring tide at Path finder creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder

creek near OOT jetty was 0.829 and 0.872 at SPM during the consecutive low tide period in the path finder creek.

Simpson diversity index (1-D) of phytoplankton communities in the stations was 0.878 at OOT jetty area and 0.859 at SPM area during the sampling conducted in High tide period of Neap tide at Path finder Creek. While Simpson diversity index (1-D) of phytoplankton communities in the path finder creek near OOT jetty was 0.883 and at SPM area was 0.856 during the consecutive low tide period. Low species diversity suggests a relatively few successful species in this habitat. The environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment. Any change in the environment would probably have quite serious effects.

**Table 45 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% Of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	216	23/31	74.19	4.093	0.9669	0.8483
	2	204	24/31	77.42	4.325	0.9416	0.8307
	3	212	19/31	61.29	3.36	0.9529	0.8553
	4	312	25/31	80.65	4.179	0.9653	0.8418
	5	255	18/31	58.06	3.068	0.9152	0.8431
	6	48	8/31	25.81	1.808	0.8082	0.844
LOW TIDE	1	167	13/31	41.94	2.345	0.813	0.7817
	2	158	14/31	45.16	2.568	0.8933	0.8313
	3	175	14/31	45.16	2.517	0.8848	0.8344
	4	229	19/31	61.29	3.313	0.9004	0.8303
	5	205	16/31	51.61	2.818	0.8807	0.8271

**Table 46 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	171	18/31	58.06	3.306	0.805	0.7573
	2	167	13/31	41.94	2.345	0.7823	0.7861
	3	182	20/31	64.52	3.651	0.8661	0.7956
	4	242	20/31	64.52	3.462	0.9051	0.822
	5	261	17/31	54.84	2.875	0.8418	0.7984
	6	28	9/31	29.03	2.401	0.8423	0.8571
LOW TIDE	1	126	15/31	48.39	2.895	0.8881	0.833
	2	113	12/31	38.71	2.327	0.8511	0.8298
	3	147	15/31	48.39	2.805	0.8733	0.8336
	4	145	15/31	48.39	2.813	0.8504	0.8229
	5	161	14/31	45.16	2.558	0.8569	0.83

**Table 47 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING SPRING TIDE IN DECEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	BLUE GREEN ALGAE	0-2	2/31	6.45
			DIATOMS	48-307	25/31	80.65
			DINOFLAGELLATES	0-5	4/31	12.90
			TOTAL PHYTO PLANKTON	<b>48-312</b>	<b>31</b>	
LOW TIDE	Sub surface	5	BLUE GREEN ALGAE	0-1	2/31	6.45
			DIATOMS	157-226	25/31	80.65
			DINOFLAGELLATES	0-2	4/31	12.90
			TOTAL PHYTO PLANKTON	<b>158-229</b>	<b>31</b>	

**TABLE 48 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN DECEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	BLUE GREEN ALGAE	0-2	1/31	3.23
			DIATOMS	26-261	26/31	83.87
			DINOFLAGELLATES	0-6	4/31	12.90
			TOTAL PHYTO PLANKTON	<b>28-261</b>	<b>31</b>	
LOW TIDE	Sub surface	5	BLUE GREEN ALGAE	0-1	1/31	3.23
			DIATOMS	112-161	26/31	83.87
			DINOFLAGELLATES	0-1	4/31	12.90
			TOTAL PHYTO PLANKTON	<b>113-161</b>	<b>31</b>	

**TABLE 49 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	343	31/39	79.49	5.139	1.018	0.867
	SPM	287	24/39	61.54	4.064	0.987	0.866
LOW TIDE	Jetty	204	19/39	48.72	3.385	0.913	0.829
	SPM	180	21/39	53.85	3.851	0.989	0.872

**TABLE 50 PHYTOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance In units/L	No of Species observed /total species	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H (log <sub>10</sub> )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	246	25/38	65.79	4.359	1.033	0.878
	SPM	273	23/38	60.53	3.922	0.977	0.859
LOW TIDE	Jetty	198	26/38	68.42	4.727	1.044	0.883
	SPM	212	19/38	50.00	3.36	0.926	0.856

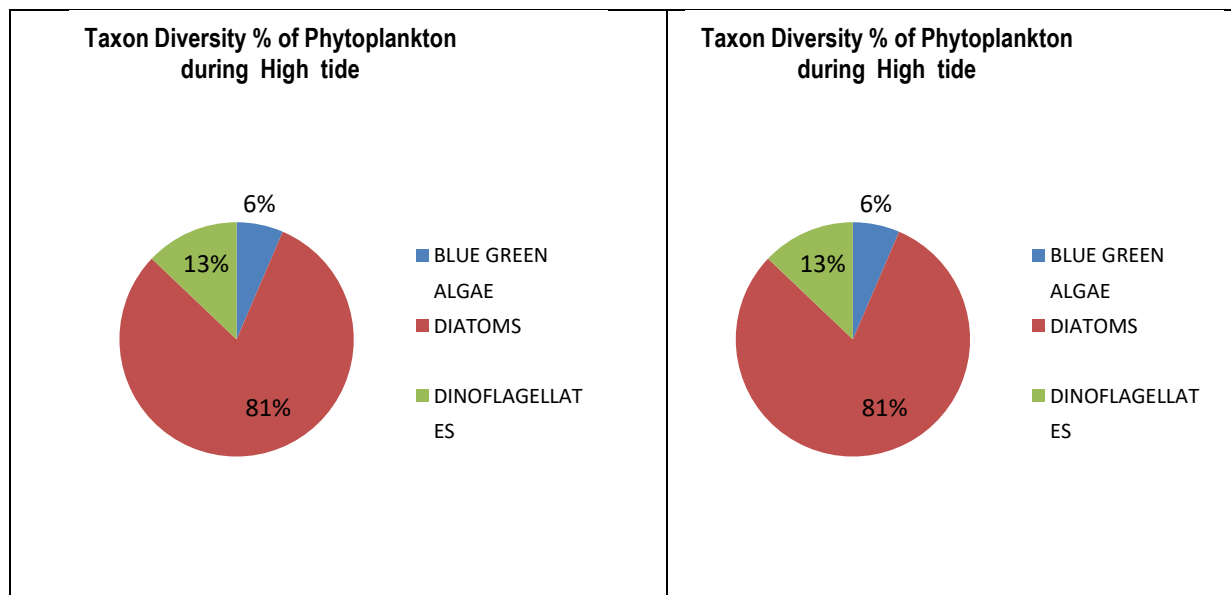
**TABLE 51 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING SPRING TIDE IN DECEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAE	5-9	5/39	12.80
			DIATOMS	279-332	30/39	76.93
			DINOFLAGELLATES	2-3	4/39	10.27
			TOTAL PHYTO PLANKTON	<b>287-343</b>	<b>39</b>	
LOW TIDE	Sub surface	2	BLUE GREEN ALGAE	2-3	5/39	12.80
			DIATOMS	178-200	30/39	76.93
			DINOFLAGELLATES	0-1	4/39	10.27
			TOTAL PHYTO PLANKTON	<b>287-343</b>	<b>39</b>	

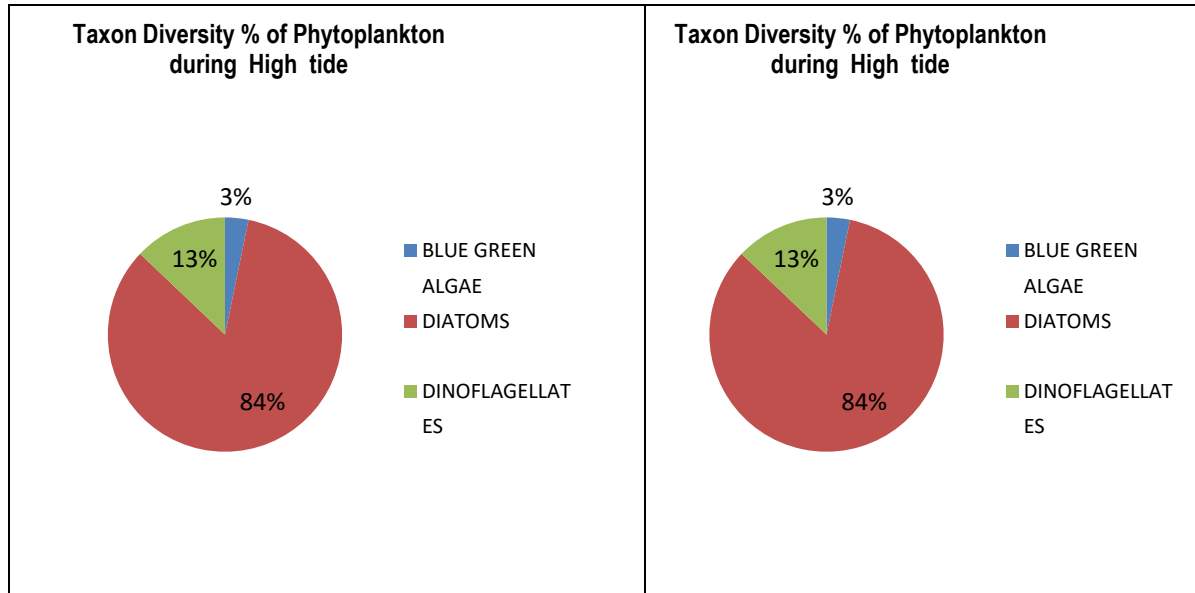
**Table 52 ABUNDANCE OF PHYTOPLANKTON SUBSURFACE SAMPLING STATIONS IN DPT OOT AT PATH FINDER CREEK , VADINAR & NEAR BY SPM, DURING NEAP TIDE IN DECEMBER 2022**

Tide	Surface	No of Sampling location	Group of phytoplankton	Phytoplankton Group range Units/L	Genera or species /total Phyto plankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	BLUE GREEN ALGAE	5-7	5/38	13.16
			GREEN ALGAE	0-1	1/38	2.63
			DIATOMS	235-266	28/38	73.68
			DINOFLAGELLATES	2-3	4/38	10.53
			TOTAL PHYTO PLANKTON	<b>246-273</b>	<b>38</b>	
LOW TIDE	Sub surface	2	BLUE GREEN ALGAE	2-3	5/38	13.16
			GREEN ALGAE	0	1/38	2.63
			DIATOMS	190-208	28/38	73.68
			DINOFLAGELLATES	2-5	4/38	10.53
			TOTAL PHYTO PLANKTON	<b>198-212</b>	<b>38</b>	

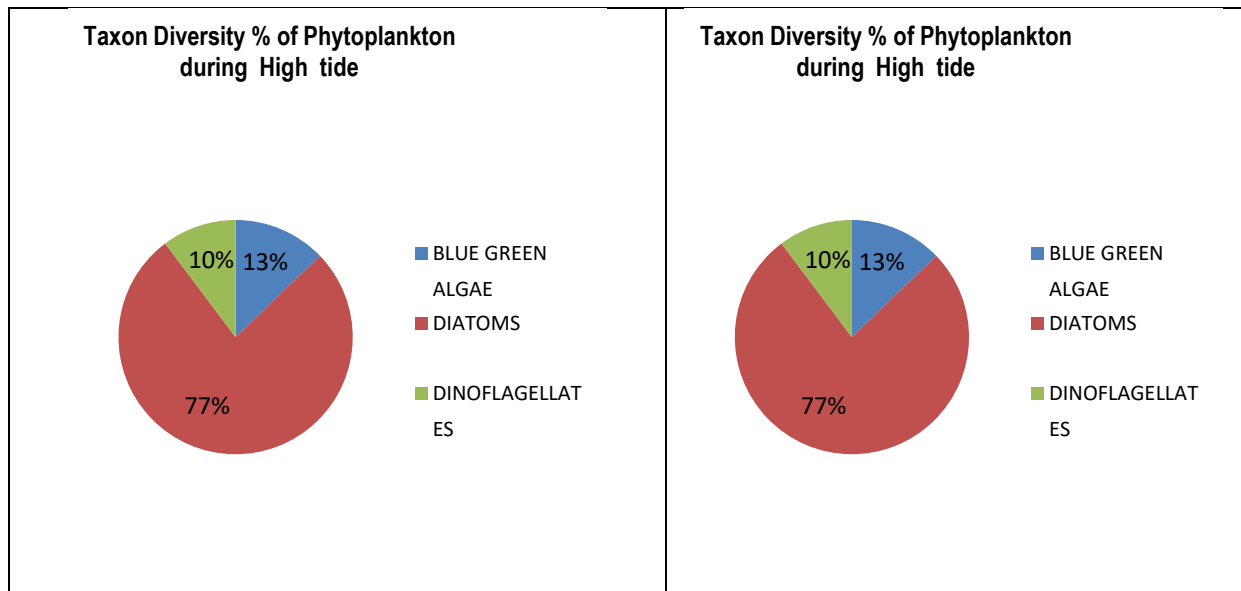
**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Kandla creek and nearby creeks**



**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Kandla creek and nearby creeks**

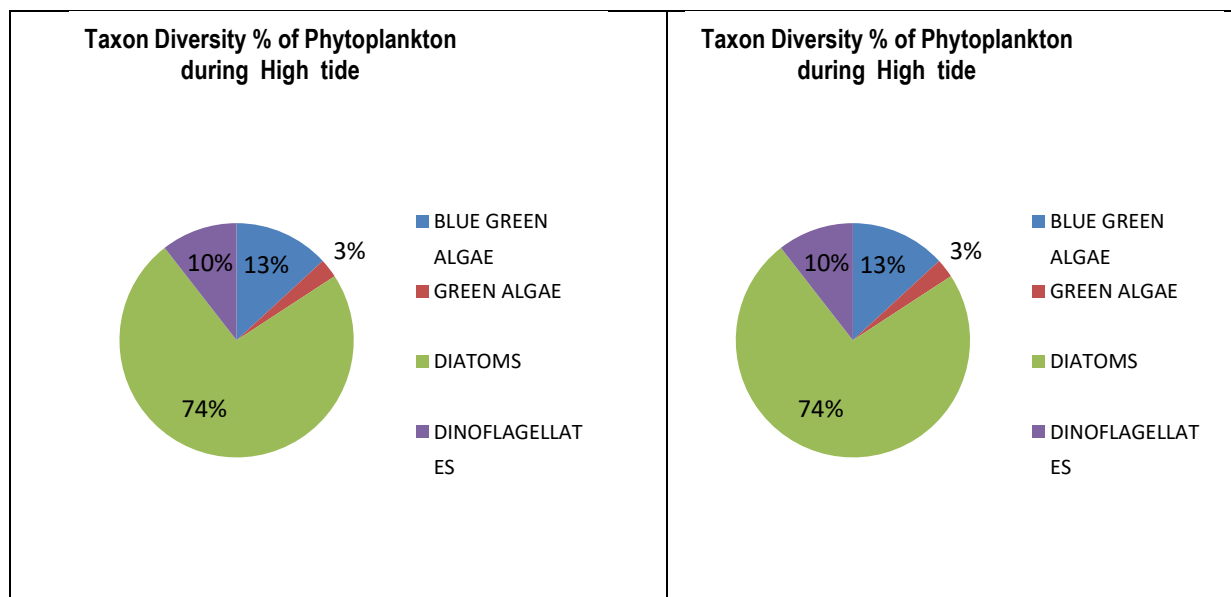


**Taxon Diversity % of Phytoplankton during High tide and Low tide period during spring tide in Path Finder Creek, Vadinar**





**Taxon Diversity % of Phytoplankton during High tide and Low tide period during Neap tide in Path Finder Creek, Vadinar**



### **ZOOPLANKTON POPULATION:**

For the evaluation of the Zooplankton population in DPT harbour area and within the immediate surroundings of the port sampling was conducted from 6 sampling locations (3 in harbour area and two in Nakti creek and one in Khori creek) during high tide period and low tide period of spring tide and Neap tide in December, 2022. The Zooplankton community of the sub surface water in the harbour and nearby creeks during spring tide was represented by mainly five groups; Tintinids, Copepods, Mysids, Urochordata, Ciliates and 8 larval forms. The Zooplankton community of the sub surface water in the harbour and nearby creeks during neap tide was represented by mainly six groups; Tintinids, Copepods, Arrow worms, Mysids, Urochordata, Ciliates and 8 larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from  $20-106 \times 10^3 \text{ N/ m}^3$  during high tide and  $55-84 \times 10^3 \text{ N/ m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT harbour area and nearby creek was varying from  $27-100 \times 10^3 \text{ N/ m}^3$  during high tide and  $60-82 \times 10^3 \text{ N/ m}^3$  during low tide of Neap Tide period.

For the evaluation of the Zooplankton population in DPT OOT jetty area in Path Finder creek and SPM in Vadinar selected 2 sampling locations (one in jetty area and one near SPM).

During spring tide sampling plankton sample were collected at Jetty area and near SPM during consecutive high tide period and low tide period. During Neap tide sampling Plankton samples were collected from jetty area and SPM during consecutive high tide period and low tide period.

The Zooplankton community of the sub surface water in the path finder creek during spring tide was represented by mainly four groups Tintinids, Copepods, Urochordata, Nematode and six larval forms. While the Zooplankton community of the sub surface water in the path Finder creeks at Jetty region and SPM during neap tide was represented by four groups, Tintinids, Copepods, Arrow worms, Urochordata and seven larval forms.

Zooplankton of the sampling stations at sub surface layer in the DPT OOT Jetty area of path finder creek was  $119 \times 10^3 \text{ N/ m}^3$  during high tide and  $55 \times 10^3 \text{ N/ m}^3$  during low tide of Spring Tide period. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area of path finder creek was  $92 \times 10^3 \text{ N/ m}^3$  during high tide and  $73 \times 10^3 \text{ N/ m}^3$  during low tide of spring Tide period.

Zooplankton of the sampling stations at sub surface layer in the DPT OOT jetty area in path finder creek was recorded  $80 \times 10^3 \text{ N/ m}^3$  during high tide and  $61 \times 10^3 \text{ N/ m}^3$  during consecutive low tide period of Neap tide. Zooplankton of the sampling stations at sub surface layer in the DPT SPM area in path finder creek was recorded  $90 \times 10^3 \text{ N/ m}^3$  during high tide and  $68 \times 10^3 \text{ N/ m}^3$  during consecutive low tide period of Neap Tide.

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### **Species Richness Indices and Diversity Indices:**

#### **Margalef's diversity index (Species Richness) S**

Margalef's diversity index (Species Richness) S of Zooplankton communities in the stations Kandla creek region and nearby creeks were varying from 1.001- 4.539 with an average of 2.878 during the sampling conducted in High tide period. Margalef's diversity index (Species Richness) S of Zooplankton communities varying from 2.864 - 3.683 with an average of 3.281 during the sampling conducted in low tide period during Spring tide.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the Kandla creek region and nearby creeks sampling stations were varying from 3.338- 5.688 with an average of 4.290 during the sampling conducted in high tide and varying from 3.404 - 4.152 with an average of 3.811 during the sampling conducted in low tide during Neap tide period.

Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.976 and 3.244 respectively. Margalef's diversity index (Species Richness) S of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 3.538 and 3.496 respectively.

Margalef's diversity index (Species Richness) S of Zooplankton communities near Jetty at Path finder creek were varying from 3.195 and 2.919 respectively during the sampling conducted in consecutive High tide period and Low tide period of Neap tide. While Margalef's diversity index (Species Richness) S of Zooplankton communities near SPM at Path finder creek were varying from 2.667- 2.607 respectively during the consecutive High tide and low tide period.

#### **Shannon-Wiener's index:**

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.473- 1.007 between selected sampling stations with an average value of 0.783 during high tide period of spring tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.860 - 0.928 between selected sampling stations with an average value of 0.894 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range of 0.911-1.169 between selected sampling stations with an average value of 0.996 during high tide period of Neap tide. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling stations in Kandla Harbour region and nearby creeks was in the range 0.886- 1.004 of between selected sampling stations with an average value of 0.939 during consecutive low tide period.

Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.901-0.911 respectively. Shannon-Wiener's Index (H) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.834 - 0.829 respectively.

Shannon-Wiener's Index (H) of Zooplankton communities near jetty at Path finder creek was varying from 0.803- 0.766 respectively during the sampling conducted consecutive High tide period and Low tide period of Neap tide. While Shannon-Wiener's Index (H) of Zooplankton communities near SPM at Path finder creek was varying from 0.737- 0.712 during the consecutive High tide and low tide period.

The Shannon-Wiener's index increases as both the richness and the evenness of the community increase. This result indicates that diversity of Zooplankton of Kandla Harbour region and nearby creeks stations is slightly high with very minimum diverse population but very few opportunist organisms are really well adapted to this environment and thrive better than other species.

**Simpson's diversity index:**

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 most of sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide of spring tide period except few stations, which was varying from 0.611-0.847 between selected sampling stations with an average of 0.756 during high tide period and was varying from 0.805- 0.846 with an average value of 0.822 between selected sampling stations during low tide.

Simpson diversity index (1-D) of Zooplankton communities was below 0.9 at all sampling stations in the Kandla Harbour region and nearby creeks during high tide and low tide period of Neap tide except few, which was varying from 0.829- 0.899 between selected sampling stations with an average of 0.856 during high tide period and was varying from 0.784 -0.861 with an average value of 0.831 between selected sampling stations during consecutive low tide .This species diversity suggests a relatively few successful species in this habitat during December ,2022 sampling.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.777 and 0.833 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.747 and 0.743 respectively.

Simpson diversity index (1-D) of Zooplankton communities in the sampling station near jetty at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of

Neap tide was recorded as 0.753- 0.776 respectively. Simpson diversity index (1-D) of Zooplankton communities in the sampling station near SPM at Path Finder Creek, Vadinar during the sampling conducted in consecutive High tide period and low tide of spring tide was recorded as 0.740 and 0.709 respectively.

**TABLE 53 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	82	21/26	80.77	4.539	1.007	0.847
	2	71	16/26	61.54	3.519	0.8284	0.7702
	3	65	14/26	53.85	3.114	0.8058	0.7644
	4	106	12/26	46.15	2.359	0.7586	0.7456
	5	80	13/26	50.00	2.738	0.823	0.7981
	6	20	4/26	15.38	1.001	0.4729	0.6105
LOW TIDE	1	84	15/26	57.69	3.16	0.9102	0.823
	2	55	14/26	53.85	3.244	0.8598	0.8088
	3	77	16/26	61.54	3.453	0.9057	0.8052
	4	66	13/26	50.00	2.864	0.8662	0.8284
	5	77	17/26	65.38	3.683	0.9283	0.8459

**TABLE 54 ZOOPLANKTON VARIATIONS IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING NEAP TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance In $No \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	1	68	25/28	89.29	5.688	1.169	0.899
	2	76	19/28	67.86	4.156	1.016	0.8684
	3	68	19/28	67.86	4.266	1.017	0.8529
	4	96	20/28	71.43	4.163	0.9455	0.8289
	5	100	20/28	71.43	4.126	0.9107	0.8091
	6	27	12/28	42.86	3.338	0.9188	0.8519
LOW TIDE	1	77	16/28	57.14	3.453	0.9303	0.8401
	2	60	18/28	64.29	4.152	0.9864	0.8605
	3	77	19/28	67.86	4.144	1.004	0.8606
	4	78	18/28	64.29	3.902	0.8859	0.7835
	5	82	16/28	57.14	3.404	0.8898	0.8127

**Table 55 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA AT KANDLA CREEK AND NEAR BY CREEKS DURING SPRING TIDE IN DECEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> / m <sup>3</sup> Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	4-22	6/26	23.08
			Copepods	4-32	8/26	30.77
			Mysids	0-2	1/26	3.85
			Urochordata	0-3	2/26	7.68
			Ciliates	0-1	1/26	3.85
			Larval forms	12-51	8/26	30.77
			<b>TOTAL ZOOPLANKTON</b>	<b>20-106</b>	<b>26</b>	
LOW TIDE	Sub surface	5	Tintinids	14-24	6/26	23.08
			Copepods	13-33	8/26	30.77
			Mysids	0-2	1/26	3.85
			Urochordata	0-2	2/26	7.68
			Ciliates	0-1	1/26	3.85
			Larval forms	23-41	8/26	30.77
			<b>TOTAL ZOOPLANKTON</b>	<b>55-84</b>	<b>26</b>	

**TABLE 56 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT HARBOUR AREA IN KANDLA CREEK AND, NEAR BY CREEKS DURING NEAP TIDE IN DECEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$ Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	6	Tintinids	6-25	7/28	25.00
			Copepods	5-30	8/28	28.57
			Arrow worms	0-2	1/28	3.57
			Mysids	0-2	1/28	3.57
			Urochordata	0-3	2/28	7.15
			Ciliates	0-2	1/28	3.57
			Larval forms	15-43	8/28	28.57
			TOTAL ZOOPLANKTON	<b>27-100</b>	<b>28</b>	
LOW TIDE	Sub surface	5	Tintinids	14-23	7/28	25.00
			Copepods	19-28	8/28	28.57
			Arrow worms	0-2	1/28	3.57
			Mysids	0-1	1/28	3.57
			Urochordata	0-2	2/28	7.15
			Ciliates	0-1	1/28	3.57
			Larval forms	22-39	8/28	28.57
			TOTAL ZOOPLANKTON	<b>60-82</b>	<b>28</b>	

**Table 57 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance $\times 10^3 N / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index $H (\log_{10})$	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	119	20/20	100	3.976	0.901	0.777
	SPM	92	17/20	85.00	3.538	0.834	0.747
LOW TIDE	Jetty	55	14/20	70.00	3.244	0.911	0.833
	SPM	73	16/20	80.00	3.496	0.829	0.743



**TABLE 58 ZOOPLANKTON VARIATION IN ABUNDANCE AND DIVERSITY IN SUB  
SURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR  
BY SPM DURING NEAP TIDE IN DECEMBER 2022**

Tide	Sampling Station	Abundance In $N \times 10^3 / m^3$	No of Species/groups observed /total species/group	% of diversity	Margalef's diversity index (Species Richness S)	Shannon Weiner index H ( $\log_{10}$ )	Diversity Index (Simpson's Index) 1-D
HIGH TIDE	Jetty	80	15/22	68.18	3.195	0.803	0.753
	SPM	90	13/22	59.09	2.667	0.737	0.740
LOW TIDE	Jetty	61	13/22	59.09	2.919	0.766	0.776
	SPM	68	12/22	54.55	2.607	0.712	0.709

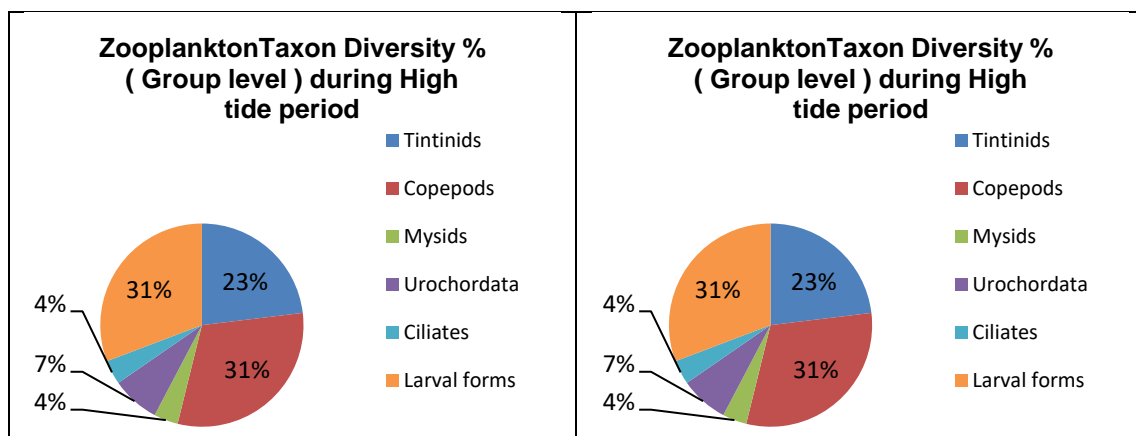
**Table 59 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT  
OOT AREA AND PATH FINDER CREEK AND NEAR BY SPM DURING SPRING TIDE IN  
DECEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton $\times 10^3 / m^3$  Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	14-22	4/20	20.00
			Copepods	22-25	7/20	35.00
			Urochordata	2-3	2/20	10.00
			Larval forms	54-67	6/20	30.00
			Nematode	0-2	1/20	5.00
			TOTAL ZOOPLANKTON	<b>92-119</b>	<b>20</b>	
LOW TIDE	Sub surface	2	Tintinids	12	4/20	20.00
			Copepods	15	7/20	35.00
			Urochordata	1-2	2/20	10.00
			Larval forms	27-44	6/20	30.00
			Nematode	0	1/20	5.00
			TOTAL ZOOPLANKTON	<b>55-73</b>	<b>20</b>	

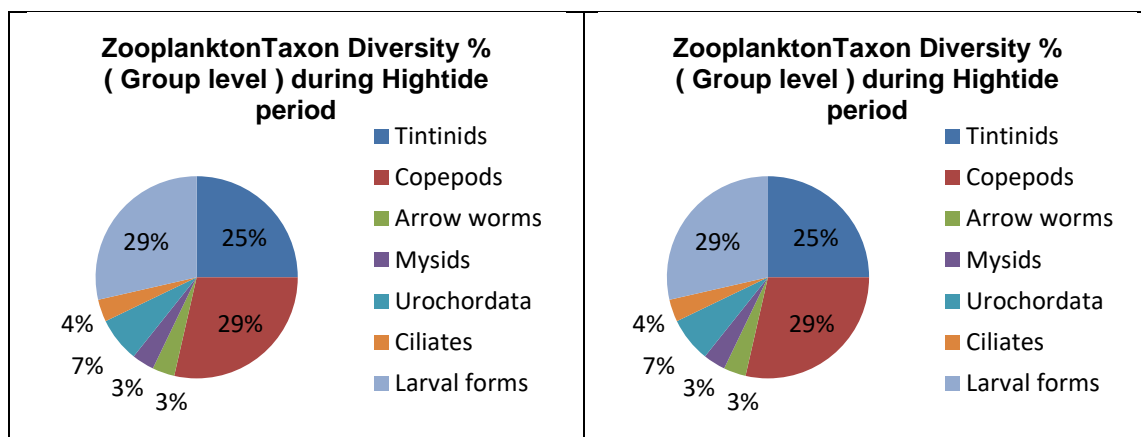
**TABLE 60 ABUNDANCE OF ZOOPLANKTON IN SUBSURFACE SAMPLING STATIONS IN DPT OOT AREA AT PATH FINDER CREEK AND NEAR BY SPM DURING NEAP TIDE IN DECEMBER 2022**

Tide	Surface	No of Sampling locations	Group of Zooplankton	Abundance of Zooplankton x10 <sup>3</sup> / m <sup>3</sup>  Group Range	Genera or species /total Zooplankton	Taxon Diversity % (Group level)
HIGH TIDE	Sub surface	2	Tintinids	23-36	5/22	22.73
			Copepods	6-15	7/22	31.82
			Arrow worms	0-1	1/22	4.55
			Urochordata	1	2/22	9.08
			Larval forms	41-46	7/22	31.82
			TOTAL ZOOPLANKTON	<b>80-90</b>	<b>22</b>	
LOW TIDE	Sub surface	2	Tintinids	21-32	5/22	22.73
			Copepods	4-8	7/22	31.82
			Arrow worms	0	1/22	4.55
			Urochordata	0-2	2/22	9.08
			Larval forms	25-37	7/22	31.82
			TOTAL ZOOPLANKTON	<b>61-68</b>	<b>22</b>	

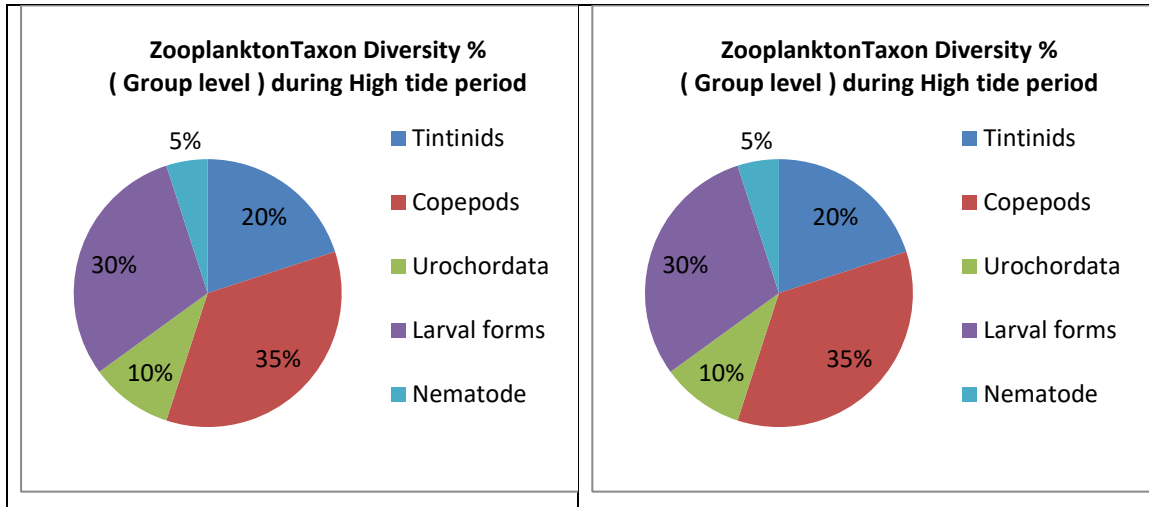
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Kandla Creek and nearby Creeks**



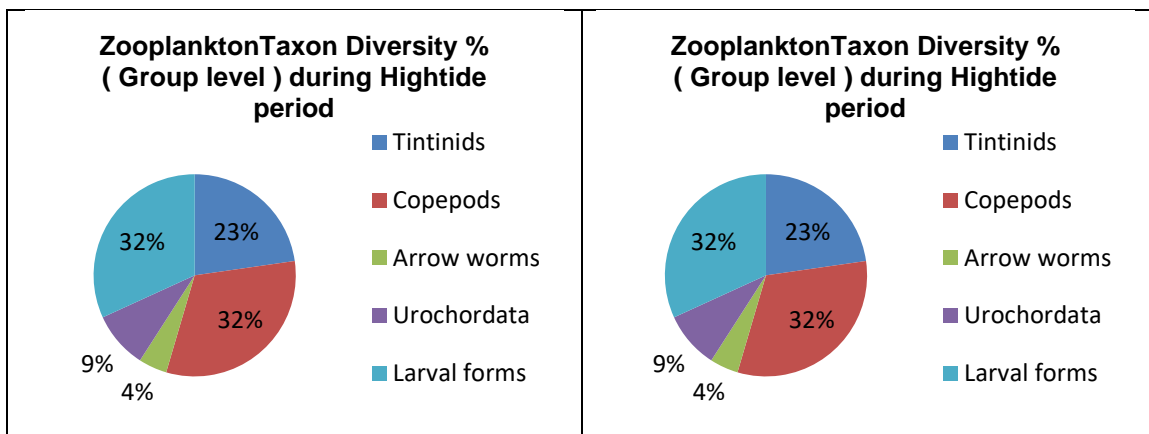
**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Kandla Creek and nearby Creeks**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Spring tide In Path Finder Creek and near Jetty**



**Taxon Diversity % of Zooplankton during High tide and Low tide period of Neap tide In Path Finder Creek near jetty and nearby SPM**



**TABLE 61 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF DECEMBER 2022**

GROUP	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
BLUE GREEN ALGAE	Nostocales	Oscillatoriaceae	<i>Oscillatoria sp.</i>	B1	Very sparse
DIATOMS	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Scattered
	Corethrales	Corethraceae	<i>Corethron sp.</i>	D3	Very sparse
	Coscinodiscals	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D4	Abundant
	Hemiaulales	Belleracheaceae	<i>Bellerachea sp.</i>	D5	Very sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Very sparse
	Melosirales	Melosiraceae	<i>Melosira sp.</i>	D7	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Guinardia sp.</i>	D8	Very sparse
			<i>Rhizosolenia sp.</i>	D9	Sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D10	Sparse
		Thalassiosiraceae	<i>Planktoniella sp.</i>	D11	Sparse
	Thalassiosirales	Lauderiaceae	<i>Lauderia sp.</i>	D12	Very sparse
		Skeletonemataceae	<i>Skeletonema sp.</i>	D13	Sparse
	Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D14	Sparse
			<i>Triceratium sp.</i>	D15	Very sparse
	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D16	Very sparse
			<i>Nitzschia sp.</i>	D17	Very sparse
			<i>Pseudo-nitzschia sp.</i>	D18	Very sparse
	Naviculales	Pleurosigmataceae	<i>Pleurosigma sp.</i>	D19	Very sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D20	Very sparse
	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp.</i>	D21	Very sparse
			<i>Fragilaria sp.</i>	D22	Sparse
			<i>Synedra sp.</i>	D23	Very sparse
	Striatellales	Striatellaceae	<i>Grammatophora sp.</i>	D24	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D25	Scattered
			<i>Thalassiothrix sp.</i>	D26	Dominant
DINO FLAGELLATES	Noctilucales	Noctilucaceae	<i>Noctiluca sp.</i>	DF1	Very sparse
	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF2	Very sparse
	Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
			<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE 62 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF DECEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Nostocales	Oscillatoriaceae	<i>Oscillatoria</i> sp.	B1	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix</i> sp.	B2	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia</i> sp	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros</i> sp.	D2	Abundant
	Corethrales	Corethraceae	<i>Corethron</i> sp	D3	Very sparse
	Coscinodiscales	Coscinodiscaceae	<i>Coscinodiscus</i> sp.	D4	Scattered
	Hemiaulales	Hemiaulaceae	<i>Cerataulina</i> sp.	D5	Very sparse
	Melosirales	Melosiraceae	<i>Melosira</i> sp	D6	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia</i> sp.	D7	Sparse
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus</i> sp	D8	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum</i> sp	D9	Scattered
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella</i> sp	D10	Very sparse
		Lauderiaceae	<i>Lauderia</i> sp	D11	Very sparse
		Skeletonemataceae	<i>Skeletonema</i> sp	D12	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontella</i> sp.	D13	Very sparse
			<i>Triceratium</i> sp.	D14	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria</i> sp.	D15	Very sparse
			<i>Nitzschia</i> sp	D16	Very sparse
			<i>Pseudo-nitzschia</i> sp.	D17	Very sparse
	Naviculales	Naviculaceae	<i>Navicula</i> sp.	D18	Very sparse
		<i>Pleurosigmataceae</i>	<i>Pleurosigma</i> sp.	D19	Sparse
Fragilariophyceae	Surirellales	Entomoneidaceae	<i>Entomoneis</i> sp.	D20	Very sparse
	Fragilariales	Fragilariaceae	<i>Asterionellopsis</i> sp	D21	Very sparse
			<i>Fragilaria</i> sp	D22	Scattered
			<i>Synedra</i> sp	D23	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema</i> sp.	D24	Scattered
			<i>Thalassiothrix</i> sp.	D25	Dominant
Noctiluca / Noctiluiphyceae (Dinokaryota)	Noctilucales	Noctilucaceae	<i>Noctiluca</i> sp.	DF1	Very sparse
Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium</i> sp.	DF2	Very sparse
	Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
			<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE 63 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF DECEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Chroococcales	Chroococcaceae	<i>Merismopedia sp.</i>	B1	Very sparse
	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B2	Very sparse
			<i>Oscillatoria sp.</i>	B3	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Planktothrix sp.</i>	B4	Very sparse
	Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B5	Very sparse
Ulvophyceae	Cladophorales	Cladophoraceae	<i>Cladophora sp.</i>	G1	Very sparse
Coscinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp</i>	D1	Abundant
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp</i>	D2	Scattered
	Corethrales	Corethraceae	<i>Corethron sp</i>	D3	Very sparse
	Coscinodisciales	Coscinodiscaceae	<i>Coscinodiscus sp.</i>	D4	Scattered
		Bellerophonaceae	<i>Bellerophon sp</i>	D5	Very sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Very sparse
		Streptothecaceae	<i>Helicotheca sp</i>	D7	Very sparse
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp</i>	D8	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp</i>	D9	Abundant
	Rhizosoleniales	Rhizosoleniaceae	<i>Rhizosolenia sp.</i>	D10	Sparse
	Thalassiosirales	Lauderiaceae	<i>Lauderia sp</i>	D11	Very sparse
		Thalassiosiraceae	<i>Planktoniella sp</i>	D12	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontella sp</i>	D13	Scattered
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D14	Dominant
			<i>Nitzschia sp</i>	D15	Scattered
			<i>Pseudo-nitzschia sp</i>	D16	Very sparse
	Naviculales	Naviculaceae	<i>Navicula sp</i>	D17	Very sparse
		Plagiotropidaceae	<i>Plagiotropis sp</i>	D18	Very sparse
		Pinnulariaceae	<i>Pinnularia sp</i>	D19	Very sparse
		Pleurosigmaaceae	<i>Pleurosigma sp</i>	D20	Very sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D21	Sparse
		Surirellaceae	<i>Campylodiscus sp</i>	D22	Very sparse
			<i>Surirella sp</i>	D23	Very sparse
Fragilariophyceae	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp.</i>	D24	Very sparse
			<i>Synedra sp.</i>	D25	Very sparse
	Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D26	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D27	Very sparse
			<i>Thalassiothrix sp.</i>	D28	Sparse
Dinophyceae	Peridiniales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
	Gonyaulacales	Pyrophacaceae	<i>Pyrophacus sp.</i>	DF2	Very sparse
		Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
			<i>Ceratium tripos</i>	DF4	Very sparse

**TABLE 64 SYSTEMATIC ACCOUNT OF PHYTOPLANKTON IN THE SAMPLING LOCATIONS IN OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING AND SPRING TIDE OF DECEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	Relative Abundance
Cyanophyceae	Chroococcales	Chroococcaceae	<i>Merismopedia sp.</i>	B1	Very sparse
	Nostocales	Oscillatoriaceae	<i>Lyngbya sp.</i>	B2	Very sparse
	Oscillatoriales	Phormidiaceae	<i>Oscillatoria sp.</i>	B3	Very sparse
			<i>Planktothrix sp.</i>	B4	Very sparse
	Stigonematales	Stigonemataceae	<i>Stigonema sp.</i>	B5	Very sparse
Coccinodiscophyceae	Biddulphiales	Biddulphiaceae	<i>Biddulphia sp.</i>	D1	Scattered
	Chaetocerotales	Chaetocerotaceae	<i>Chaetoceros sp.</i>	D2	Abundant
	Corethrales	Corethraceae	<i>Corethron sp.</i>	D3	Very sparse
	Coccinodiscals	Coccinodiscaceae	<i>Coccinodiscus sp.</i>	D4	Dominant
	Hemiaulales	Bellerucheaceae	<i>Belleruche sp.</i>	D5	Very sparse
		Hemiaulaceae	<i>Cerataulina sp.</i>	D6	Very sparse
		Streptothecaceae	<i>Helicotheca sp.</i>	D7	Very sparse
	Rhizosoleniales	Rhizosoleniaceae	<i>Guinardia sp.</i>	D8	Very sparse
			<i>Rhizosolenia sp.</i>	D9	Abundant
	Leptocylindrales	Leptocylindraceae	<i>Leptocylindrus sp.</i>	D10	Very sparse
	Lithodesmiales	Lithodesmiaceae	<i>Ditylum sp.</i>	D11	Abundant
	Thalassiosirales	Thalassiosiraceae	<i>Planktoniella sp.</i>	D12	Very sparse
			<i>Thalassiosira sp.</i>	D13	Very sparse
		Lauderiaceae	<i>Lauderia sp.</i>	D14	Very sparse
	Triceratiales	Triceratiaceae	<i>Odontella sp.</i>	D15	Sparse
			<i>Triceratium sp.</i>	D16	Very sparse
Bacillariophyceae	Bacillariales	Bacillariaceae	<i>Bacillaria sp.</i>	D17	Dominant
			<i>Cylindrotheca sp.</i>	D18	Very sparse
			<i>Nitzschia sp.</i>	D19	Sparse
			<i>Pseudo-nitzschia sp.</i>	D20	Very sparse
	Naviculales	Pleurosigmataceae	<i>Pleurosigma sp.</i>	D21	Sparse
	Striatellales	Striatellaceae	<i>Striatella sp.</i>	D22	Very sparse
	Surirellales	Entomoneidaceae	<i>Entomoneis sp.</i>	D23	Very sparse
		Surirellaceae	<i>Surirella sp.</i>	D24	Very sparse
Fragilariophyceae	Climacospheniales	Climacospheniaceae	<i>Climacosphenia sp.</i>	D25	Very sparse
	Fragilariales	Fragilariaceae	<i>Asterionellopsis sp.</i>	D26	Very sparse
			<i>Synedra sp.</i>	D27	Very sparse
	Licmophorales	Licmophoraceae	<i>Licmophora sp.</i>	D28	Very sparse
	Thalassionematales	Thalassionemataceae	<i>Thalassionema sp.</i>	D29	Sparse
			<i>Thalassiothrix sp.</i>	D30	Scattered
Dinophyceae	Peridinales	Protoperidiniaceae	<i>Protoperidinium sp.</i>	DF1	Very sparse
	Dinophysales	Dinophysaceae	<i>Dinophysis sp.</i>	DF2	Very sparse
	Gonyaulacales	Ceratiaceae	<i>Ceratium furca</i>	DF3	Very sparse
			<i>Ceratium tripos</i>	DF4	Very sparse



**TABLE 65 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING NEAP TIDE OF DECEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Abundant
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Very sparse
		Tintinnidae	<i>Amphorellopsis sp.</i>	T5	Very sparse
			<i>Eutintinnus sp.</i>	T6	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T7	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C5	Scattered
	Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C6	Very sparse
		Euterpinae	<i>Euterpina sp.</i>	C7	Very sparse
	Poecilostomatoida	Oncaeidae	<i>Oncaea sp.</i>	C8	Very sparse
Sagittoidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea	L2	Very sparse
Maxillopoda			Cirripede larvae	L3	Very sparse
Thecostraca			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Gastropoda			Opisthobranchia larvae	L6	Very sparse
Streptoneura			Trochophore larvae	L7	Very sparse
Polychaeta			Veliger larvae of bivalves	L8	Very sparse
Pelecypoda					

**TABLE 66 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING OF DPT HARBOUR AREA AT KANDLA CREEK AND NEARBY CREEKS DURING SPRING TIDE OF DECEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Scattered
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis mortensenii</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Sparse
		Tintinnidae	<i>Eutintinnus sp.</i>	T5	Very sparse
		Xystonellidae	<i>Favella sp.</i>	T6	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Acartiidae	<i>Acartia sp.</i>	C3	Very sparse
		Clausocalanidae	<i>Clausocalanus sp.</i>	C4	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C5	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C6	Abundant
	Harpacticoida	Ectinosomatidae	<i>Microsetella sp.</i>	C7	Very sparse
		Euterpinae	<i>Euterpina sp.</i>	C8	Very sparse
Malacostraca	Mysida, Decapoda	Penaeidae	<i>Metapenaeus sp.</i>	M1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Oligohymenophorea	Sessilida	Zoothamniidae	<i>Zoothamnium sp.</i>	CI1	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea	L2	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
			Cyphonautes larvae	L4	Very sparse
			Ophiopluteus larvae	L5	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L6	Very sparse
Polychaeta			Trochophore larvae	L7	Sparse
Pelecypoda			Veliger larvae of bivalves	L8	Very sparse

**TABLE 67 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING NEAP TIDE OF DECEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Abundant
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis gracilis</i>	T3	Very sparse
			<i>Tintinnopsis radix</i>	T4	Scattered
		Xystonellidae	<i>Favella sp.</i>	T5	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Very sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C4	Sparse
	Harpacticoida	Euterpinae	<i>Euterpina sp.</i>	C5	Very sparse
		Ectinosomatidae	<i>Microsetella sp.</i>	C6	Very sparse
	Poecilostomatoida	Corycaidae	<i>Corycaeus sp.</i>	C7	Very sparse
Sagittioidea	Aphragmophora	Sagittidae	<i>Sagitta sp.</i>	A1	Very sparse
Appendicularia		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Asciacea			Ascidian tadpole larvae	L2	Very sparse
Malacostraca Decapoda			Brachyuran zoea	L3	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L4	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L5	Very sparse
Polychaeta			Trochophore larvae	L6	Very sparse
Pelecypoda			Veliger larvae of bivalves	L7	Very sparse

**TABLE 68 SYSTEMATIC ACCOUNT OF ZOOPLANKTON FROM THE SAMPLING LOCATIONS OF DPT OOT AREA AT PATH FINDER CREEK AND NEARBY SPM AT VADINAR DURING SPRING TIDE OF DECEMBER 2022:**

CLASS	ORDER	FAMILY	GENUS/SPECIES	#	RELATIVE ABUNDANCE
Spirotrichea	Tintinnida	Tintinnidiidae	<i>Leprotintinnus sp.</i>	T1	Scattered
		Codonellidae	<i>Tintinnopsis failakkaensis</i>	T2	Very sparse
			<i>Tintinnopsis radix</i>	T3	Sparse
		Xystonellidae	<i>Favella sp.</i>	T4	Very sparse
Crustacea Subclass: Copepoda	Calanoida	Paracalanidae	<i>Acrocalanus sp.</i>	C1	Very sparse
			<i>Parvocalanus sp.</i>	C2	Very sparse
		Centropagidae	<i>Centropages sp.</i>	C3	Very sparse
	Cyclopoida	Oithonidae	<i>Oithona sp.</i>	C4	Abundant
	Harpacticoida	Euterpinae	<i>Euterpina sp.</i>	C5	Very sparse
		Ectinosomatidae	<i>Microsetella sp.</i>	C6	Very sparse
	Poecilostomatoida	Corycaidae	<i>Corycaeus sp.</i>	C7	Very sparse
		Fritillariidae	<i>Fritillaria sp.</i>	U1	Very sparse
Appendicularia		Oikopleuridae	<i>Oikopleura sp.</i>	U2	Very sparse
Copepoda			Nauplius larvae of copepods	L1	Dominant
Malacostraca Decapoda			Brachyuran zoea	L2	Very sparse
Maxillopoda Thecostraca			Cirripede larvae	L3	Very sparse
Gastropoda Streptoneura			Opisthobranchia larvae	L4	Very sparse
Polychaeta			Trochophore larvae	L5	Sparse
Pelecypoda			Veliger larvae of bivalves	L6	Very sparse
			Unidentified nematodes	N1	Very sparse

**BENTHIC ORGANISMS:**

Few Benthic organisms were observed in the collected sediments by using the Van-veen grabs during the sampling conducted during spring tide period and Neap tide period from DPT harbour region and nearby creek. The meio-benthic organisms during spring tide were represented by Polychaetes *Nereis sp.*, during Neap tide by *Neries sp.*, *Cossura sp.*, *Heteromastus sp.* Population of benthic fauna was varying from 0-30- N/m<sup>2</sup> during spring tide and 10-40 N/m<sup>2</sup> during Neap tide. The benthic communities at path finder Creek were represented by Polychaetes *Heteromastus sp.* and *Notomastus sp.* Their population was varying as 20 N/m<sup>2</sup> at OOT jetty premises and 40 N/m<sup>2</sup> near the SPM area during spring tide and 50 N/m<sup>2</sup> at OOT jetty premises and 70 N/m<sup>2</sup> near the SPM area during Neap tide period.

**Table 69 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING SPRING TIDE IN DECEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPT HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family: NEREIDAE <i>Nereis sp.</i>	10	0	0	20	30	NS
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	10	0	0	20	30	NS

NS : No sample

**Table 70 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT HARBOUR AREA CREEKS DURING NEAP TIDE IN DECEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS						
REPRESENTATION BY GROUP	DPT HARBOUR			CREEKS		
<b>Benthic fauna</b>						
<b>POLYCHAETES</b>	DPA-1	DPA-2	DPA-3	DPA-4	DPA-5	DPA-6
Family : NEREIDAE <i>Nereis sp.</i>	20	30	10	10	20	NS
Family; Cossuride <i>Cossura sp.</i>	10	0	10	0	10	
Family; Capitellidae <i>Heteromastus sp.</i>	0	0	0	0	10	NS
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	30	30	20	10	40	

**Table 71 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT OOT JETTY AREA, VADINAR DURING SPRING TIDE IN DECEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family; Capitellidae <i>Heteromastus sp.</i>	20	40
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	20	40

**Table 72 BENTHIC FAUNA IN THE SAMPLING LOCATIONS IN DPT OOT JETTY AREA, VADINAR DURING NEAP TIDE IN DECEMBER 2022**

ABUNDANCE IN NO/M <sup>2</sup> DIFFERENT SAMPLING STATIONS		
REPRESENTATION BY GROUP	OOT Jetty Area	SPM area
<b>POLYCHAETES</b>		
Family; Capitellidae <i>Heteromastus sp.</i>	40	50
Family : Capitellidae <i>Notomastus sp.</i>	10	20
TOTAL Benthic Fauna NUMBER/ M <sup>2</sup>	50	70

## **CHAPTER-11**

### **CONCLUSIVE SUMMARY & REMEDIAL MEASURES**

### 11.0 Conclusive Summary and Remedial measures Suggested

- The AAQ monitoring of six locations at Deendayal Port Authority indicates that the mean  $PM_{10}$  values for four locations viz. Marine Bhavan, Oil Jetty, Estate Office and Coal storage area were found higher than the permissible limit (standards  $100 \mu g/m^3$ ) while  $PM_{2.5}$  were higher at Marine Bhavan and Coal storage ( $60 \mu g/m^3$ ). The higher concentration of Particulate matter at Marine Bhavan may be due to vehicles emissions during loading-unloading of food grains and timbers; at Estate office due to construction work, vehicles emission produced from trucks, heavy duty vehicles that pass through the road outside Kandla port and Oil jetty area; while at Coal Storage area lifting of coal from grab yard and other coal handling processes. Moreover, the transportation of coal produces pollution from heavy vehicles. At Tuna port location and Gopalpuri Location, the concentration all parameter was within the standard limit. The concentration of  $PM_{10}$  at Gopalpuri was varied from  $92-109 \mu g/m^3$  while mean value was  $98 \mu g/m^3$  and  $PM_{2.5}$  concentration ranged from  $35-56 \mu g/m^3$  while mean value was observed  $46.0 \mu g/m^3$  which were within the prescribed standard limit ( $100 \mu g/m^3$  and  $60 \mu g/m^3$ ), At Tuna port the concentration of  $PM_{10}$  was ranged from  $78-59 \mu g/m^3$  while mean was  $67 \mu g/m$  and the concentration of  $PM_{2.5}$  ranged was  $26-40 \mu g/m^3$  and mean was  $33 \mu g/m^3$  which were within the standard limit ( $100 \mu g/m^3$  and  $60 \mu g/m^3$ ) prescribed by NAAQS.
- At Vadinar, the average concentration of  $PM_{10}$  was  $108 \mu g/m^3$  and  $PM_{2.5}$  was  $40 \mu g/m^3$  at Admin Colony, the average  $PM_{10}$  concentration  $99 \mu g/m^3$  and  $PM_{2.5}$   $38 \mu g/m^3$  was at Signal building which was within the standard limit.
- During winter, the concentration of  $PM_{10}$  and  $PM_{2.5}$  has been slowly augmented and reached a peak in the evening due to surface inversion of temperature after sunset. Thus, the pollutants are subsequently trapped in the lower layer of the atmosphere due to high atmospheric air pressure.
- Further, precautionary measures and management strategies to minimize the effect of particulate as well as gaseous pollutants have also been suggested for achieving its ambient levels in and around Kandla Port and Vadinar Port, Gujarat, India.
- Drinking water at all the twenty locations was found potable and it was found within in line of BIS standards (IS: 10500-2012).



- Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. All sampling location were within the permissible limit day time 75 dB (A) and night time 70 dB (A) for the industrial area.
- The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) STP and Vadinar were in line with the standards set by the Central Pollution Control Board.
- It was suggested to monitor the STP performance on regular basis to avoid flow of contamination / Polluted water into the sea.
- Good species diversity suggests a relatively successful species in this habitat. A greater number of successful species and a more stable ecosystem. More ecological niches are available and the environment is less likely to be hostile complex food webs environmental change is less likely to be damaging to the ecosystem as a whole.
- The results obtained from the study for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.
- The mean day time temperature at Deendayal Port was 25.20 °C. The day-time maximum temperature was 28.30°C and minimum was 21.7 °C. The mean night time temperature recorded was 24.33 °C. The night-time maximum temperature was 26.60°C and minimum was 22.15 °C. The mean Solar Radiation in December 1st December 2022 to 15th December 2022 was 89.76 w/m<sup>2</sup>. The maximum solar radiation was recorded 606.1 w/m<sup>2</sup> in 4<sup>th</sup> December, 2022 and the minimum solar radiation was recorded 0.0 w/m<sup>2</sup> in December, 2022. The mean Relative humidity was 60.25 % for the 1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 of December. Maximum Relative humidity was recorded 79.0 % and minimum Relative humidity was recorded 38.0 %. The average wind velocity for the entire 1<sup>st</sup> December 2022 to 15th December 2022 of December was 3.07 m/s. Maximum wind velocity was recorded 9.0 m/s. The wind direction was mostly North-East.
- The results obtained from the study for the 1<sup>st</sup> December 2022 to 15th December 2022 of December 2022 for biological and ecological parameters in marine water for Arabian Sea at surrounding area of Deendayal Port Authority (DPA) Kandla and Vadinar were not affected by Port activities.

### **Reasons for higher Values of PM<sub>10</sub>**

- The unloading of coal directly in the truck, using grabs cause coal to spread in air as well as coal dust to fall on ground. This settled coal dust again mixes with the air while trucks travel through it.
- Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in spillage of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increased PM values around marine Bhavan & Coal storage area.

### **Remedial Measures**

The values of PM<sub>10</sub> & PM<sub>2.5</sub> during the 1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 of December, 2022 were beyond the standard limit at 4 locations (Marine Bhavan, Estate office Oil Jetty and Coal storage) at Gopalpuri and Tuna Port concentration of particulate matter was within the standard limit. Given below are the remedial measures suggest to minimize the Air pollution.

- During 1<sup>st</sup> December 2022 to 15<sup>th</sup> December 2022 overall ambient air quality of the DPA was within CPCB permissible limits except TSPM, PM<sub>10</sub>, PM<sub>2.5</sub> at Coal storage area, Marine Bhavan, Oil Jetty. To improve air quality the port was using number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port.

### **Solution towards the Green port:**

Today, it is increasingly recognized that air pollution hurts human health. Consequently, efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits.

The guidelines can be considered a basis for governments for the implementation of a strategic plan focused on the reduction of multi pollutant emission, as well as of the overall air pollution related risk.

- The plantation should be all along the periphery of the port and inside and outside the port along with the road. Trees having high dust trapping efficiency (*Azadirachta indica*, *Cassia fistula*, *Delonix regia*, *Ficus religiosa*, *Pterocarpus marsupium*) are to be grown alongside the roads.
- The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.
- The vehicles should be covered during transportation and the vehicle carrying the coal should not be overloaded by raising the height of carriage.
- The water sprinklers should be use during transportation of loaded heavy vehicles on raw road.
- It should be ensuring that regular sweeping of coal internal, main road and space a free circulation.
- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle- Mask advised in sensitive areas.
- Department for use maintenance should have a routine checkup noise level by replacing bearings, tights of all loose parts that can vibrate.
- Speed control is also an effective way to mitigate noise pollution, the lowest sound emission arises from vehicles moving smoothly.
- Use of renewable energy like solar energy should be optimal and ensure to work continuously.
- Keep neat and clean public transport and all basic items at public interaction places as much as possible.
- Technology like Electric cart, Inter-Terminal Transfer (ITT) are worthy selection to reduce Port operation efficiency and fuel cost.
- Conventional RTGCs should be altered as E-RTGCs counting inside the port completely.
- Initiate Natural Gas (CNG) as fuel by all buses and trucks.

### **Green Ports Initiative**

- Deendayal Port is committed to sustainable development and adequate measures are being taken to maintain the Environmental well-being of the Port and its surrounding environs. Weighing in the environmental perspective for sustained growth, the Ministry of Shipping had started “Project Green Ports” which will help in making the Major Ports across India cleaner and greener. “Project Green Ports” will have two verticals - one is “Green Ports Initiatives” related to environmental issues and second is “Swachh Bharat Abhiyaan”.
- The Green Port Initiatives include twelve initiatives such as preparation and monitoring plan, acquiring equipments required for monitoring environmental pollution, acquiring dust suppression system, setting up of waste water treatment plants/ garbage disposal plant, setting up Green Cover area, projects for energy generation from renewable energy sources, completion of shortfalls of Oil Spill Response (OSR) facilities (Tier-I), prohibition of disposal of almost all kind of garbage at sea, improving the quality of harbour wastes etc.
- Deendayal port has also appointed GEMI as an Advisor for “Making Deendayal Port a Green Port - Intended Sustainable Development within the Green Port Initiatives.
- Deendayal Port has also signed MOU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Trust. The plantation is being carried out by the Social Forestry division of Kachchh.

## **CHAPTER-12**

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# **ANNEXURE - III**

DEENDAYAL PORT AUTHORITY - MARINE DEPARTMENT				
Statement of Hazardous & Non Hazardous Waste disposal from the vessels at Kandla & Vadinar Port Year 2022-23				
Sr.No.	MONTH	HAZARDOUS WASTE DATA for FY 2022-23		
		Total	Used spent Oil	Waste residue containing oil
		Quantity Disposed (MT)		
1	Apr-22	1237.33	412.44	824.89
2	May-22	1285.56	428.52	857.04
4	Jun-22	1568.41	522.80	1045.61
5	Jul-22	1238.46	412.82	825.64
3	Aug-22	1414.94	471.65	943.29
4	Sep-22	872.60	290.87	581.73
5	Oct-22	1210.04	403.35	806.69
3	Nov-22	938.71	312.90	625.81
4	Dec-22	1286.64	428.88	857.76
5	Jan-23	1284.40	428.13	856.27
3	Feb-23	762.19	254.06	508.13
4	Mar-23	637.09	212.36	424.73
<b>Total</b>	--		<b>4578.79</b>	<b>9157.58</b>
<b>Total Hazardous waste Genreted for FY 2022-23</b>				<b>13736.37</b>

  
 उप संरक्षक  
 दीनदयाल पतन प्राधिकरण  
 Deputy Conservator  
 Deendayal Port Authority

## Marine Department

Statement showing the Collection and disposal of Hazardous and Non-Hazardous Wastes carried out by various parties from April - 2022 to Mar - 2023

No.	Name of Party	Type of Licence	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	Total
1	Alicid Organic Industries Ltd	Hazardous	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Amar Hydrocarbon Pvt. Ltd	Hazardous	-	-	-	-	-	-	-	-	-	19.00	-	-	19.00
3	Atlas Organics Pvt. Ltd	Hazardous	21.39	35.28	-	-	34.06	-	-	18.80	10.98	-	17.06	-	137.57
4	Aviation Corporation	Hazardous	35.12	50.34	-	-	-	-	-	-	-	-	-	-	85.46
5	Fine Refiners Pvt. Ltd	Hazardous	-	14.50	53.77	21.08	-	20.11	16.32	-	43.56	-	39.65	-	208.99
6	Mohalaxmi Asphalt Pvt Ltd	Hazardous	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Pryansi Corporation	Hazardous	52.91	22.44	11.38	30.33	-	30.65	-	-	17.56	-	49.18	36.05	250.50
8	Revolucion Petrochem LLP	Hazardous	874.00	965.00	964.00	710.12	1,058.06	463.81	713.57	524.23	787.61	888.73	339.75	257.12	8,546.00
9	Shano Oil Process	Hazardous	-	-	-	-	-	-	-	-	-	-	-	-	-
10	United Shipping Company	Hazardous	253.91	198.00	539.26	476.93	322.82	358.03	480.15	395.68	426.93	376.67	316.55	343.92	4,488.85
11	Chitrukut Trading & Industries	Non-Hazardous	-	0.16	0.19	0.19	0.17	0.35	6.36	-	31.38	12.42	3.94	16.54	71.70
12	Golden Shipping Services	Non-Hazardous	77.42	38.26	19.63	1.14	30.28	8.36	21.82	26.57	15.06	22.82	18.42	46.48	326.26
13	Green Earth Marine Solution	Non-Hazardous	-	39.72	3.46	2.88	3.24	2.30	-	3.60	-	1.30	2.88	-	59.38
14	Harish A. Pandya	Non-Hazardous	3.58	0.06	3.20	-	-	4.47	1.13	-	0.22	-	5.70	4.89	23.25
15	K M Enterprise	Non-Hazardous	30.15	47.56	57.24	101.56	64.00	35.28	46.08	63.36	72.93	65.02	91.77	41.82	716.77
16	Naaz Shipping Services Ent	Non-Hazardous	-	-	-	-	-	-	-	-	-	10.80	-	-	10.80
17	New India Marine Work	Non-Hazardous	1.44	2.16	-	-	-	-	-	-	-	-	2.16	1.08	6.84
18	Omega Marine Services	Non-Hazardous	350.63	73.10	42.15	-	104.40	25.46	23.69	45.97	53.31	19.80	43.32	23.29	805.12
19	V K Enterprises	Non-Hazardous	23.76	28.08	12.96	10.80	15.12	17.28	10.80	12.96	15.12	10.80	12.96	10.80	181.44
20	Vishwa Trade-link Inc	Non-Hazardous	21.92	11.74	20.65	30.10	29.38	29.88	31.48	35.44	14.59	15.91	10.52	20.02	271.63
Hazardous Total			1,237.33	1,285.56	1,568.41	1,238.46	1,414.94	872.60	1,210.04	938.71	1,286.64	1,284.40	762.19	637.09	13,736.37
Non-Hazardous Total			508.90	240.84	159.48	146.67	246.59	123.38	141.36	187.90	202.61	158.87	191.67	164.92	2,473.19

  
 उपा संरक्षक  
 दीनदयाल पतन प्राधिकरण  
 Deputy Conservator  
 Deendayal Port Authority

# **ANNEXURE - IV**



**DEENDAYAL PORT AUTHORITY  
MARINE DEPARTMENT**

**Statement of Hazardous & Non Hazardous Waste  
disposal from the vessels at Kandla & Vadinar Port  
YEAR 2022-23**

(In MT)

Sr. No.	MONTH	YEAR	Hazardous (Sludge)	Non Hazardous (Garbage)
1	APRIL	2022	1237.33	508.90
2	MAY	2022	1285.56	240.84
3	JUNE	2022	1568.41	159.48
4	JULY	2022	1238.46	146.67
5	AUGUST	2022	1414.94	246.59
6	SEPTEMBER	2022	872.60	123.38
7	OCTOBER	2022	1210.04	141.36
8	NOVEMBER	2022	938.71	187.90
9	DECEMBER	2022	1286.64	202.61
10	JANUARY	2023	1284.40	158.87
11	FEBRUARY	2023	762.19	191.67
12	MARCH	2023	637.09	164.92
	<b>TOTAL</b>		<b>13736.37</b>	<b>2473.19</b>

  
**Deputy Conservator**  
Deedayal Port Authority



# **Annexure -2**

**Monitoring the Implementation of Environmental Safeguards**  
**Ministry of Environment Forest & Climate Change**  
**Integrated Regional Office (WZ), Gandhinagar**  
**Monitoring Report**  
**(for the period up to May, 2023)**

**DATA SHEET**

1.	Project type: River-valley/ Mining / Industry / Thermal / Nuclear / Other (specify)		:	Infrastructure & miscellaneous projects + CRZ
2.	Name of the project		:	Development of 3 Remaining Integrated Facilities (stage I) within the existing Deendayal Port Trust (Erstwhile: Kandla Port Trust) at Gandhidham, Kutch, Gujarat.
3.	Clearance letter (s) / OM No. and Date		:	Environment and CRZ clearance accorded by the MoEF&CC, GoI vide file no. 10-9/2017-IA-III dated 18/2/2020.
4.	Location		:	
	a.	District (S)	:	Kachchh
	b.	State (s)	:	Gujarat
	c.	Latitude/ Longitude	:	23°01' N, 70°13' E
5.	Address for correspondence		:	
	a.	Address of Concerned Project Chief Engineer (with pin code & Telephone/telex/fax numbers)	:	Chief Engineer, Deendayal Port Authority, A.O. Building, Gandhidham- 370 201. P.O. Box no. 50. Phone: 02836 233192 02836 220050
	b.	Address of Project: Engineer/Manager (with pin code/ Fax numbers)	:	Same as above
6.	Salient features		:	
	a.	of the project	:	<b>1.</b> Development of Container Terminal at Tuna off-Tekra on BOT Basis: (Jetty: T-shape 1100m X 54m, Capacity: 2.19 million TEUs/Annum, Capital Dredging: 13,56,000 M3, Maintenance Dredging 271200 M3/year, Land Area req.: 84 ha, Breakwater: Length of 1400 m, with 20 m of height, Estimated Cost: 3097 cr.). <b>2.</b> Construction of Port Craft Jetty & Shifting of SNA Section. (Dredging: 27357.00 m3, Estimated Cost: 23.17 cr.). <b>3.</b> Providing Railway Line from NH 8A to Tuna Port. (Length – 11 km, Estimated

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				cost: 94 cr.).
	b.	of the environmental management plans	:	The salient feature of the EMP has already been submitted with last compliance report submitted
7.		Production details during the compliance period and (or) during the previous financial year		Project at Sr.No.1 – container terminal at Tuna Tekra – No construction activity started.  Project at Sr. no 2 – For Parking of port Crafts.  Project at Sr.no. 3 – Railway Line from NH 8 A to tuna.
8.	The breakup of the project area		:	~95 Ha
	a.	submergence area forest & non-forest	:	NIL
	b.	Others	:	NIL
9.	Breakup of the project affected Population with enumeration of Those losing houses / dwelling units Only agricultural land only, both Dwelling units & agricultural Land & landless labourers/artisan		:	NIL
	a.	SC, ST/Adivasis	:	NIL
	b.	Others (Please indicate whether these Figures are based on any scientific And systematic survey carried out Or only provisional figures, if a Survey is carried out give details And years of survey)	:	NIL
10.	Financial details		:	
	a.	Project cost as originally planned and subsequently revised estimates and the year of price reference :		
	1.	Estimated Cost of the Project	:	Total Rs. 3214.17 Crore  1. Development of Container Terminal at Tuna off-Tekra on a BOT Basis (Estimated Cost: 3097 cr.). 2. Construction of Port Craft Jetty & Shifting of SNA Section (Estimated Cost: 23.17 cr.). 3. Providing Railway Line from NH 8A to Tuna Port. (Estimated cost: 94 cr.).

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	b.	Allocation made for environ-mental management plans with item wise and year wise Break-up.	:	The allocation made under the "Environmental Services & Clearance of other related Expenditure" scheme during BE 2023-2024 is Rs. 274 Lakhs.
	c.	Benefit cost ratio / Internal rate of Return and the year of assessment	:	<p>1. Development of Container Terminal at Tuna off-Tekra on a BOT Basis. (Project IRR 14.77 %, Economic IRR 15.97%).</p> <p>2. Providing Railway Line from NH 8A to Tuna Port. (Project IRR 14.4 % and EIRR 15.47%).</p> <p>3. Construction of the Port Craft jetty &amp; shifting of the SNA Section is essential, looking towards the safety aspect &amp; smooth operation of the entire Port (essential urgent requirement).</p>
	d.	Whether (c) includes the Cost of environmental management as shown in the above.	:	Yes
	e.	Actual expenditure incurred on the project so far	:	<p>The projects viz. Construction of the Port Craft jetty &amp; shifting of the SNA Section (Actual Cost: Rs. 22 crores) and Railway line NH 8 A to Tuna (Rs. 94 crores deposited by DPA to Indian Railways) have already been completed.</p> <p>The Project at Sr. No. 1 of the EC &amp; CRZ Clearance dated 18/02/2020 i.e. Development of Container Terminal at Tuna off Tekra on BOT Basis has not yet started</p>
	f.	Actual expenditure incurred on the environmental management plans so far	:	The expenditure made under the scheme of "Environmental Services & Clearance thereof other related Expenditure" is Rs. 73.99 Lakhs from Dec, 2022 to May 2023.
11.	Forest land requirement		:	
	a.	The status of approval for diversion of forest land for non-forestry use	:	NIL
	b.	The status of clearing felling	:	NIL
	c.	The status of compensatory afforestation, it any	:	NIL

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	d.	Comments on the viability & sustainability of compensatory afforestation program in the light of actual field experience so far	:	NIL
12.		The status of clear felling in Non-forest areas (such as submergence area of reservoir, approach roads), it any with quantitative information	:	NIL
13.		Status of construction	:	
	a.	Date of commencement ( Actual and/or planned )	:	1.Development of Container Terminal at Tuna off-Tekra on BOT Basis – No construction activity has started yet. 2.Construction of Port Craft Jetty & Shifting of SNA Section – Work Completed. 3.Providing Railway Line from NH 8A to Tuna Port. – Work completed.
	b.	Date of completion ( Actual and/or planned )	:	1. Development of Container Terminal at Tuna off-Tekra on BOT Basis – No construction activity has started yet. Planned completion June 2025 (tentative). 2. Construction of Port Craft Jetty & Shifting of SNA Section – Work Completed. 3. Providing Railway Line from NH 8A to Tuna Port. – Work completed.
14.		Reasons for the delay if the Project is yet to start	:	The projects viz. Construction of the Port Craft jetty & shifting of the SNA Section and Railway line NH 8 A to Tuna have already been completed.  The Project at Sr. No. 1 of the EC & CRZ Clearance dated 18/02/2020 i.e. Development of Container Terminal at Tuna off Tekra on BOT Basis has not yet started.
15		Details of site visit :  a) The dates on which the project was monitored by the MoEF&CC Regional Office on previous occasions (if applicable).  b) Date of site visit for this monitoring report.		-----  -----

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16	<p>Details of correspondence with project authorities for obtaining action plans/information on status of compliance to safeguards other than the routine letters for logistic support for site visit.</p> <p>(The first monitoring report may contain the details of all the letters issued so far but the later reports may cover only the letters issued subsequently)</p>	:	-----
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