DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

www.deendayalport.gov.in

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

EG/WK/4751/Part (remaining 3 facilities)/ 357

Dated:12/09/2023

To,
The Director (Environment) & Member Secretary,
Gujarat Coastal Zone Management Authority,
Govt. of Gujarat,
Forest & Environment Department,
Block No.14, 8th floor,
Sachivalaya,
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 – **Submission of Point-wise Compliances of the stipulated conditions in CRZ Recommendations reg.**

Ref.:
1) Letter No. ENV-I0-2015-248-E (T-Cell) dated 29/6/2016 of Director (Environment) & Additional Secretary, Forest & Environment Department, GoG.
2) DPT letter no. EG/WK/4751/Part (remaining 3 facilities)/78 dated 22 (24)/12/2020 alongwith point-wise compliance report of the stipulated conditions mentioned in the CRZ Recommendation letter dated 29/6/2016.
3) DPT letter no. EG/WK/4751/Part (remaining 3 facilities)/40 Dated 13/07/2021.
4) DPT letter no. EG/WK/4751/Part (remaining 3 facilities)/150 Dated 8/2/2022.
5) DPA letter no. EG/WK/4751/Part (remaining 3 facilities)/134 Dated 06/07/2022
6) DPA letter no. EG/WK/4751/Part (remaining 3 facilities)/281 Dated 18/04/2023

Sir,

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

In this connection, it is to state that, the Gujarat Coastal Zone Management Authority vide above referred letter dated 29/6/2016 had recommended remaining 3 project activities (Phase I) of Deendayal Port Authority (Erstwhile: Deendayal Port Trust). Subsequently, the MoEF&CC, GoI had accorded the Environmental & CRZ Clearance vide letter dated 18/2/2020. In this regard, DPA vide above referred letters had regularly submitted compliance report of the stipulated conditions, to the Director (Env.) & Member Secretary, GCZMA, F & E Dept., GoG.

Now, as directed under Specific Condition No. 28 mentioned in the CRZ Clearance letter dated 29/6/2016 i.e. ***A six-monthly report on compliance of the conditions mentioned in this letter shall have to be furnished by the DPT on a regular basis to this Department /MoEF&CC, GoI***, please find enclosed herewith compliance report (For Period upto May, 2023) of stipulated conditions along with necessary annexure, for kind information & record please **(Annexure I).**

............Cont.........

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 same through e-mail ID gczma.crz@gmail.com & direnv@gujarat.gov.in.

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

Thanking you.

Yours faithfully,

12/09/24

Manager(Env.)
Deendayal Port Authority

Encl.: As above

Copy to:

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

Annexure -I

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	**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, Break water: Length of 1400 m, with 20 m of height, Estimated Cost: 3097 cr.).*	The Board of DPA approved the Feasibility Report in its meeting on 19.02.2021. The MoPSW,GoI vide communication dated 21/10/2022 has conveyed approval granted by the Cabinet Committee on Economic Affairs to the project. 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. **No construction activity started yet.**
2	**Providing Railway Line from NH 8A to Tuna Port.** *(Length – 11 km, Estimated cost: 94 cr.)*	**Work completed.**
3	**Construction of Port Craft Jetty & Shifting of SNA Section.** *(Dredging : 27357.00 m3, Estimated Cost: 23.17 cr.)*	**Work completed.**

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.

Sr. No.	Conditions in CRZ Recommendation Letter	Compliance
	Specific Conditions	
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.	The Projects at Sr. No. 2 & 3 of the EC & CRZ Clearance have already been completed. 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.
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 (**Copy enclosed as Annexure A**). 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.	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, 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.

		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.	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. 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 & to the MoEF&CC, GoI. 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.
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.	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, 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. 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&CC, GoI, Gandhinagar &

		to the MoEF&CC, GoI, New Delhi along with six monthly compliance reports submitted. 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 **Annexure B.**
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.	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, 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.
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.	As per the directions of the GCZMA and MoEF&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. 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.

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 (**Copy enclosed as Annexure A**).
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 **Annexure C**. 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

		DG Shipping circulars regarding the reception facilities at Swachch Sagar portal. Further, DPA has appointed GEMI, Gandhinagar for the work of “Preparation of Plan for Management of Plastic Wastes, Solid Waste, including C&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. 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&CC, GoI, Gandhinagar as well as to the MoEF&CC, GoI, New Delhi along with compliance reports submitted. 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 **Annexure B**. 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. 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 **Annexure D**. 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.

		The final Report submitted by M/s GUIDE, Bhuj for the period 2021-2022 is attached herewith as **Annexure E.** Further, Dredged Material will be disposed of at designated location as identified by the CWPRS, Pune. For energy conservation measures, DPA is already generating 20 MW of Wind energy. In addition to it, DPA has commissioned a 45 kWP Solar Plant at Gandhidham. DPA has installed 400 KWP solar plant and 600 KWP to be installed this year by PPP operator. 4000 Acres of land has been identified for developing 150 MW Hybrid (Solar Cum Wind) Energy Park. DPA is also planning to install RE Hybrid Park of total 70 MW for captive utilization in phase manner. Further, for Oil Spill Management, DPA is already having Oil Spill Contingency Plan in place and Oil Response System as per the NOS-DCP guidelines.
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.	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, 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. Further, DPA has already prepared a mangrove preservation plan for the entire Kandla area.
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.	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. 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).

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. ▪ Deendayal Port already has an updated Disaster Management Plan (A copy of the Plan has already been submitted with the earlier compliances). ▪ Further, the Local Oil Spill Contingency Plan is already available with Deendayal Port Authority. ▪ DPA has also executed MOU with Oil Companies, i.e., IOCL, HPCL, BPCL etc., for combating the Oil Spill at Kandla
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.	DPA has planted about one lakhs trees in roadside dividers, colony areas at Kandla and Gopalpuri, in the greenbelt area of Gandhidham & Adipur Township, Sewage Treatment Plants at Gopalpuri & Kandla and extensive green belt development plans initiated at different locations in Township areas. 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 **Annexure D.** 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.
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 **Annexure F.**
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.	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). 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&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 **Annexure C**.
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

		dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as **Annexure C**. DPA has been submitting the environmental monitoring report along with the six-monthly compliance report to IRO, MoEF&CC, GoI.
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 -A

GPCB

GUJARAT POLLUTION CONTROL BOARD

PARYAVARAN BHAVAN, SECTOR 10-A,
GANDHINAGAR - 382010,
(T) 079-23232152

By R.P.A.D

AMENDMENT TO CONSENT TO ESTABLISH (CTE)

CTE-125870

NO: PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / **Date: -**

To,
M/s. Kandla Port Trust,
Developing Integrated Facilities within existing KPT, at Kandla,
Kandla & Tuna area,
Tal : Gandhidham, Dist : Kutch – 370 201

Subject : Consent to Establish (CTE) issued vides CTE - 89537 vide letter no. **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017.**

Reference :
1. Board has issued CTE vide letter **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017.**
2. Your application for CTE validity extension/ CTE Fresh Inward no. 271834 dated 07/01/2023.

Sir,

Without prejudice to the powers of this Board under the Water (Prevention and Control of Pollution) Act-1974, the Air (Prevention and Control of Pollution) Act-1981 and the Environment (Protection) Act-1986 and without reducing your responsibilities under the said Acts in any way. The Board had granted **Consent to Establish (NOC)** vide order no. **CTE – 89537** vide letter no. **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017** for the plant at **Developing Integrated Facilities within existing KPT, at Kandla, Kandla & Tuna area, Ta. Gandhidham, Dist. Kutch.**

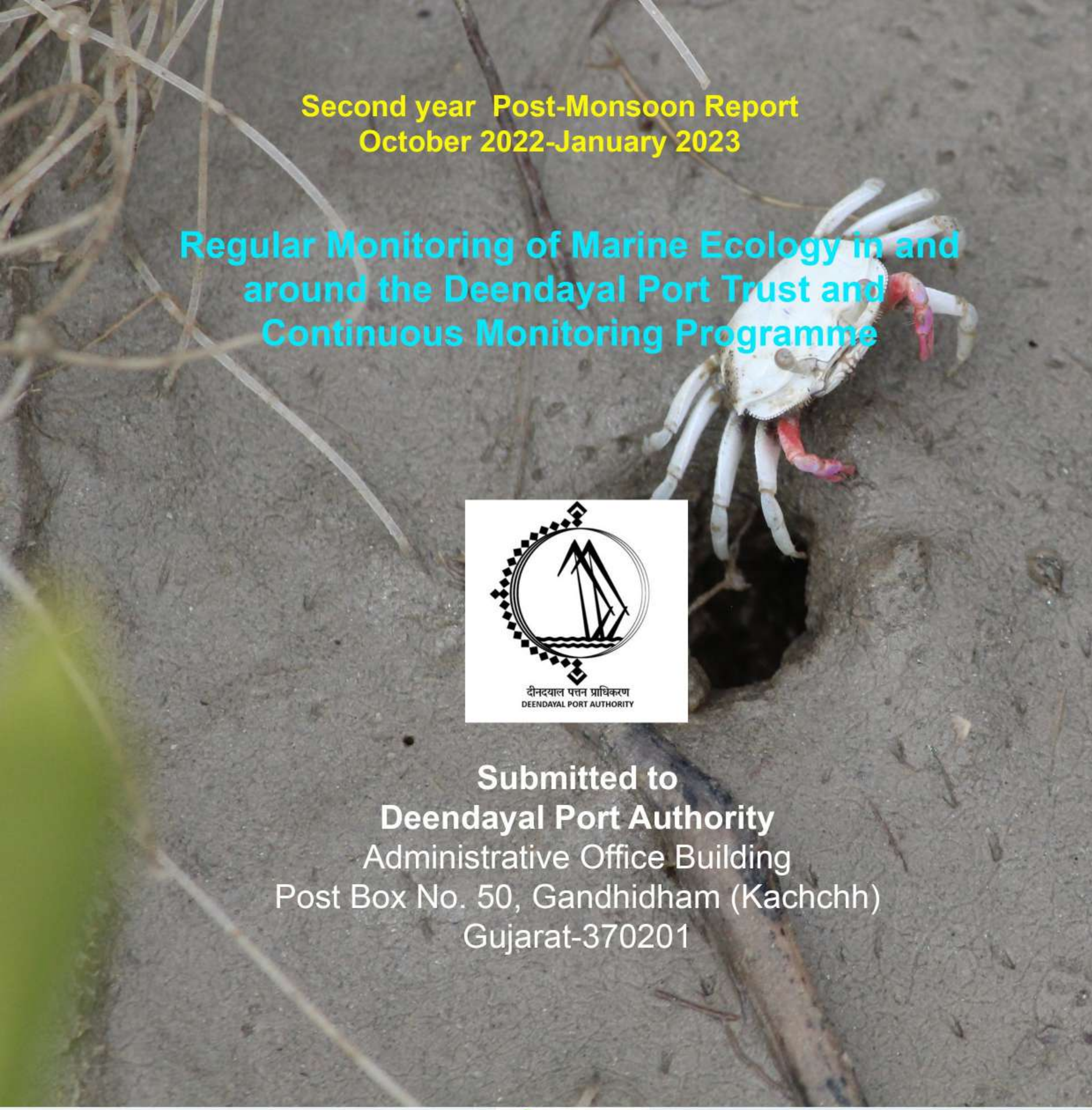
The Board has right to review & amend the conditions of the said CTE order. Now considering your application for CTE-Amendment inward no. 271834 dated 07/01/2023 for validity extension of the CTE order dated 27/04/2023, the said order is amended as below:

1. The validity mentioned in the CTE order no- **CTE – 89537** issued vide letter no. **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017 shall be read as CTE order no. CTE-125870 dated 27/04/2023, valid up to 15/11/2025.**
2. The rest of the conditions of Consent to Establish (CTE) order No: **CTE – 89537** issued vide letter no. **PC/ CCA- KUTCH-1231(2)/ GPCB ID: 44000 / 429717 dated 04/12/2017** shall remain unchanged and industry shall comply with the same judicially.

For and on behalf of
Gujarat Pollution Control Board

(T. C. Patel)
Unit Head
Page 1 of 1

Annexure -B



Second year Post-Monsoon Report
October 2022-January 2023

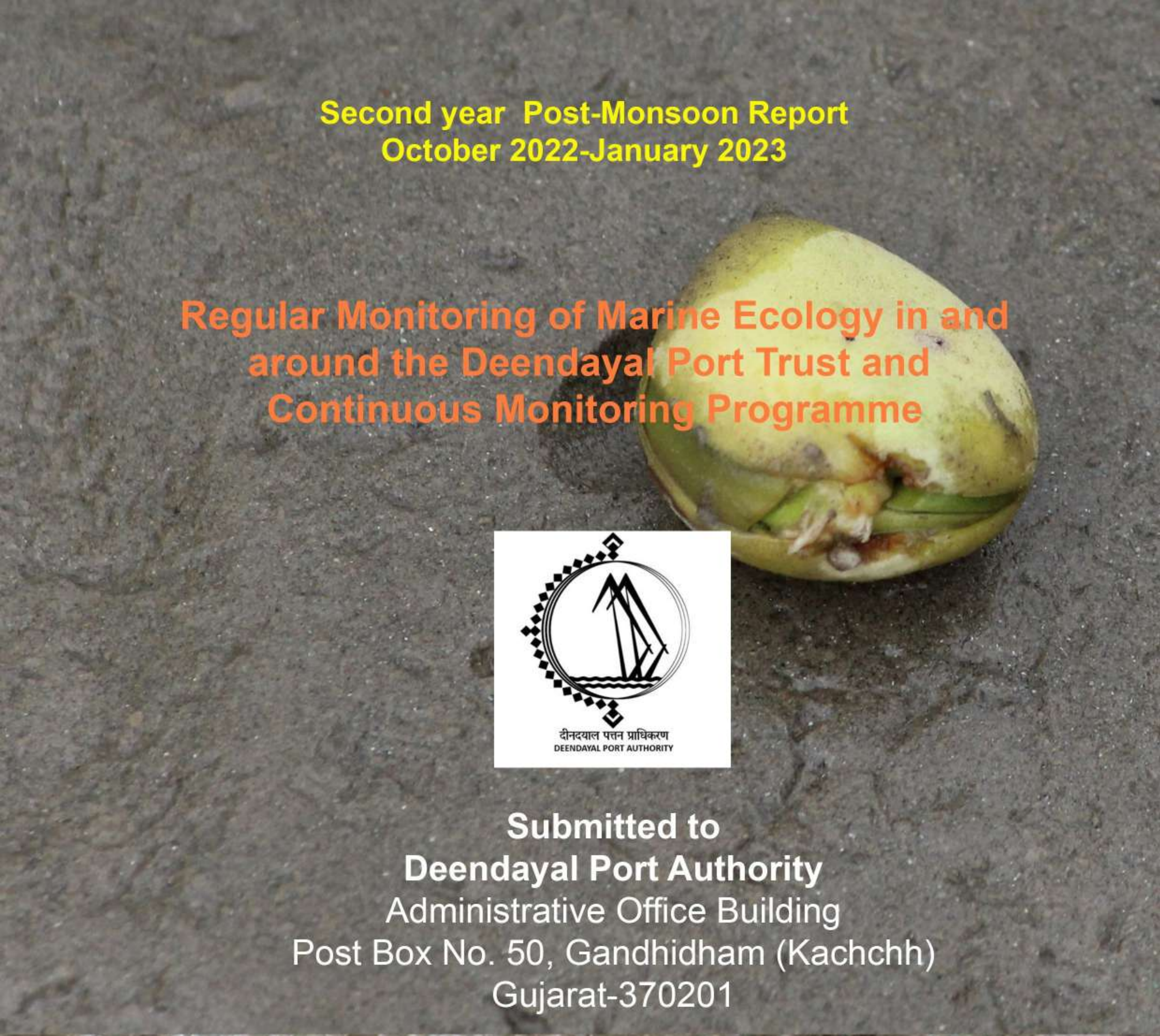
Regular Monitoring of Marine Ecology in and around the Deendayal Port Trust and Continuous Monitoring Programme

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

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

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

Project Coordinator

Dr. V. Vijay Kumar, Director

Principal Investigator

Dr. Durga Prasad Behera	Project Scientist	Phytoplankton & Zooplankton, Physico-chemical parameters, Marine Fisheries, Intertidal and Subtidal benthos

Core Team

Dr. Jaikumar, M.	Senior Scientist	Mangrove & Mudflat
Dr. L. Prabha Devi	Advisor	Management Plan
Dr. Nikunj B. Gajera,	Scientist	Avifauna
Dr. Kapilkumar Ingle	Project Scientist	Mangrove Ecology
Dr. Dhara Dixit	Project Scientist	Halophytes, Sediment

Team members

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

Snapshot

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	**Components of the report**	
7a	Mangroves	The overall average density was 3011 trees/ha of *A. marina* 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.

7c	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%).
7d	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.
7e	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%).
7f	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%).
7g	Seaweeds	No seaweed is reported in the DPA area.
7h	Seagrass	No seagrass is reported in the DPA area.
7i	Marine reptiles	One species of reptile was recorded from the DPA area.
7j	Marine mammals	Two species of marine mammal was recorded from the DPA area.
7k	Halophytes	Four halophytes were recorded along the selected Deendayal Port Authority sites during the Monsoon sampling; among the halophyte species recorded, *Salicornia brachiata* alone was found in the 3 sampling locations. The percentage of *Salicornia brachiata* was found to be the highest at stations S-11 (100%) and the lowest at S-3.
7l	Avifauna	A total of 79 species belonging to 9 orders, 32families 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 to127 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).

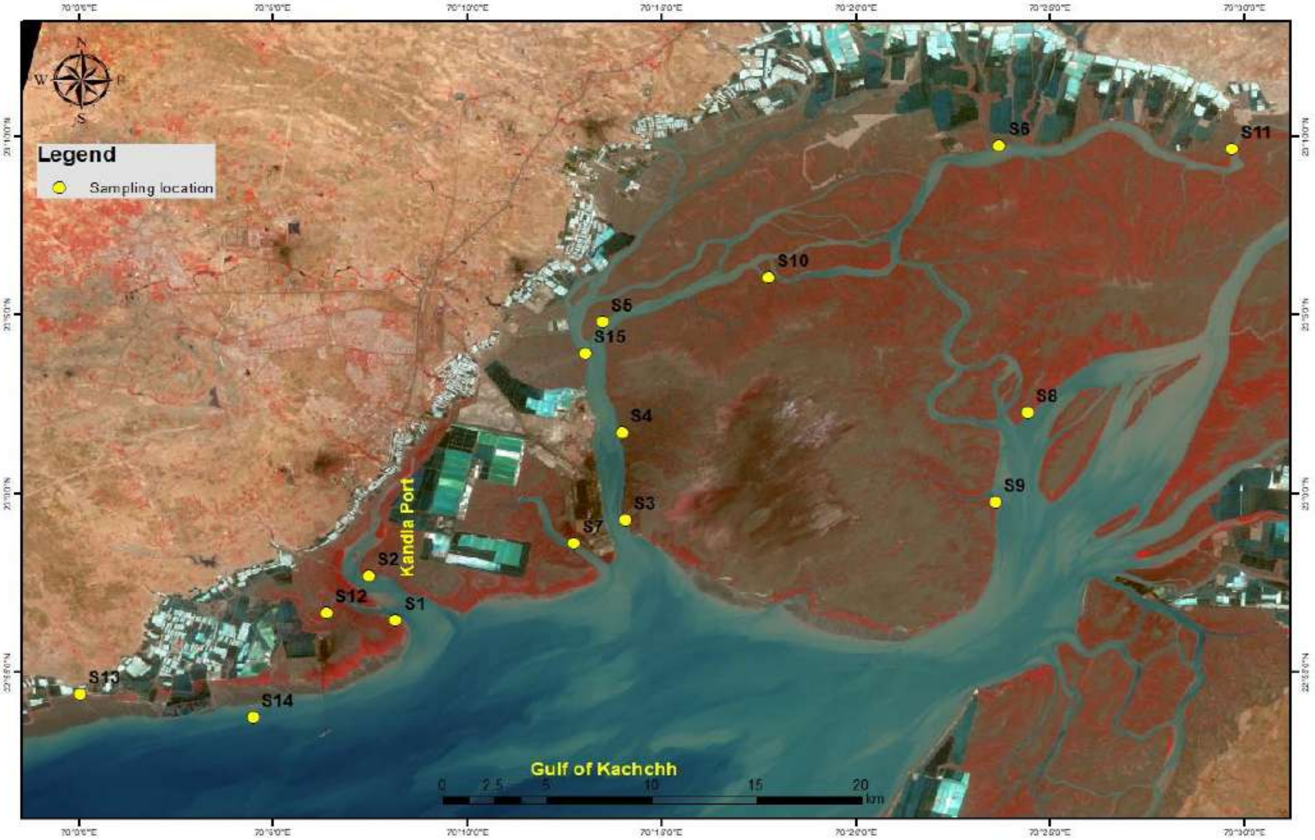

Figure 1: Map showing the sampling locations 2021-2024

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

Parameters	
Water	**Mangrove & Other Flora**
• pH	**Mangrove**
• 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)	**Halophytes:**
Nutrients	• Percentage of distribution
Nitrate (NO_3)	• Diversity
• Nitrite (NO_2)	
• Total Nitrogen	**Seagrass and Seaweed**
• **Sediment**	• Occurrence, distribution, and diversity.
• Texture	**Intertidal fauna**
• Total organic carbon (TOC)	• Composition, distribution, diversity, density and other characteristics.
• **Biological Parameters**	**Avifauna**
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 $0.04m^2$ 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_2 is used and O_2 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^2 (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^2 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^2 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^2).

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^2. 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^2. 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).

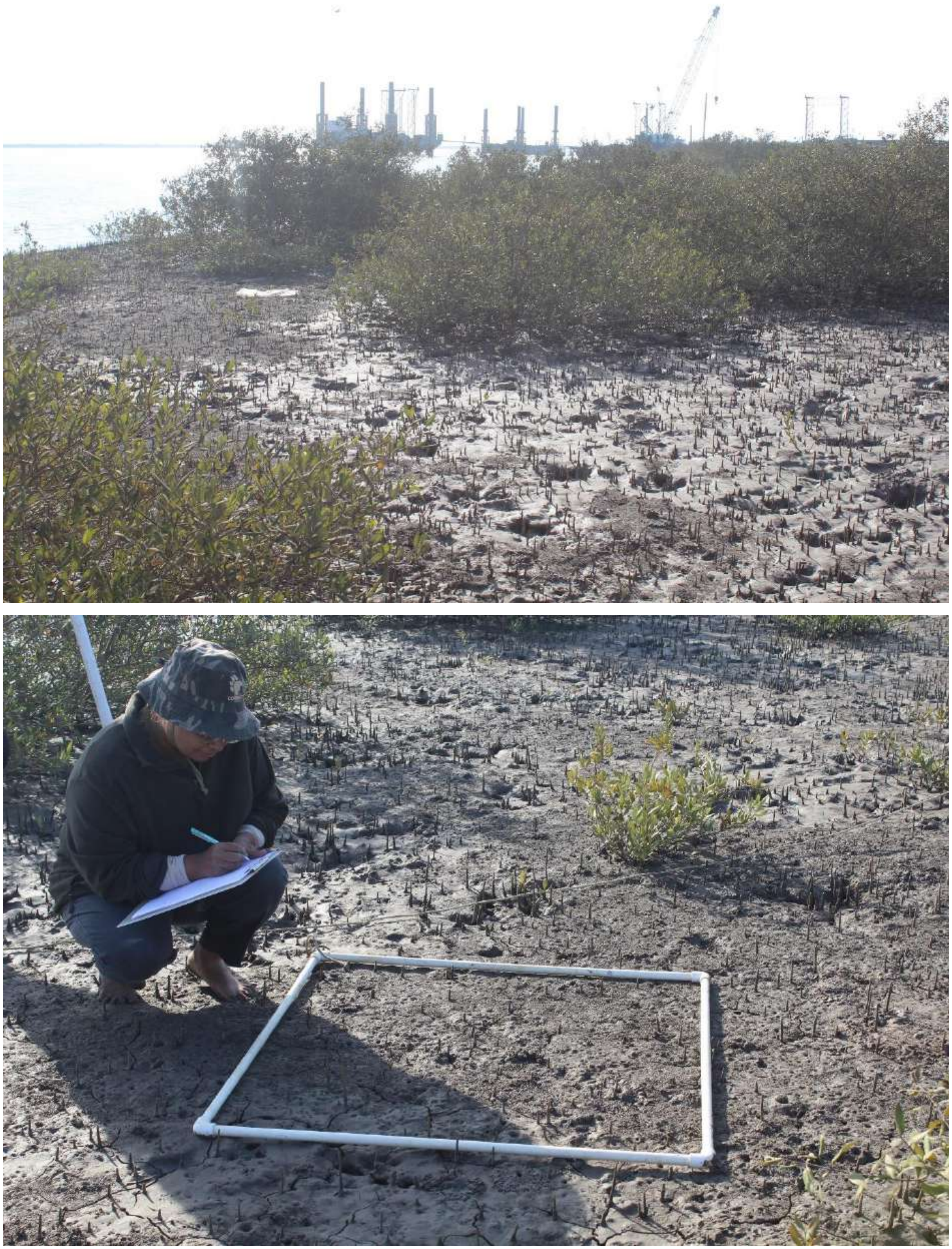

Plate 1: Estimation of intertidal fauna by the quadrate method

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 H2SO4) by utilizing the heat evolved with the addition of H_2SO4. 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^2 for regeneration and 2×2 m^2 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, quadrate 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 quadrate 1 x $1m^2$ 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 quadrate 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 (Dadrasnia 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 8.75 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.

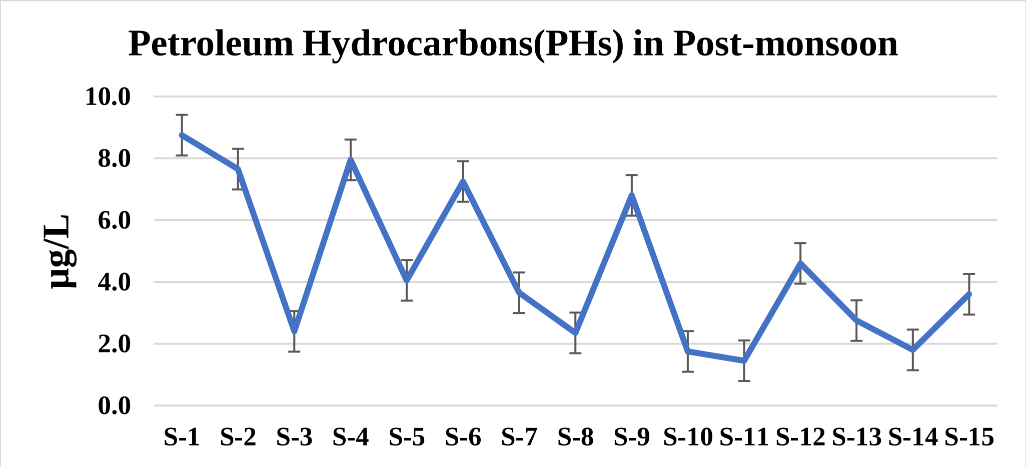

Figure 2: Petroleum hydrocarbons in water (µg/L) during Post-monsoon 2022-2023

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_3) (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_2) (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 (Percetnage) 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.

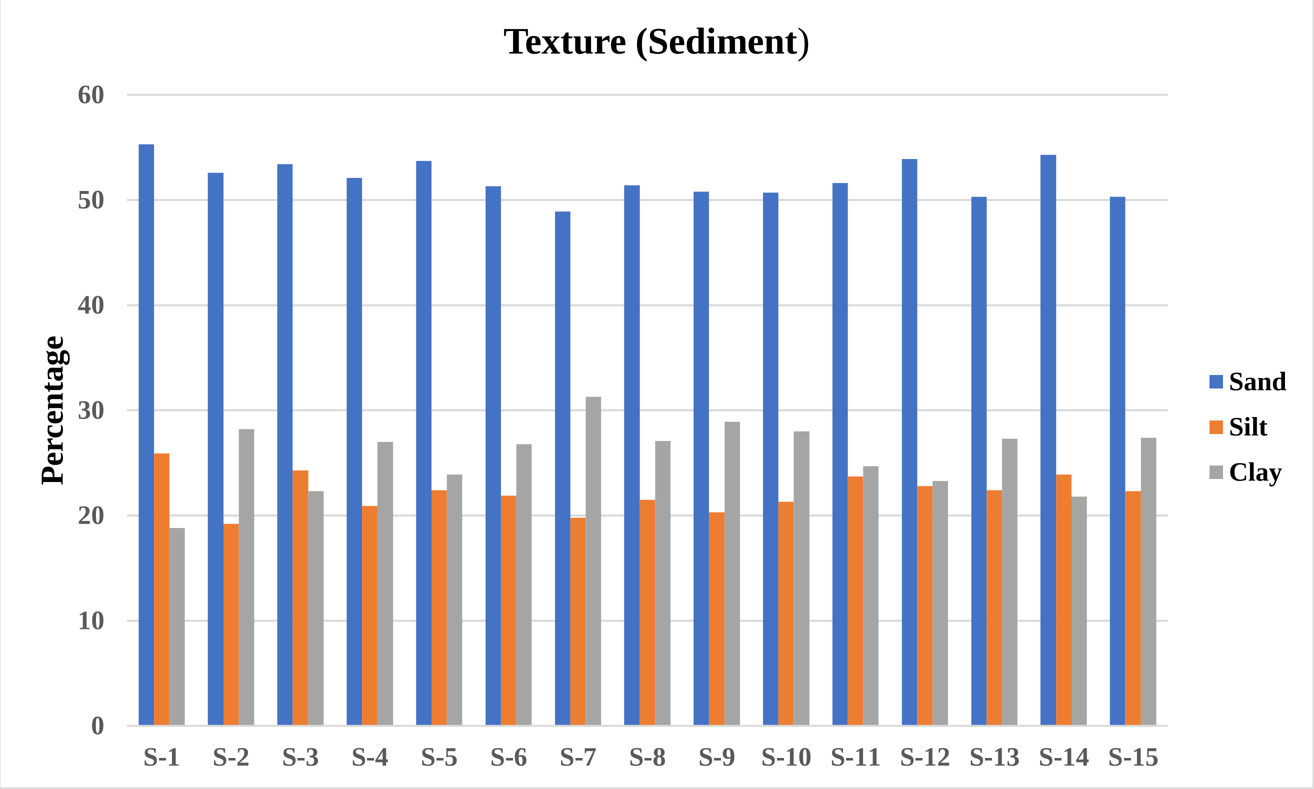

Figure 3: Textural characteristic of sediment at DPA in Post-monsoon 2022-2023

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.

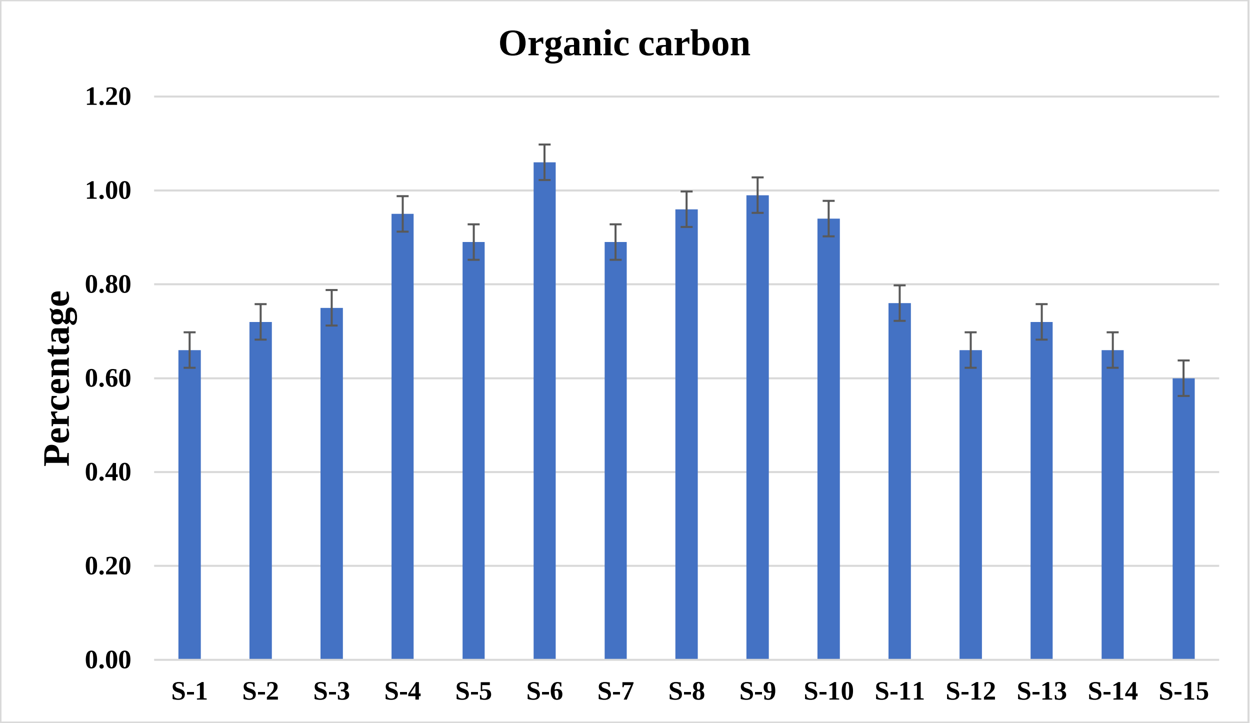

Figure 4: Total Organic Carbon content (%) in DPA during Post-monsoon 2022-2023

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.

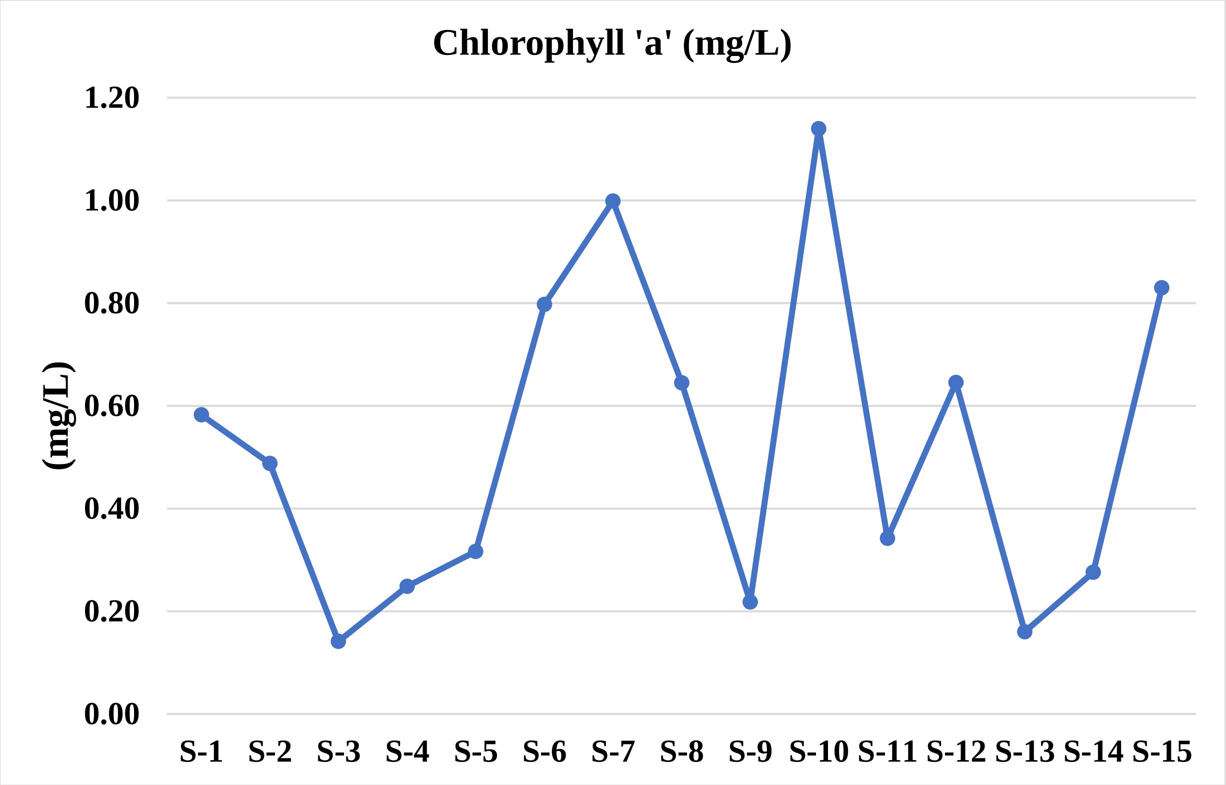

Figure 5: Chlorophyll ‘a’ concentration at the study stations in Post-monsoon 2022-2023

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.

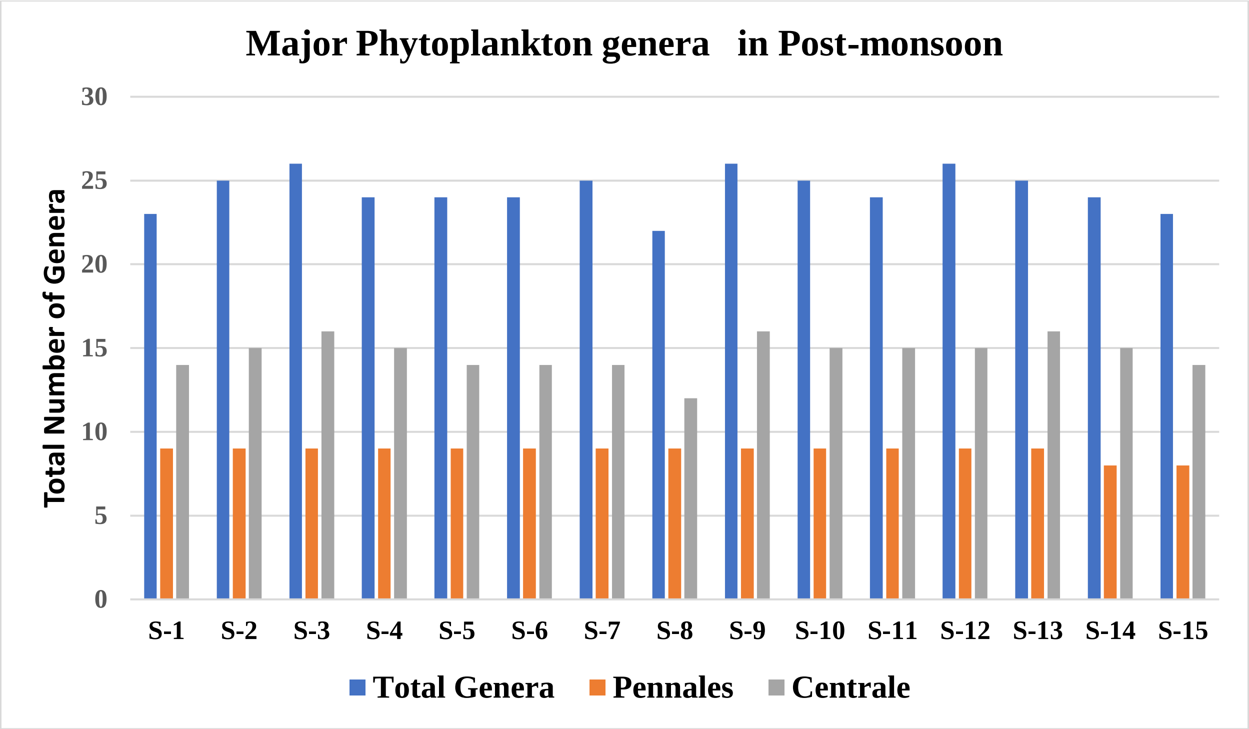

Figure 6: Number of Phytoplankton genera in Post-monsoon 2022-2023

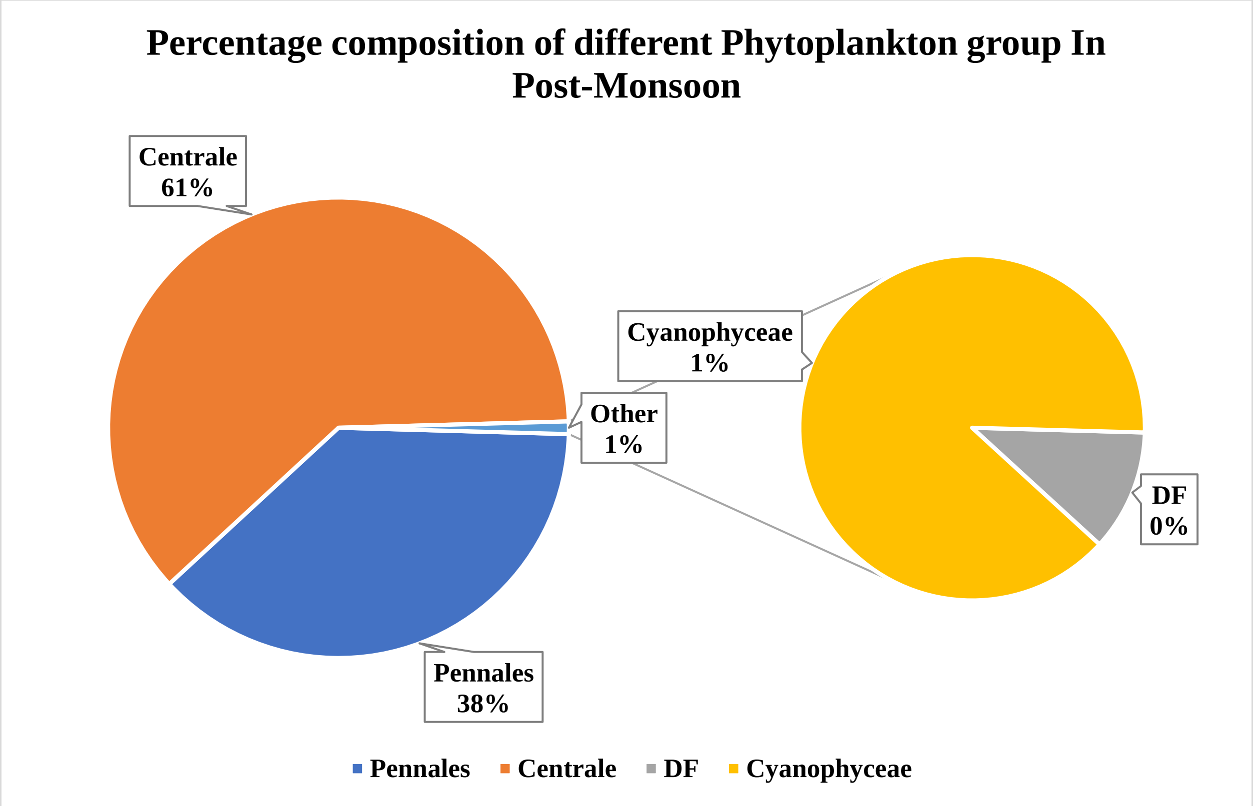

Figure 7: Percentage composition of phytoplankton groups in Post-monsoon 2022-2023

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.

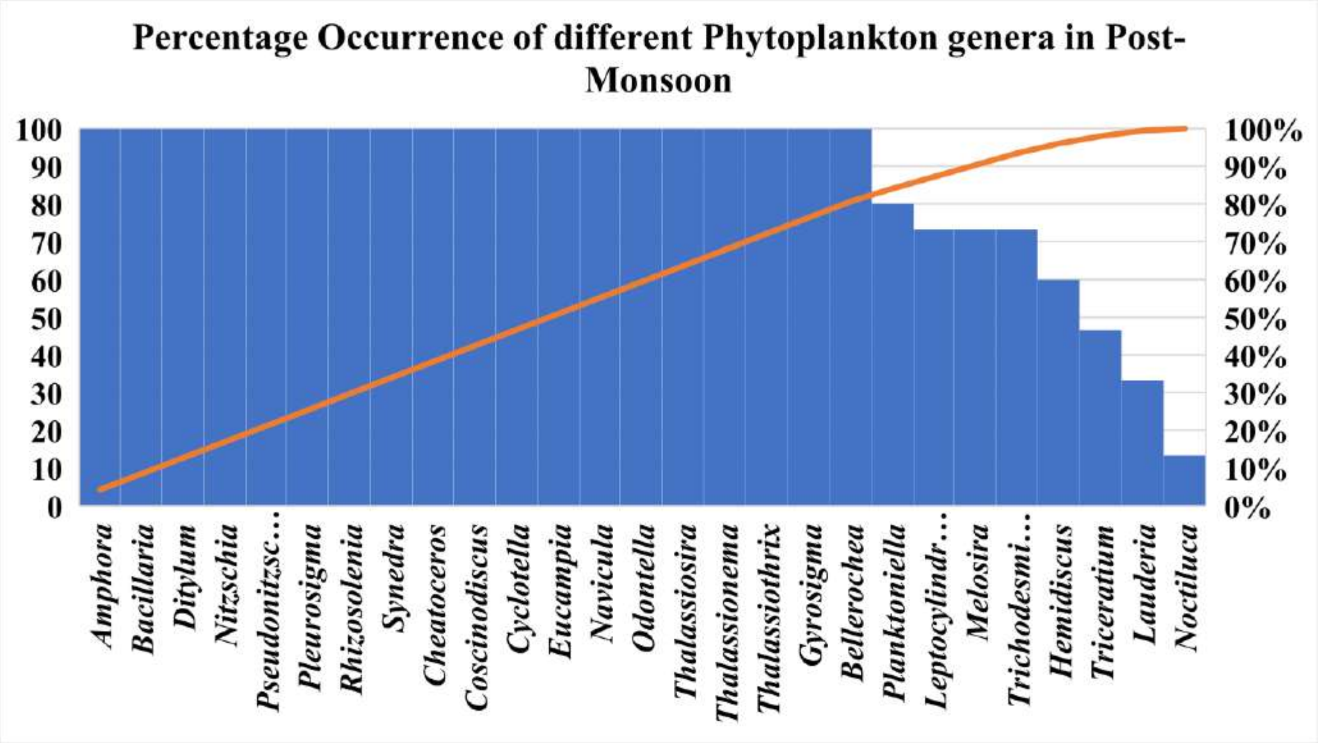

Figure 8: Percentage occurrence of phytoplankton genera in Post-monsoon 2022-2023

Phytoplankton density and diversity

The density signifies the abundance of plankton which is measured as cell/ individual/L. The phytoplankton density varied from 16,320No/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.

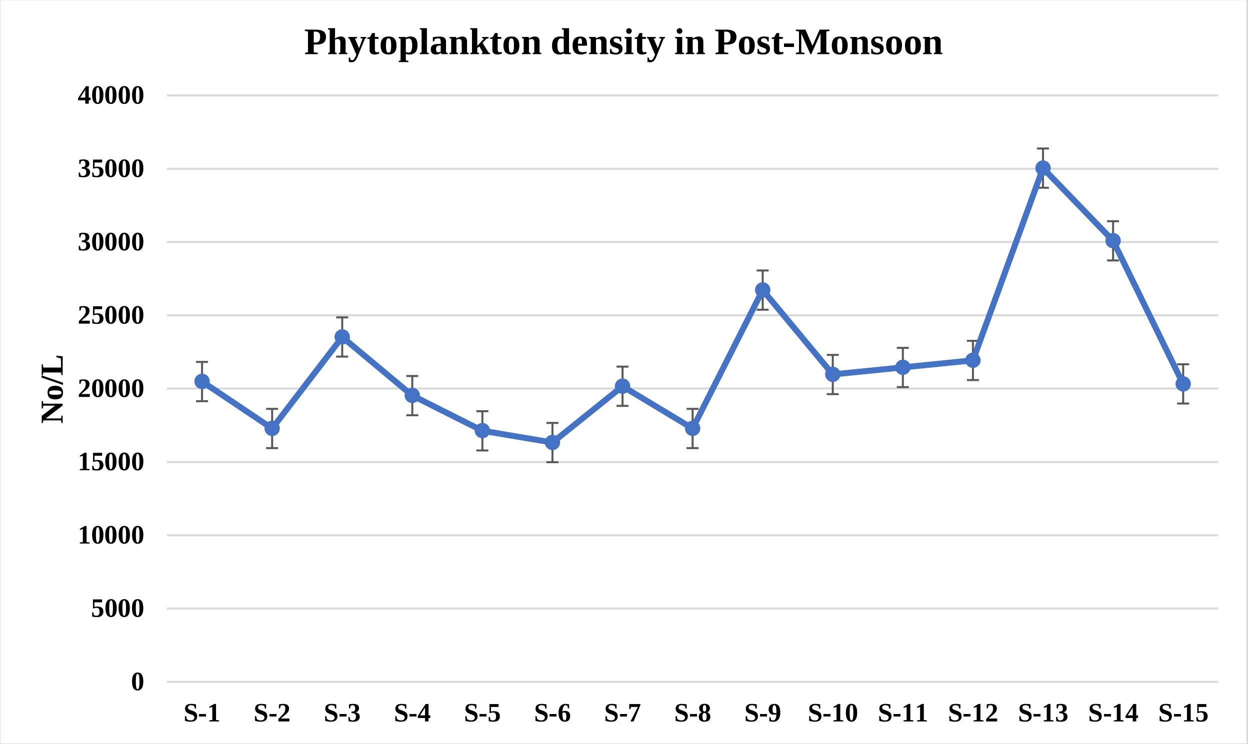

Figure 9: Phytoplankton density in Post-monsoon 2022-2023

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).

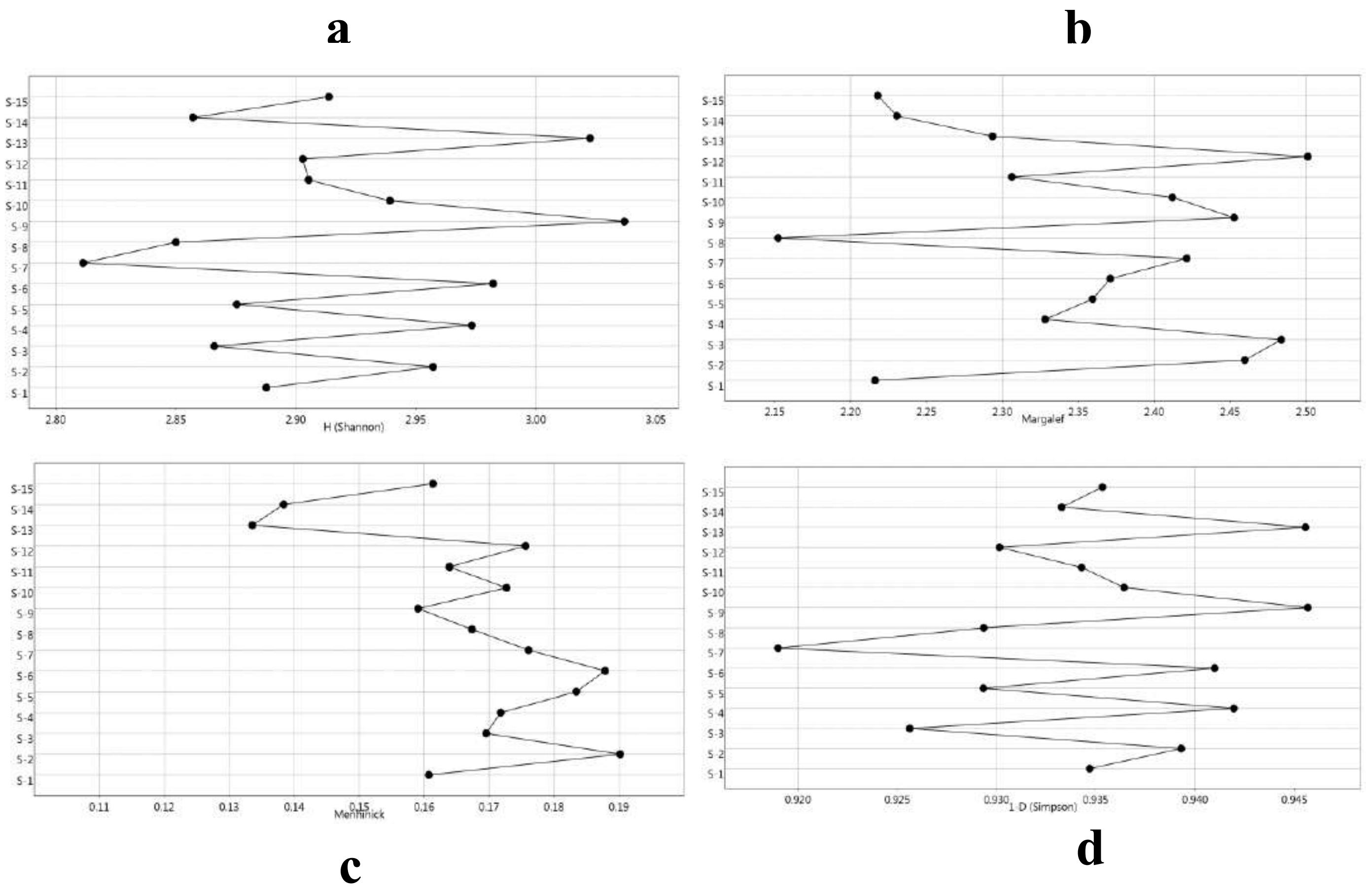

Figure 10: Different diversity indices of Phytoplankton

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	*Amphora*	320	160	320	320	640	800	160	480	1120	800	320	1280	320	160	1440	2.6	100
	Bacillaria	960	960	640	320	160	480	640	960	1120	800	480	640	1440	800	1280	3.6	100
	Ditylum	960	1280	1760	1440	800	320	640	960	2240	960	2080	1760	2240	1760	640	6.0	100
	Nitzschia	1760	1440	800	320	640	960	2240	960	2080	1760	1440	1280	2240	1600	1120	6.3	100
	Pseudonitzschia	480	640	320	800	640	480	1120	800	320	160	640	160	160	160	320	2.2	100
	Pleurosigma	320	320	640	160	160	320	160	480	1120	640	160	320	960	1280	640	2.3	100
	Rhizosolenia	640	960	960	1280	800	480	640	160	800	640	640	800	1440	1600	480	3.8	100
	Synedra	1760	1440	1120	1280	2240	1280	1120	1920	1600	1440	960	1760	2720	2400	1760	7.6	100
	Navicula	1120	640	640	1280	800	640	320	480	1440	160	1120	480	1760	0	0	3.3	87
Centrales	*Cheatoceros*	1600	1440	2720	2080	1760	1600	3360	960	1280	2720	2560	1760	3200	3040	1600	9.7	100
	Coscinodiscus	1760	1600	3360	960	1280	1600	1440	2720	2080	1760	1600	3360	2400	3040	2720	9.7	100
	Cyclotella	160	160	160	480	320	160	320	160	480	480	640	320	800	1440	960	2.1	100
	Eucampia	480	320	320	320	160	160	640	320	800	480	160	320	320	160	800	1.8	100
	Lauderia	160	160	0	0	0	0	0	0	160	0	160	0	0	0	0	0.2	33
	Leptocylindricus	480	160	160	160	320	320	0	0	160	160	0	320	1280	640	320	1.4	73
	Melosira	160	320	320	160	160	320	0	0	160	320	160	0	320	0	160	0.8	73
	Odontella	1120	1440	1760	1440	800	480	640	960	2400	960	2400	1760	2400	3040	800	6.8	100
	Planktoniella	0	0	160	640	320	480	640	800	0	320	640	480	800	160	320	1.8	80
	Triceratium	0	0	160	320	0	0	160	0	320	0	0	160	480	160	0	0.5	47
	Thalassiosira	160	320	800	1120	160	1280	800	960	1120	320	640	160	1120	960	320	3.1	100
	Hemidiscus	0	160	160	0	0	0	160	0	160	160	160	320	320	160	0	0.5	60
	Thalassionema	2560	640	2880	800	2240	480	2720	640	1120	1600	960	1600	2400	2720	1760	7.7	100
	Thalassiothrix	960	1120	800	1120	480	1280	640	1120	960	1440	640	800	1440	1120	800	4.5	100
	Gyrosigma	640	480	1120	960	640	320	160	640	800	1280	1120	960	1440	1120	640	3.8	100
	Bellerochea	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

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 gernera, of the Calanoida ranked first in terms of generic representation *,Acartia Acrocalanus*, *Aetideus Nannocalanus .Temora a*nd *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

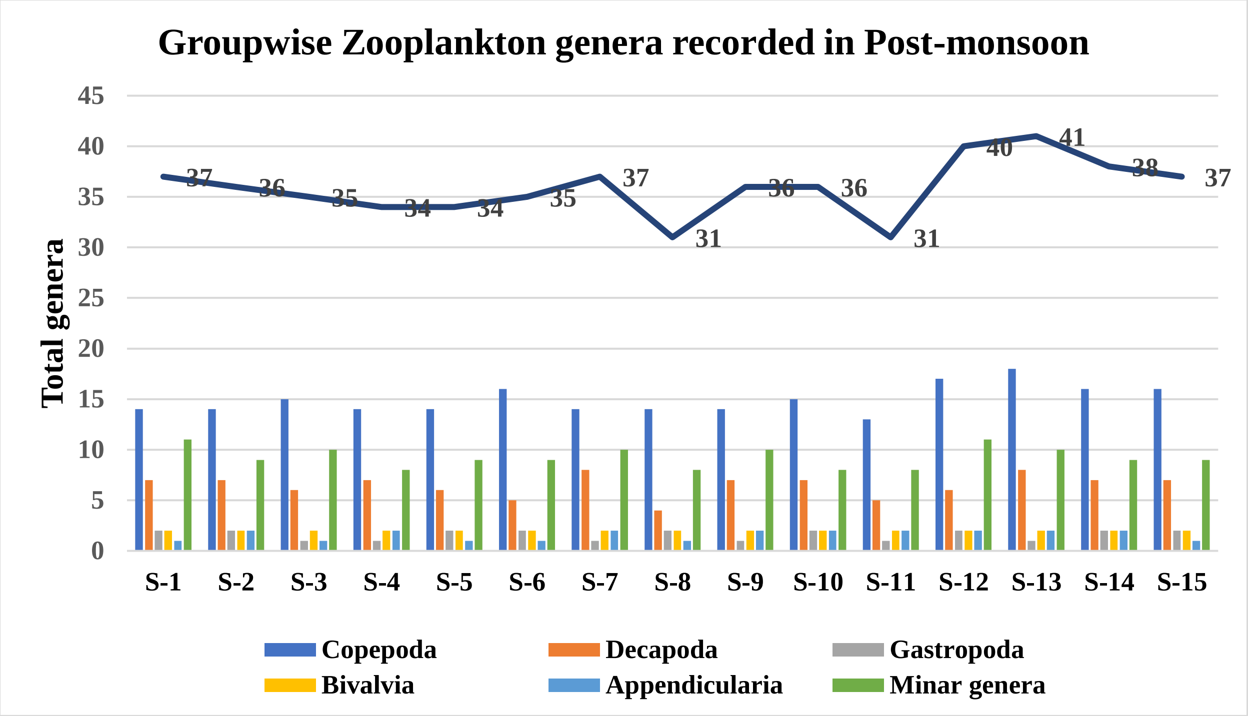

Figure 11: Phylum and generic status of zooplankton during Post-monsoon 2022-2023

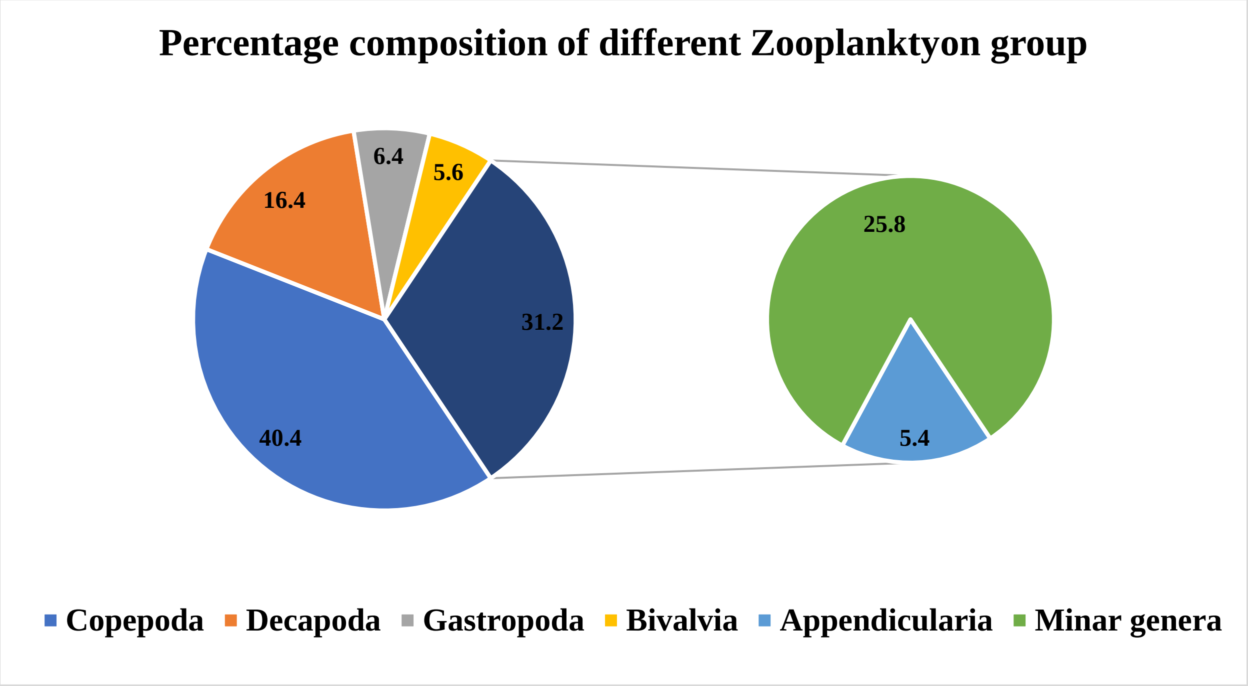

Figure 12: Percentage composition of zooplankton groups during Post-monsoon 2022-2023

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).

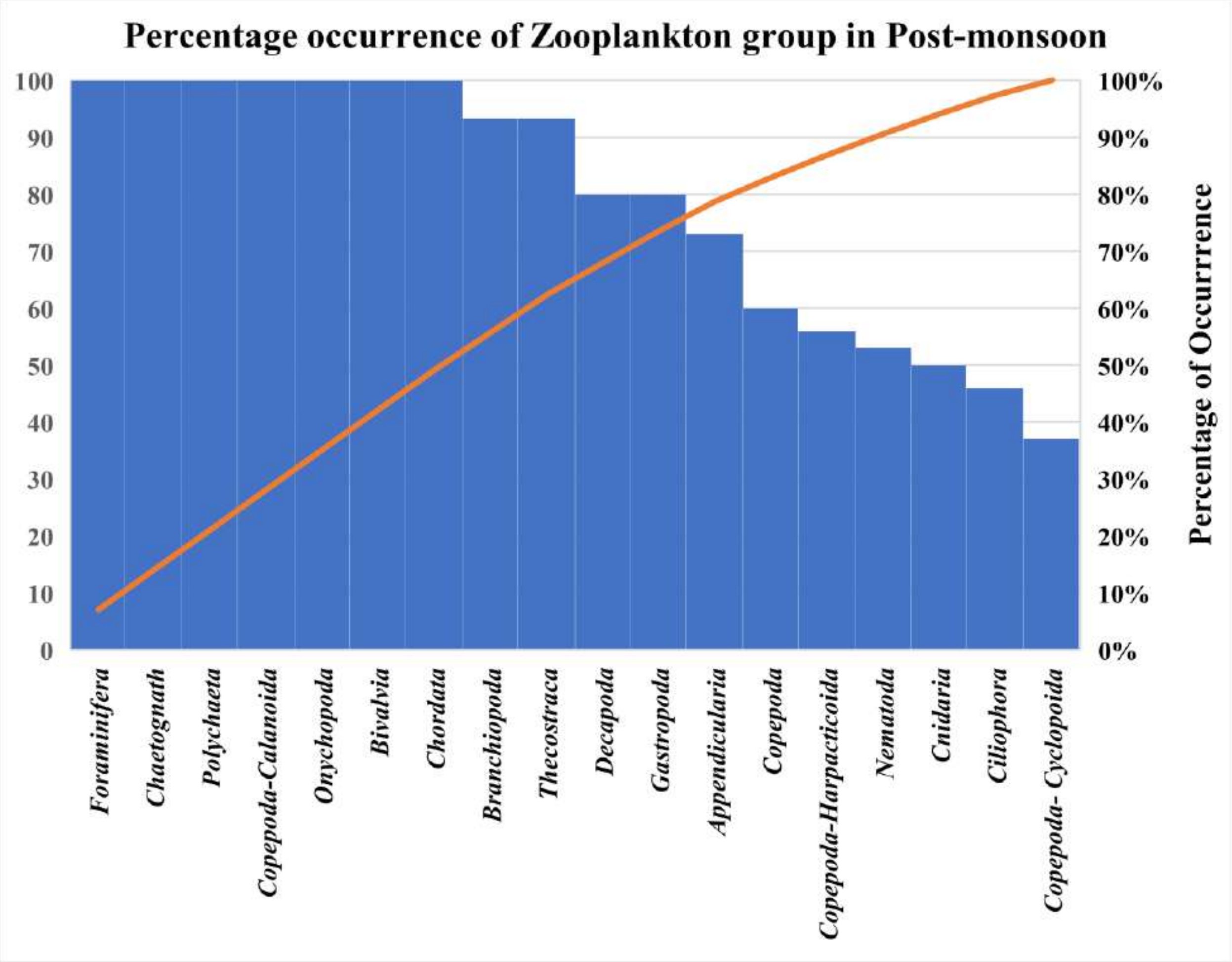

Figure 13: Percentage occurrence of Zooplankton groups during Post-monsoon 2022-2023

Density of zooplankton

Zooplankton population density values during the Post-monsoon 2022 at the 15 sampling sites ranged from 16,840 No/L to37,280 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).

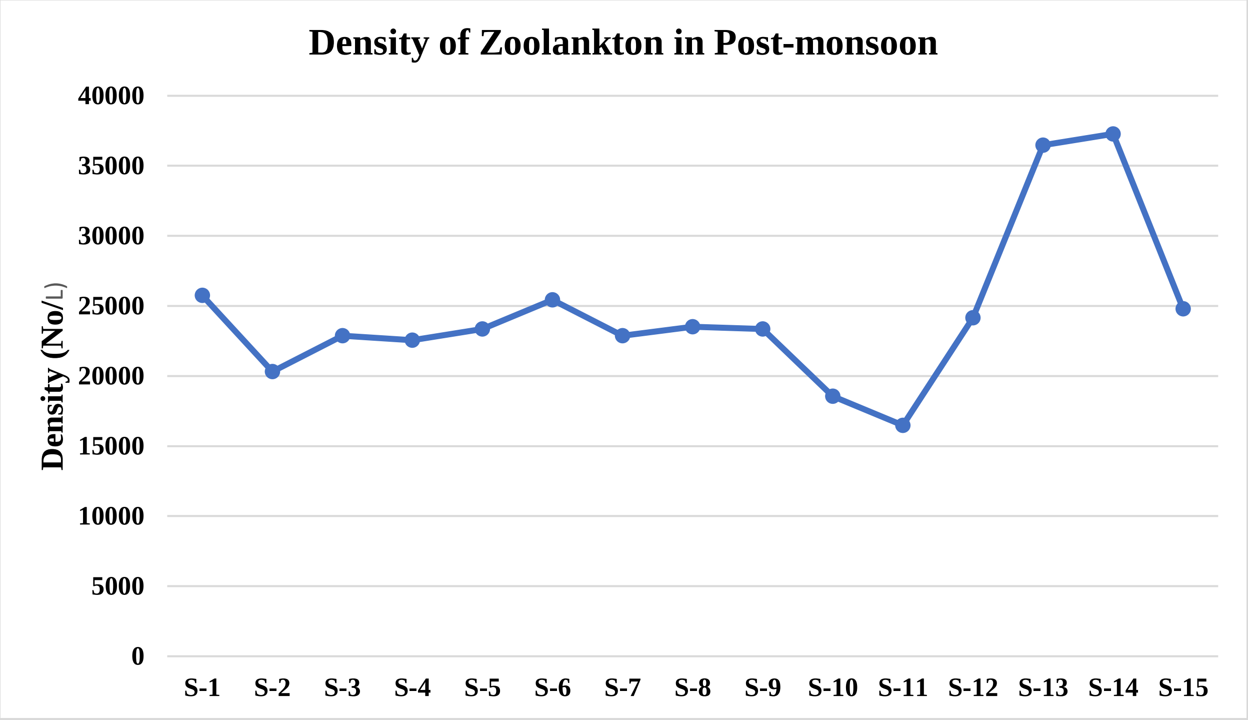

Figure 14: Zooplankton Density in the different stations during Post-monsoon 2022-2023

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**	*Globigerina*	2400	320	1120	2880	160	3680	1920	800	480	640	960	160	1440	480	1760	5.2	100
Colenterate	**Cnidaria**	*Obelia*	160	0	320	0	160	0	0	160	160	0	0	0	160	0	0	0.3	47
		Physalia	0	0	160	0	0	160	160	0	160	0	0	320	160	0	160	0.3	53
Ciliophora		*Tintinnopsis*	160	0	0	0	0	0	160	0	0	0	0	160	0	0	0	0.1	20
		Codonellopsis	320	160	320	0	160	320	160	0	0	160	160	320	320	160	0	0.7	73
	Chaetognath	*Sagitta*	480	320	640	160	160	800	1760	1120	1440	640	800	480	1120	480	320	2.9	100
Annelida	**Nematoda**	*Nematode worm*	480	160	0	160	0	0	160	0	320	0	0	160	0	160	160	0.5	53
	Polychaeta	*Polychaete larvae*	480	2880	640	480	1120	160	320	640	160	640	320	800	480	1120	1760	3.3	100
Arthropoda	**Copepoda Calanoida**	*Acartia*	1440	960	800	800	320	1120	800	1600	1760	1280	480	0	800	2720	480	4.2	
		Acrocalanus	1760	1280	2560	480	2720	960	960	1440	1600	1440	960	800	2720	2080	1760	6.4	100
		Aetideus	640	320	480	1280	800	960	1120	1600	320	480	640	1760	1440	800	480	3.6	
		Calanopia	640	320	160	160	1120	480	800	1120	160	320	480	1120	800	480	640	2.4	
		Calanus	800	800	320	1120	800	1600	1760	1280	480	0	800	2720	480	1440	1120	4.2	
		Centropages	320	160	320	320	160	160	480	800	160	160	320	640	1600	2080	1120	2.4	
		Eucalanus	640	320	160	160	1120	480	800	1120	160	320	480	1120	800	480	640	2.4	
		Labidocera	320	320	160	160	320	480	160	800	640	320	320	160	160	640	160	1.4	
		Nannocalanus	320	1120	800	1600	1760	1280	480	0	800	2720	480	640	800	960	1120	4.0	
		Paracalanus	480	320	160	160	160	320	160	320	320	640	480	480	320	160	320	1.3	
		Pseudodiaptomus	480	480	160	320	320	160	480	480	160	320	320	160	320	160	160	1.2	
		Temora	640	320	480	1280	800	960	1120	1600	320	480	640	1760	2880	1440	480	4.1	
		Tomopteris	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0.0	
	Copepoda Harpacticoida	*Corycaeus*	0	0	160	0	0	160	0	320	0	160	0	160	0	0	160	0.3	40
		Clytemnestra	320	160	320	0	160	160	0	0	0	160	0	160	320	160	0	0.5	60
		Euterpina	160	0	160	320	0	320	0	320	480	160	0	160	640	320	160	0.9	73
		Microsetella	0	0	0	160	0	320	0	160	0	160	0	160	160	320	160	0.4	53
	Copepoda-Cyclopoida	*Oithona*	0	160	0	0	0	0	160	0	160	0	320	0	160	0	0	0.3	33
		Oncaea	0	0	0	0	160	0	160	0	0	0	0	160	160	320	160	0.3	40

	Decapoda	*Caridean larvae*	640	320	160	480	640	800	160	320	1120	320	640	160	640	320	800	2.0	100
		Euphausia	1600	320	1440	320	640	1920	640	320	3360	2400	1920	1760	1280	5600	2240	7.0	100
		Lucifer	160	640	0	640	320	0	160	0	160	320	160	0	160	160	1600	1.2	73
		Megalopa larva	160	0	160	0	0	160	160	0	160	0	0	160	320	160	0	0.4	53
		Mysis	480	320	1440	320	160	160	160	0	160	320	0	160	160	160	160	1.1	87
		Nauplius larvae	960	320	640	480	160	0	800	320	160	160	640	160	1440	640	320	2.0	93
		Phyllosoma larva	0	160	0	320	0	0	160	0	0	160	0	0	160	0	160	0.3	40
		Zoea larvae	1120	800	320	640	160	480	160	320	1120	800	160	800	960	320	640	2.4	100
	Branchiopoda	*Cladocera*	480	1280	1600	480	2400	160	0	640	1120	320	160	960	1440	800	1120	3.5	93
	Thecostraca	*Cirriped nauplius*	640	320	160	160	0	320	640	800	320	160	480	160	1120	800	160	1.7	93
	Onychopoda	*Evadne*	800	640	320	640	160	480	160	160	320	160	320	160	640	800	160	1.6	100
Mollusca	**Gastropoda**	*Creseis*	160	160	0	0	160	320	0	160	0	320	0	160	0	320	480	0.6	60
		Gastropod larvae	1920	640	320	3360	2400	1920	1600	320	1440	320	640	1280	2080	1760	1280	5.8	100
	Bivalvia	*Bivalve larvae*	1280	480	1440	960	320	320	1120	640	800	320	160	640	640	1760	160	3.0	100
		Veliger Larva	320	960	640	160	640	160	320	320	1120	320	160	960	1760	1440	160	2.6	100
Chordata		*fish larvae*	160	1280	1760	640	800	2080	1440	1120	800	320	1120	1280	3360	2880	1760	5.7	1000
Appendicularia		*Oikopleura*	1440	640	2080	800	1920	1120	960	2400	640	160	800	640	1920	2400	320	5.0	100
		Copelata	0	160	0	160	0	0	160	0	320	480	160	160	0	0	0	0.4	47
Total Density			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

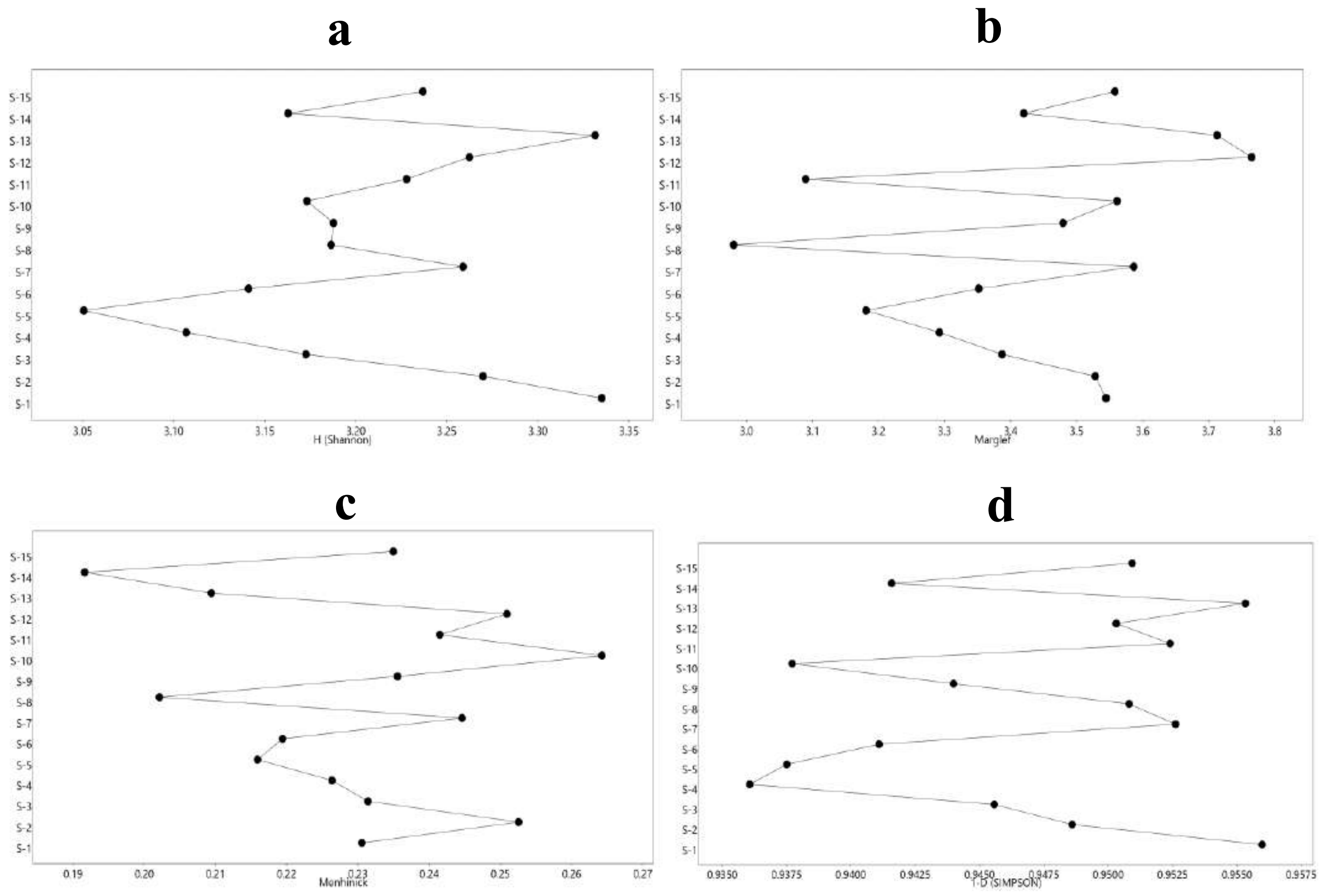

Figure 15: Diversity indices of Zooplankton

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^2 quadrate was placed randomly, and all visible macro-faunal organisms encountered inside the quadrate were identified, counted and recorded. At each site along the transects that run perpendicular to the waterfront, three to six replicate quadrate 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 (1species), 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).

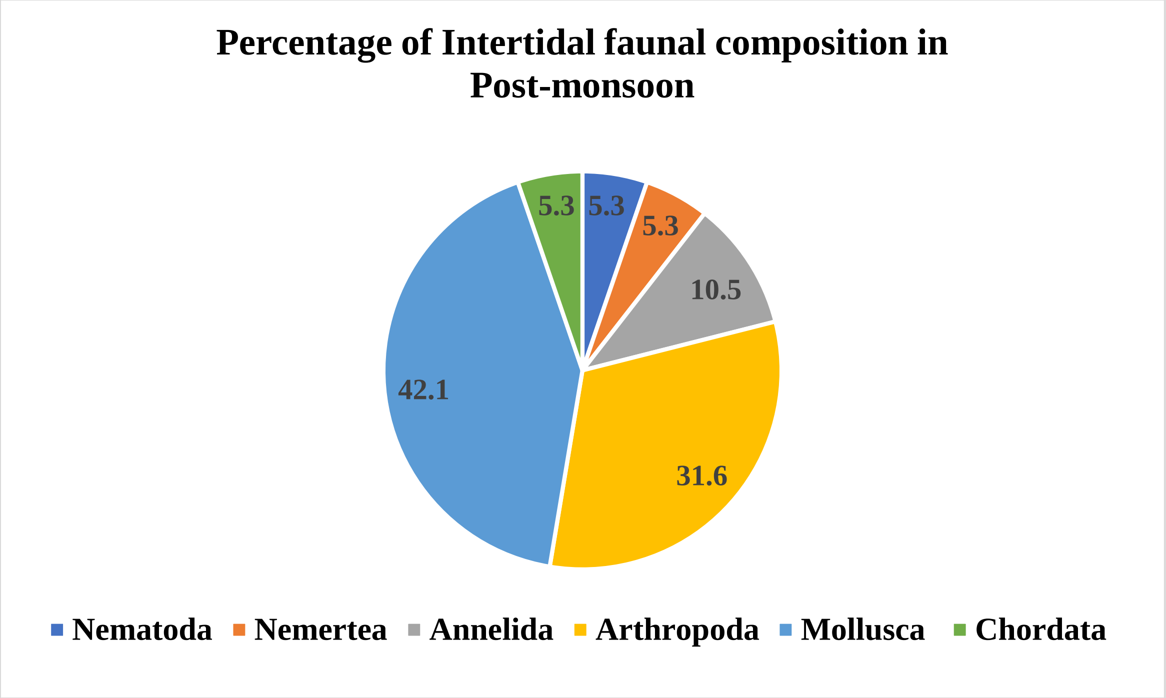

Figure 16: Intertidal Faunal composition (percentage) during post-monsoon 2022-2023

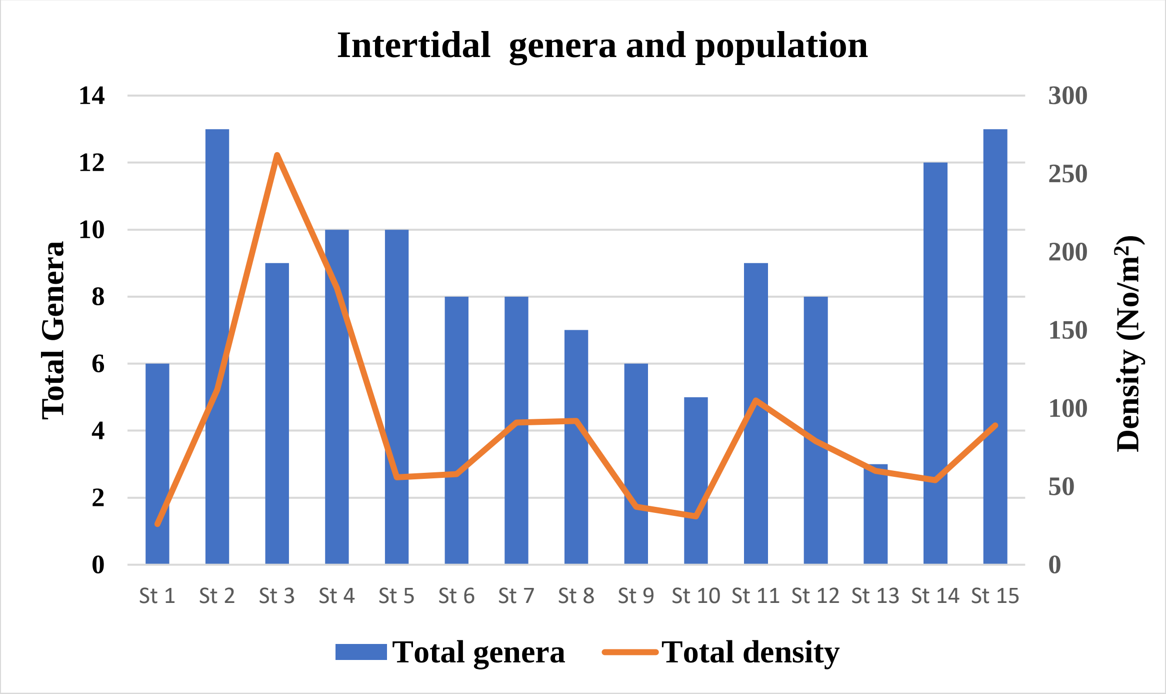

Figure 17 Intertidal genera and population density in Post-monsoon 2022-2023

Intertidal genera and total Population density in (No/m^2)

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/m2 to 262 No/m2 with average variation of 89 No/m2. 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 Metaplax indica (0.1%).

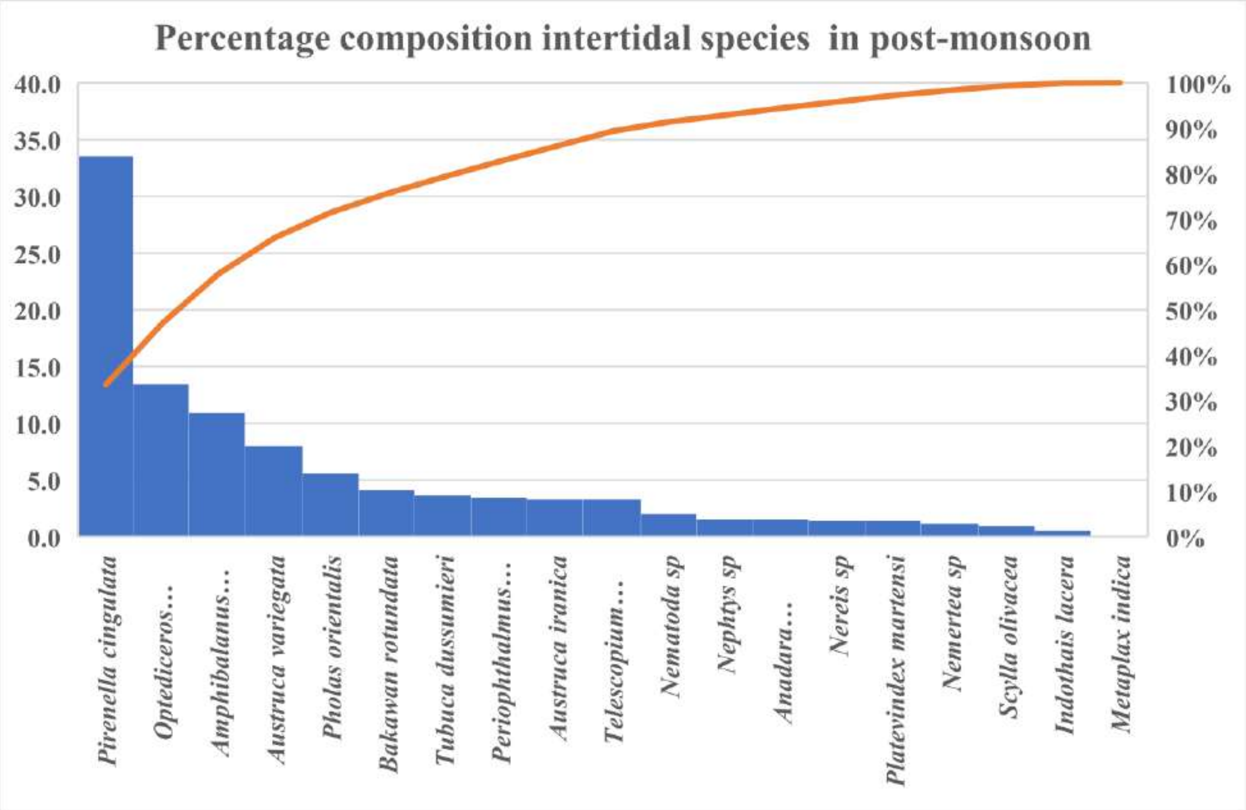

Figure 18: Percentage composition of Intertidal species during post-monsoon 2022-2023

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.

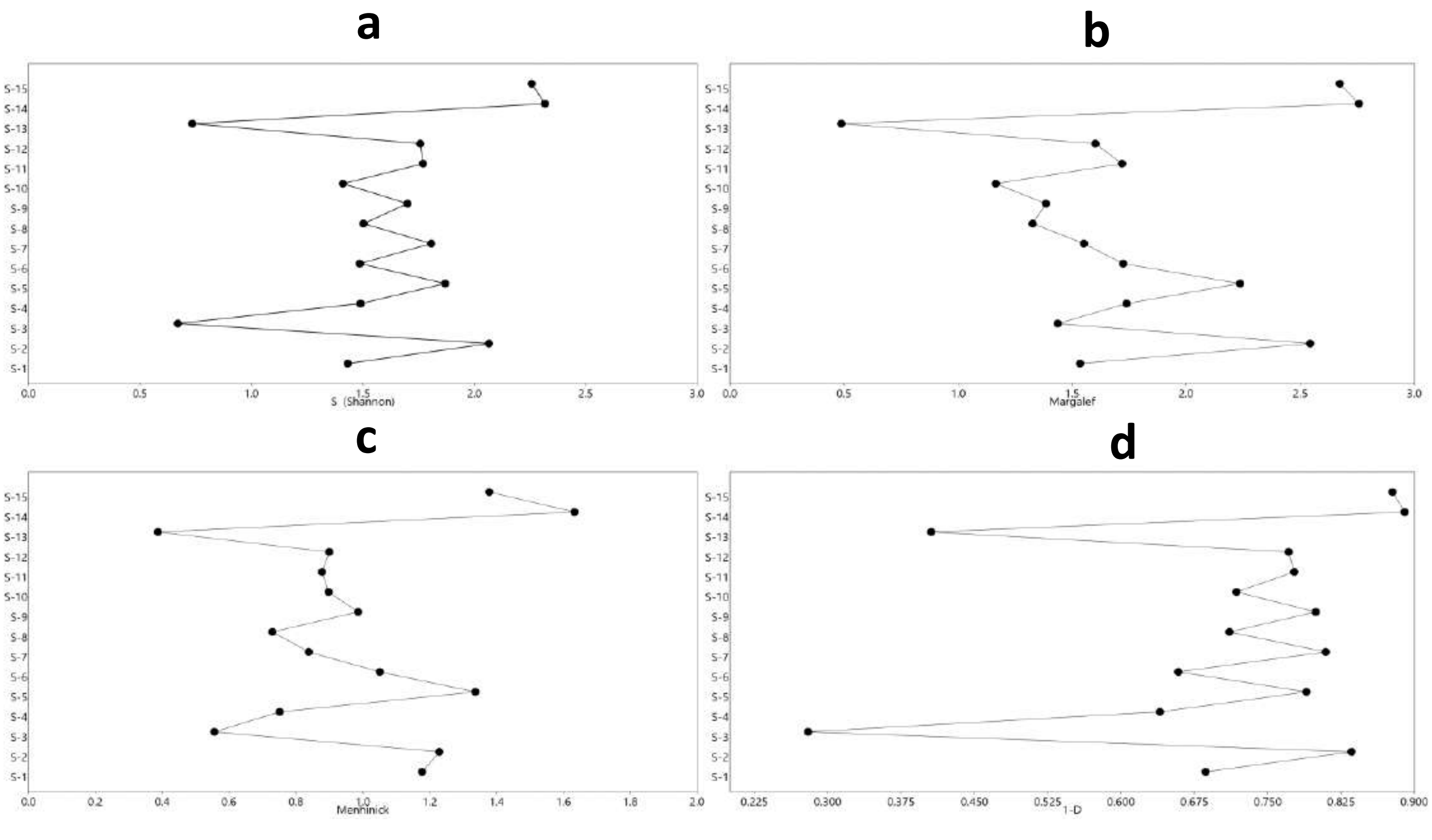

Figure 19: Diversity indices of Intertidal fauna during post-monsoon 2022-2023

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

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^2. 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^2. 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 a*l., (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.)

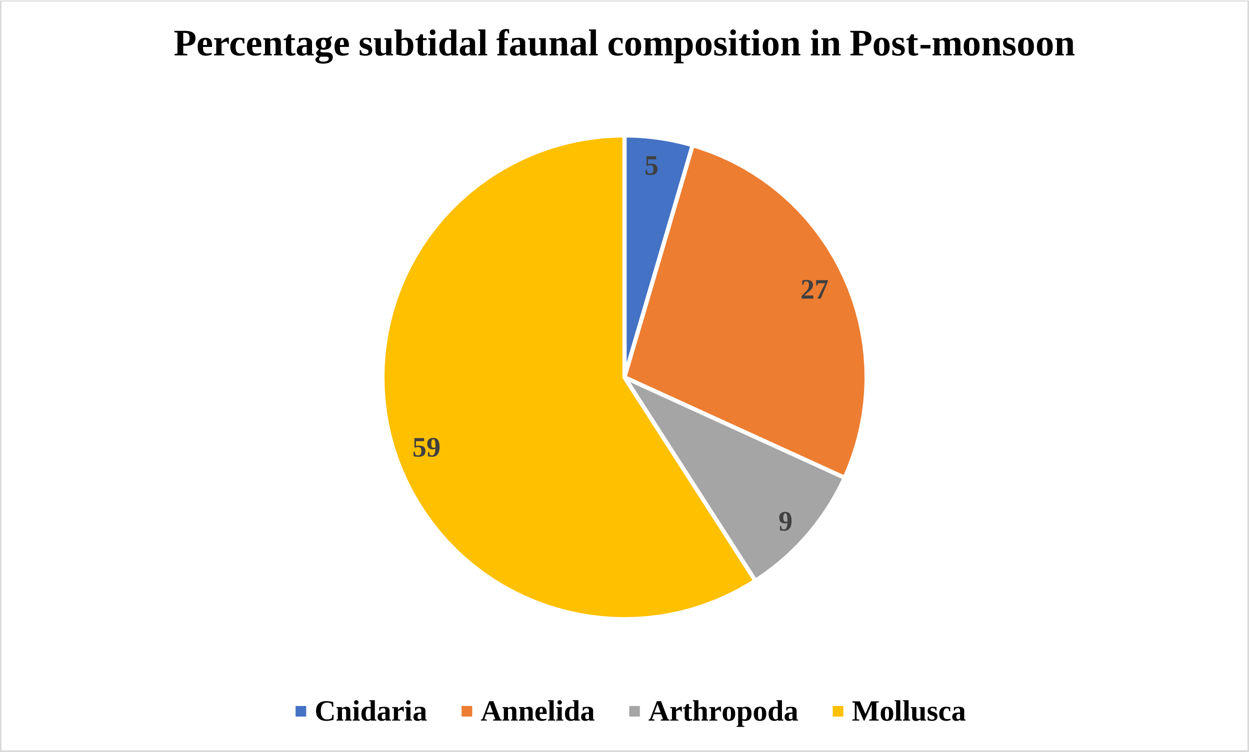

Figure 20. Phylum composition of subtidal macrobenthos during Post-monsoon 2022-2023

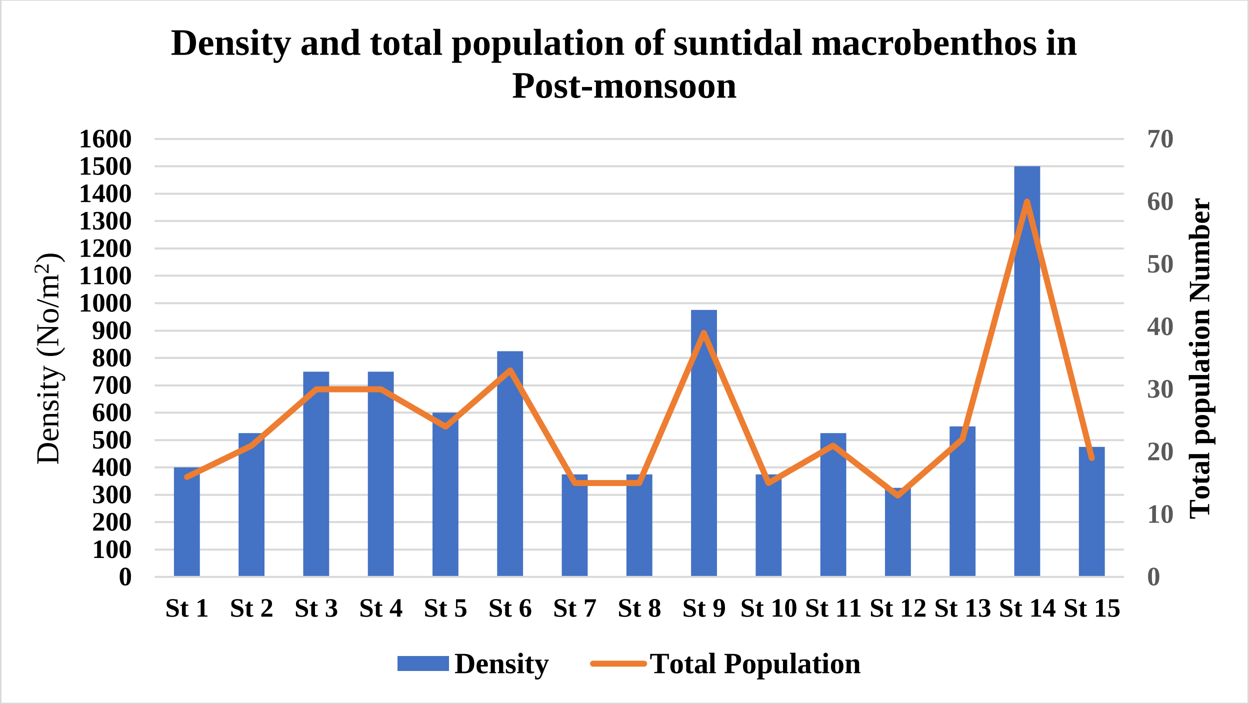

Figure 21: Total genera and population density macrobenthos during Post-monsoon 2022-2023

Total genera &populationa density(No/m^2)

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^2 to 1500 No/m2 with average 622 No/m^2. The highest population density was recorded at S-14 (1500 No/ m^2) followed by S-9 (975 No/ m^2) 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 *Glauconome 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.*

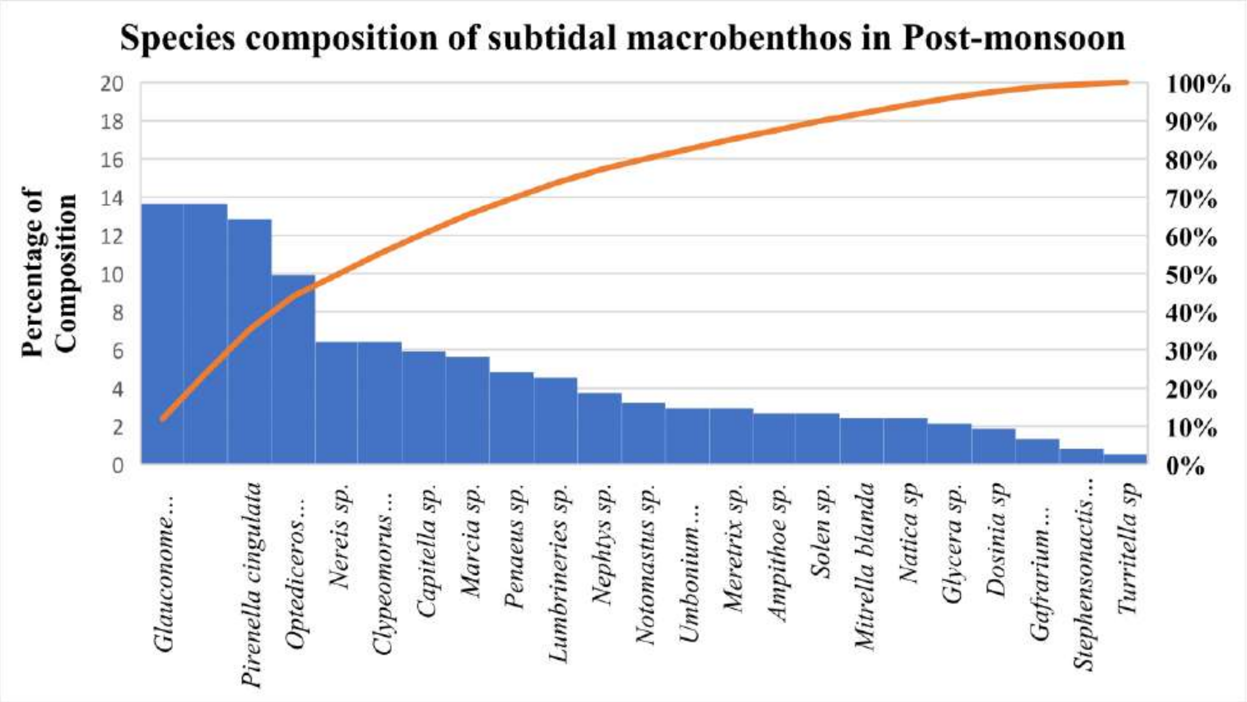

Figure 22. Percentage composition of Subtidal Macrobenthic species in Post-monsoon 2022-2023

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.

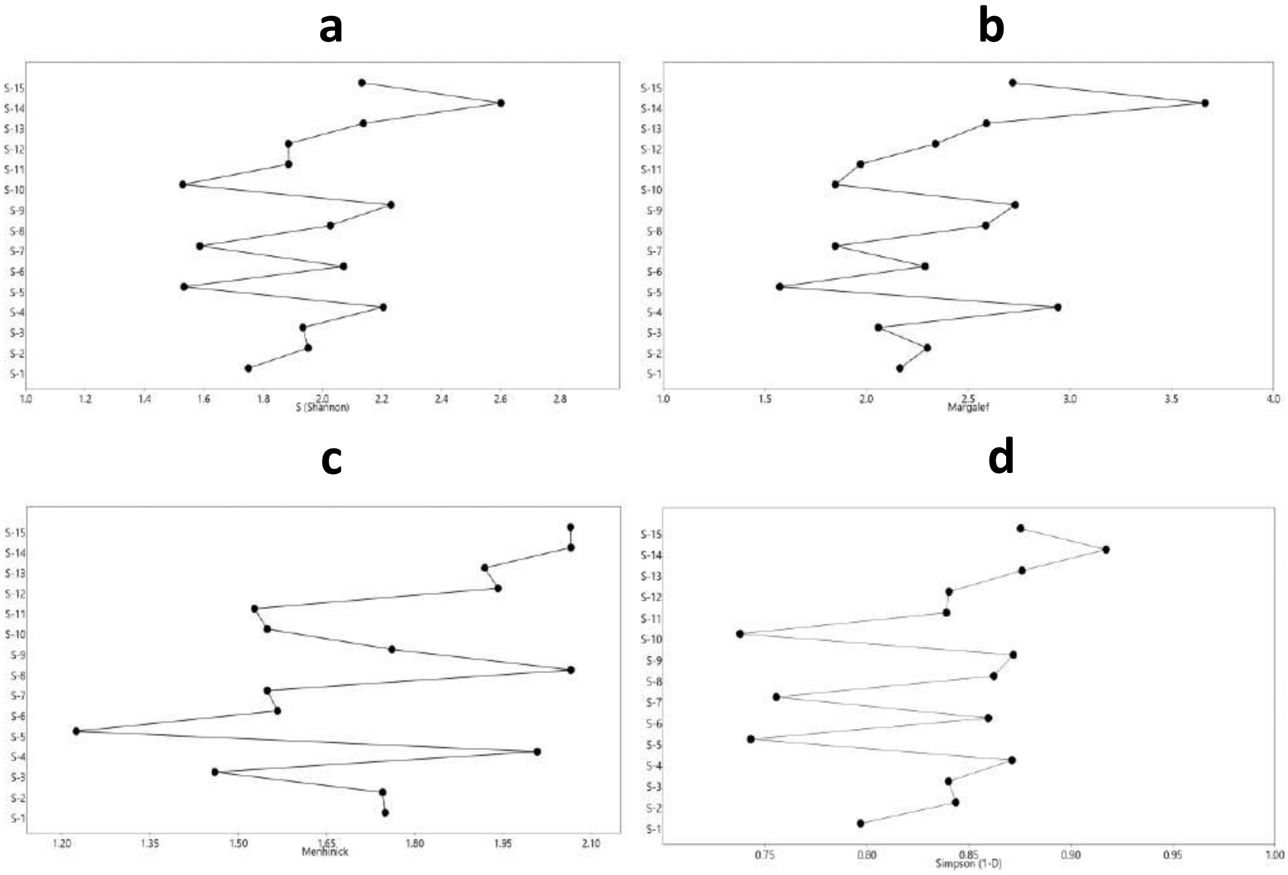

Figure 23: Diversity indices of Subtidal fauna during Post-monsoon 2022-2023
a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index

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
Cnidaria	*Stephensonactis* sp.	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0.8
Annelida	*Capitella* sp.	0	3	0	0	3	0	0	0	5	4	3	1	0	3	0	5.9
	Glycera sp.	0	1	0	0	0	0	2	0	2	0	0	0	3	0	0	2.1
	Lumbrineries sp.	1	0	4	3	0	0	1	0	0	2	0	2	2	0	2	4.6
	Nephtys sp.	2	0	2	1	0	3	0	2	3	0	0	0	0	1	0	3.8
	Nereis sp.	0	3	1	1	0	4	0	0	3	1	4	0	4	0	3	6.4
	Notomastus sp.	2	0	0	2	0	3	0	0	2	0	0	0	3	0	0	3.2
Arthropoda	Ampithoe sp.	0	0	0	0	2	0	0	1	3	0	0	2	0	2	0	2.7
	Penaeus sp.	0	2	0	0	1	4	0	0	3	0	2	0	2	1	3	4.8
Mollusca	*Umbonium vestiarium*	1	0	0	2	0	3	0	1	0	1	0	0	0	3	0	2.9
	Mitrella blanda	0	0	0	0	0	0	0	0	0	0	2	0	0	7	0	2.4
	Clypeomorus bifasciata	0	0	0	0	0	0	0	2	10	0	2	3	0	6	1	6.4
	Natica sp	0	0	0	1	0	0	0	0	0	0	0	0	1	7	0	2.4
	Optediceros breviculum	4	5	6	4	2	2	3	2	1	0	0	0	0	5	3	9.9
	Pirenella cingulata	5	0	5	6	7	5	1	2	3	1	5	2	3	1	2	12.9
	Turritella sp	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.5
	Marcia sp.	0	0	3	2	0	1	2	3	0	0	0	1	2	5	2	5.6
	Glauconome angulata	0	2	7	6	9	8	6	2	0	6	3	2	0	0	0	13.7
	Dosinia sp	0	0	2	2	0	0	0	0	0	0	0	0	0	3	0	1.9
	Gafrarium divaricatum	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	1.3
	Meretrix sp.	0	4	0	0	0	0	0	0	0	0	0	0	0	6	1	2.9
	Solen sp.	0	0	0	0	0	0	0	0	4	0	0	0	0	6	0	2.7
Density No/m^2		**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 Chaetomprpha* 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 Deedayal 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**
Aeluropus lagopoides		0	0	0	0	0	0	0	0	0	33	0	0	0	0
Salicornia brachiata		0	10%	52%	81%	0	0	64%	100%	35	100%	0	0	0	66%
Salvadora persica		0	0	0	0	0	0	0	0	20%	0	0	0	0	0
Sesuvium portulacastrum		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 km2. 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).

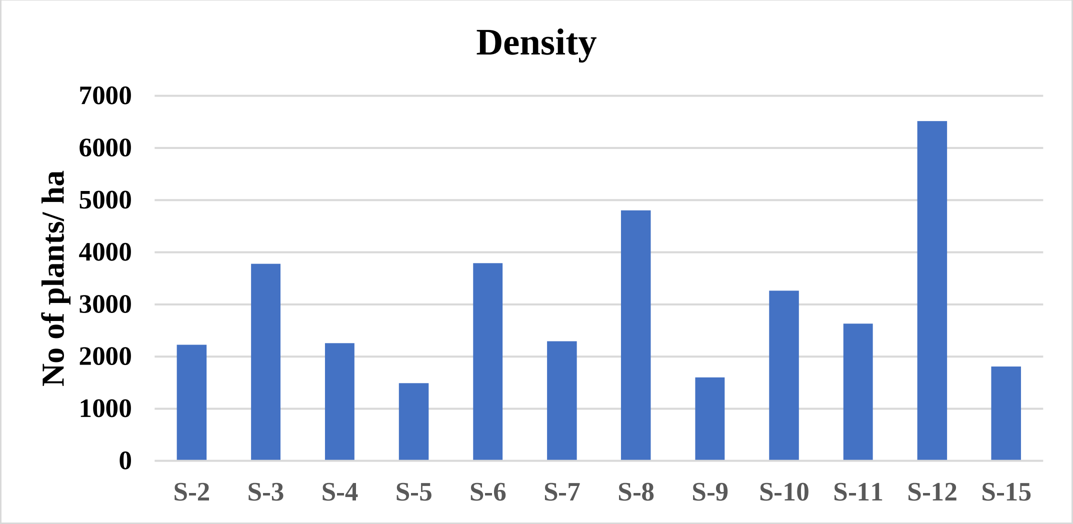

Figure 24. Mangrove Plant density during Post-monsoon 2022-2023

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.

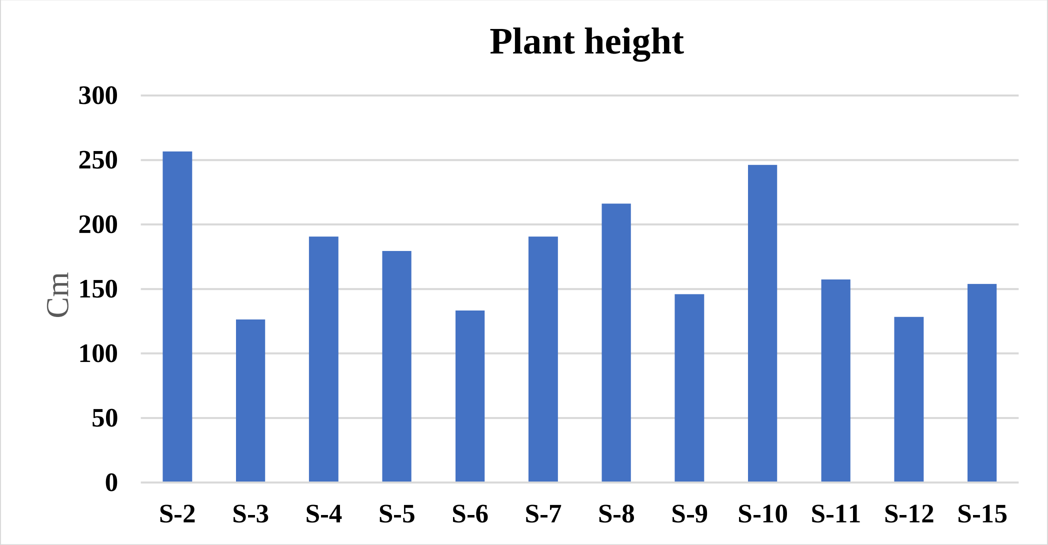

Figure 25. Plant height during Post-monsoon 2022-2023

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 m2 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).

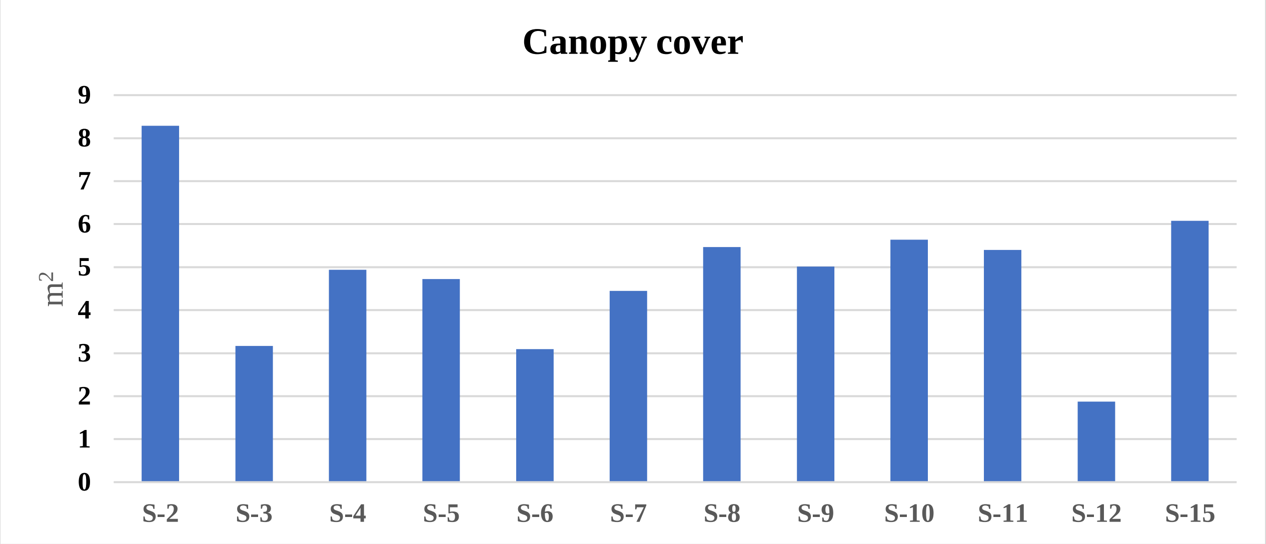

Figure 26. Mangrove canopy cover during Post-monsoon 2022-2023

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).

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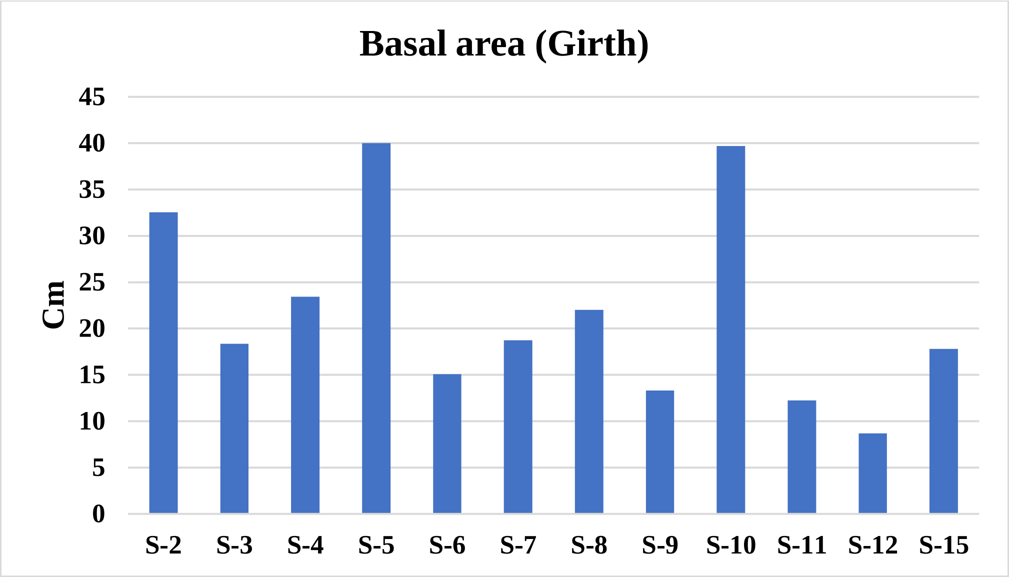


Figure 27. Mangrove basal area during Post-monsoon 2022-2023

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^2)			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
Tuna creek					
S-2	2226.55	140000	11775	1 : 5.29	11.89 : 1
S-12	6515.31	70000	11750	1 : 1.80	5.96 : 1
Mean	4370.93	105000	11763	1 : 2.69	8.93 : 1
Phang creek					
S-5	1490.74	80000	6562	1 : 4.40	12.19 : 1
S-10	3265.31	43000	11250	1 : 3.45	3.82 : 1
Mean	2378.03	61500	8906	1 : 3.75	6.91 : 1
Kandla creek					
S-3	3780.86	46500	28625	1 : 7.57	1.62 : 1
S-4	2256.25	84000	7000	1 : 3.10	12.00 : 1
S-15	1810.77	48000	8750	1 : 4.83	5.49 : 1
Mean	2615.96	59500	14792	1 : 5.65	4.02 : 1
Kharo creek					
S-7	2290.89	45000	22250	1 : 9.71	2.02 : 1
Jangi creek					
S-6	3790.74	54444	12500	1 : 3.30	4.36 : 1
S-11	2629.85	34500	4375	1 : 1.66	7.89 : 1
Mean	3210.30	44472	8438	1 : 2.63	5.27 : 1
Navlakhi creek					
S-8	4805.21	141000	16000	1 : 3.33	8.81 : 1
S-9	1600.00	42000	13500	1 : 8.44	3.11 : 1
Mean	3202.61	91500	14750	1 : 4.61	6.20 : 1
Overall average	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 klunzinger*i, *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

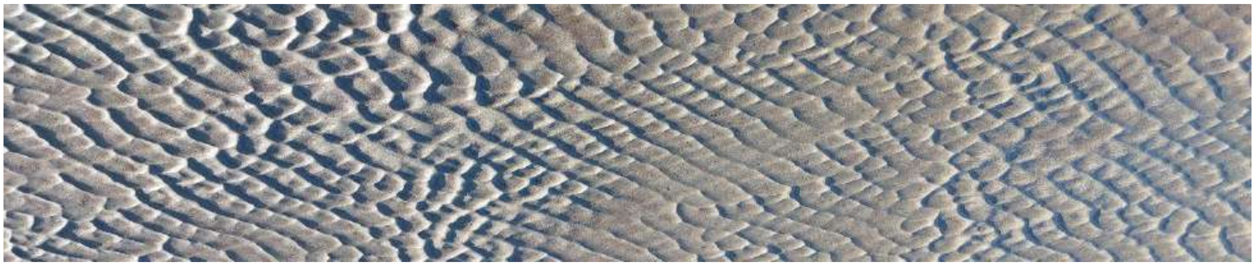
Mudflats and mangroves establish a major ecosystem of the DPA coastal region and the significance of ecosystem services rendered by mudflat is endorsed in Coastal Regulation Zone (CRZ, 2011) as it accords special status to highly productive zone. Mudflat has an assemblage of plant-animal-geomorphological 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^3 to 1.52 g/cm^3. The highest bulk density was recorded at S-13 and the lowest bulk density was recorded at site S-1 located at Tuna creeek.

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.



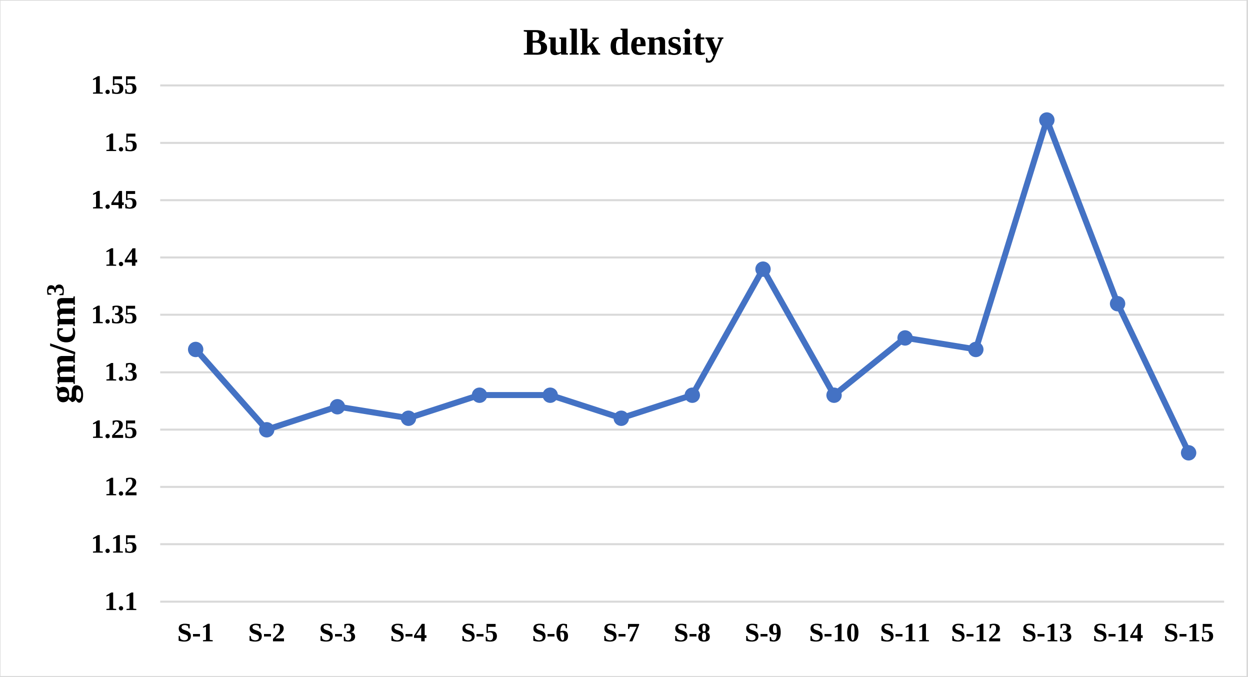


Figure 28: Bulk density of mudflat sediment during Post-monsoon 2022-2023

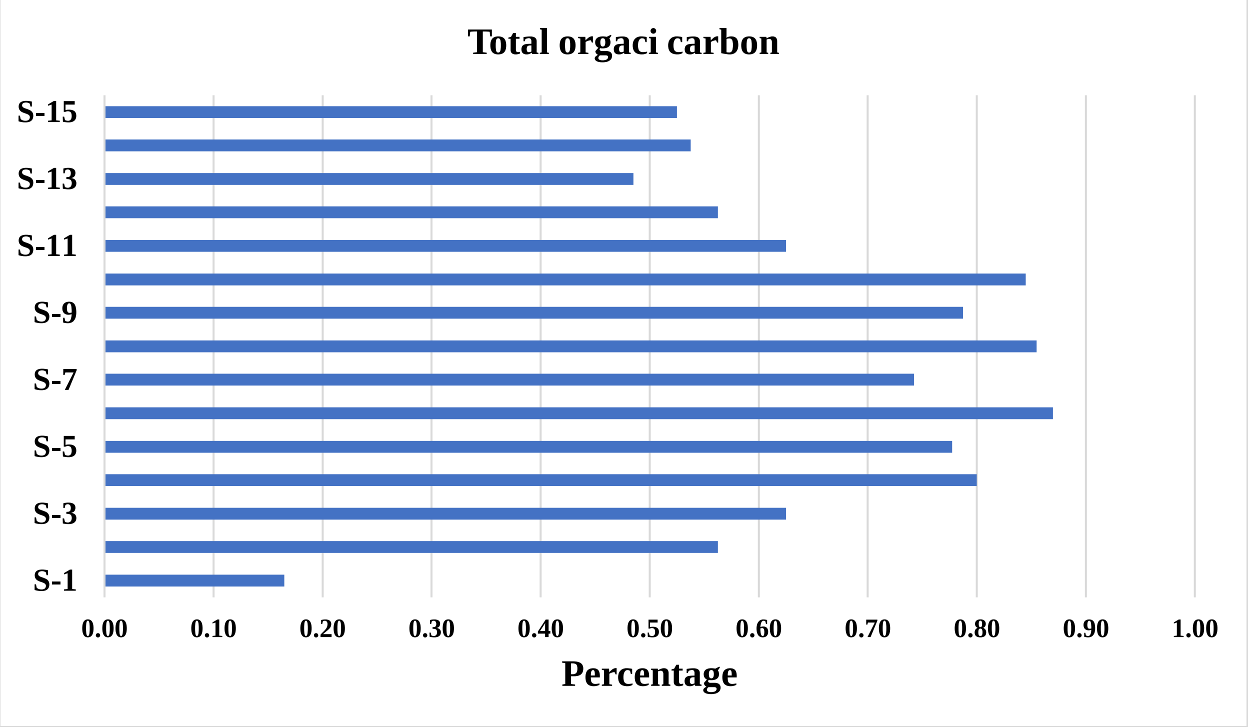


Figure 29: Percentage of Total Organic Carbon in the mudflat in Post-monsoon 2022

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).

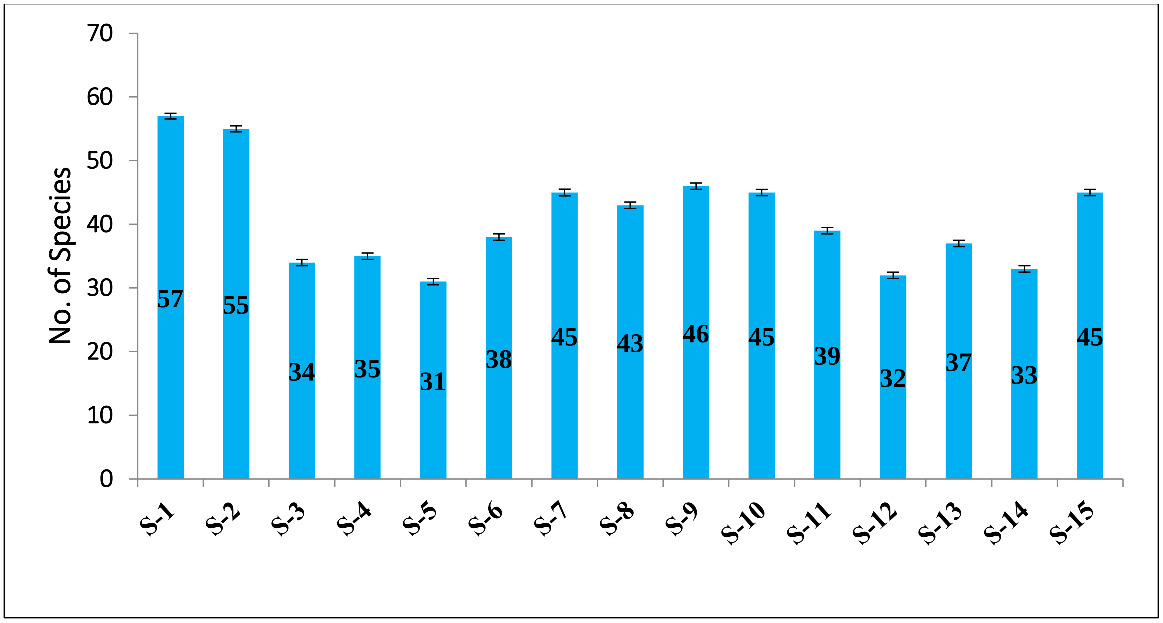


Figure 30. Number of Avian species recorded from the DPA in Post-monsoon2022-2023

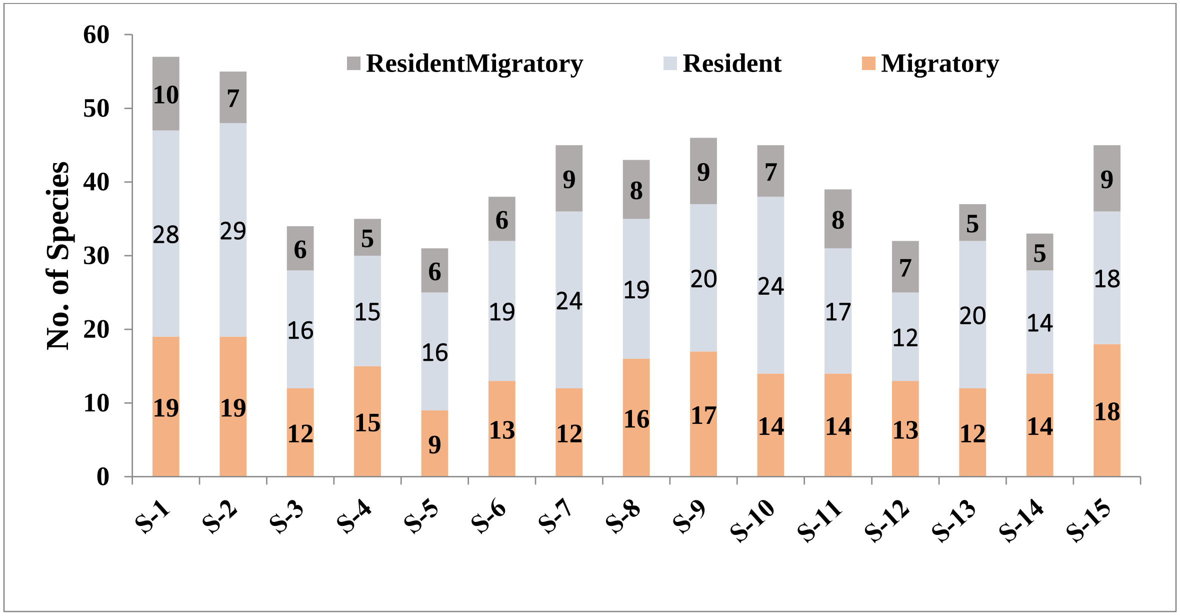


Figure 31. Behavioral status of Avian species from the DPA in Post-monsoon 2022-2023

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)

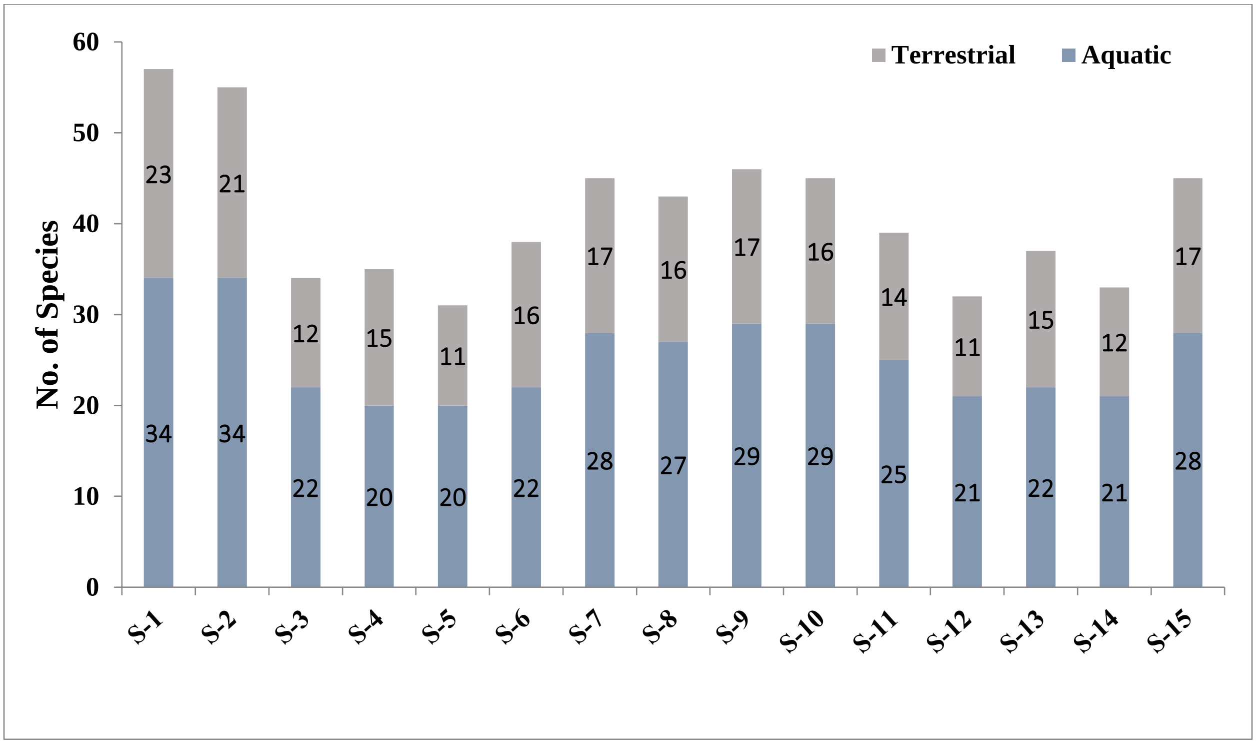


Figure 32. Habitat wise distribution of Bird species in Post-monsoon 2022-2023 from DPA

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 recoded from Site 3,6,8&11) and least species found of frugivores, omnivores and nectorivores.

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

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

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Annexure -C

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 (17th April-16th May, 2023)

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

Submitted to:

Deendayal Port Authority (DPA), Kandla

Gujarat Environment Management Institute (GEMI)

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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

A	Acceptable Limits as per IS: 10500:2012
AAQ	Ambient Air Quality
AWS	Automatic Weather monitoring stations
BIS	Bureau of Indian Standards
BOD	Biochemical Oxygen Demand
BQL	Below Quantification Limit
CCA	Consolidated Consent & Authorization
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DO	Dissolved Oxygen
DPA	Deendayal Port Authority
EC	Electrical Conductivity
EMMP	Environmental monitoring and Management Plan
EMP	Environment Management Plan
FPS	Fine Particulate Sampler
FY	Financial Year
GEMI	Gujarat Environment Management Institute
IFFCO	Indian Farmers Fertiliser Cooperative Limited
IMD	India Meteorological Department
IOCL	Indian Oil Corporation Limited
LNG	Liquefied Natural Gas
MGO	Marine Gas Oil
MMTPA	Million Metric Tonnes Per Annum
MoEF	Ministry of Environment & Forests
MoEF&CC	Ministry of Environment, Forest and Climate Change
NAAQS	National Ambient Air Quality Standards
NO_x	Nitrogen oxides
NTU	Nephelometric Turbidity Unit
OOT	Off Shore Oil Terminal
OSR	Oil Spill Response
P	Permissible Limits as per IS: 10500:2012
PAH	Poly Aromatic Hydrocarbons
PM	Particulate Matter
PTFE	Polytetrafluoroethylene
RCC	Reinforced Concrete Cement
RDS	Respirable Dust Sampler
SAR	Sodium Adsorption Ratio
SBM	Single Bouy Mooring
SO_x	Sulfur oxides
STP	Sewage Treatment Plant
TC	Total Coliforms
TDS	Total Dissolved Solids
TOC	Total organic Carbon
TSS	Total Suspended Solids
VOC	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 14th 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_4, PO_4, 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 transhipment), 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:

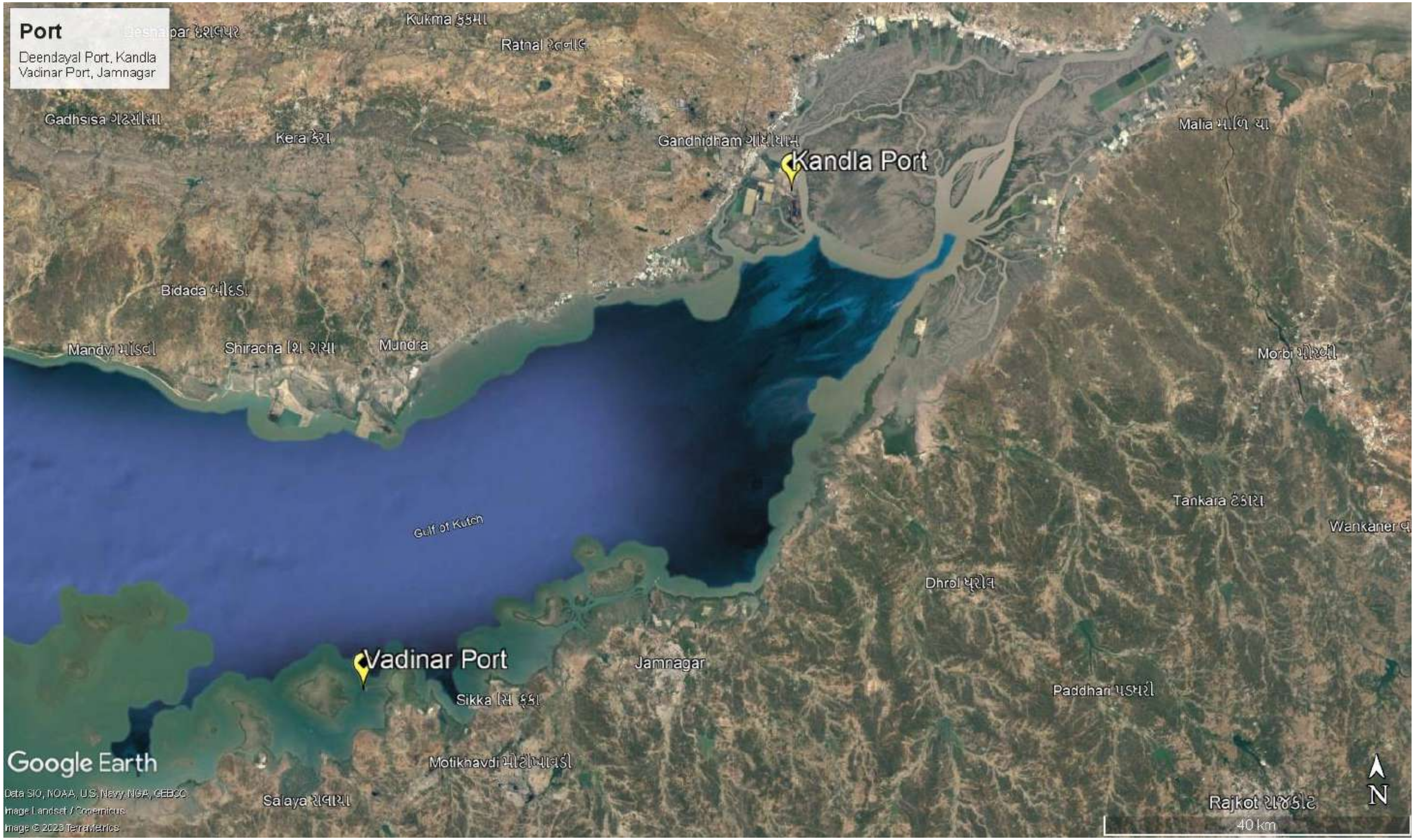


Figure 1: Locations Map of Kandla and Vadinar

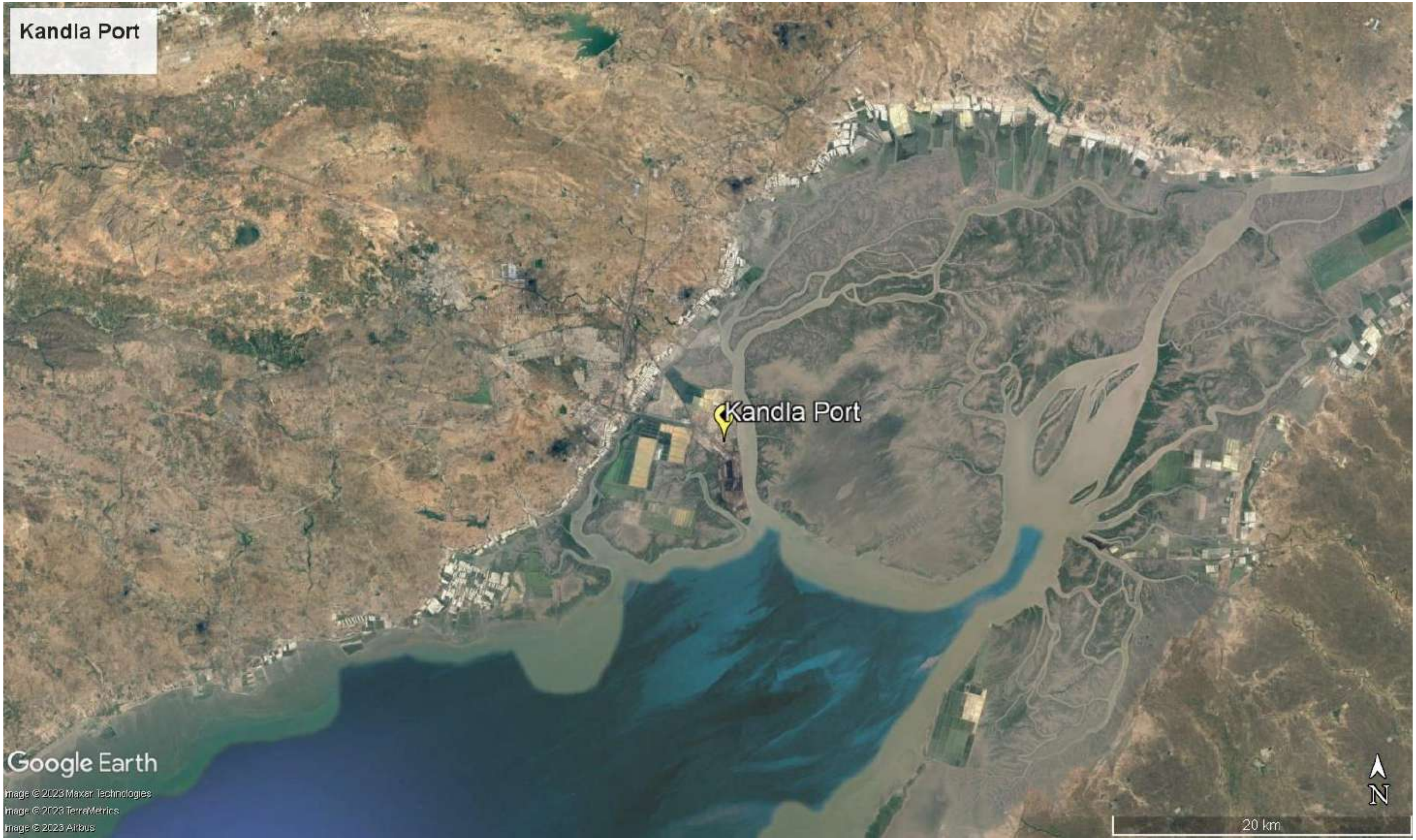


Figure 2: Map of Kandla Port

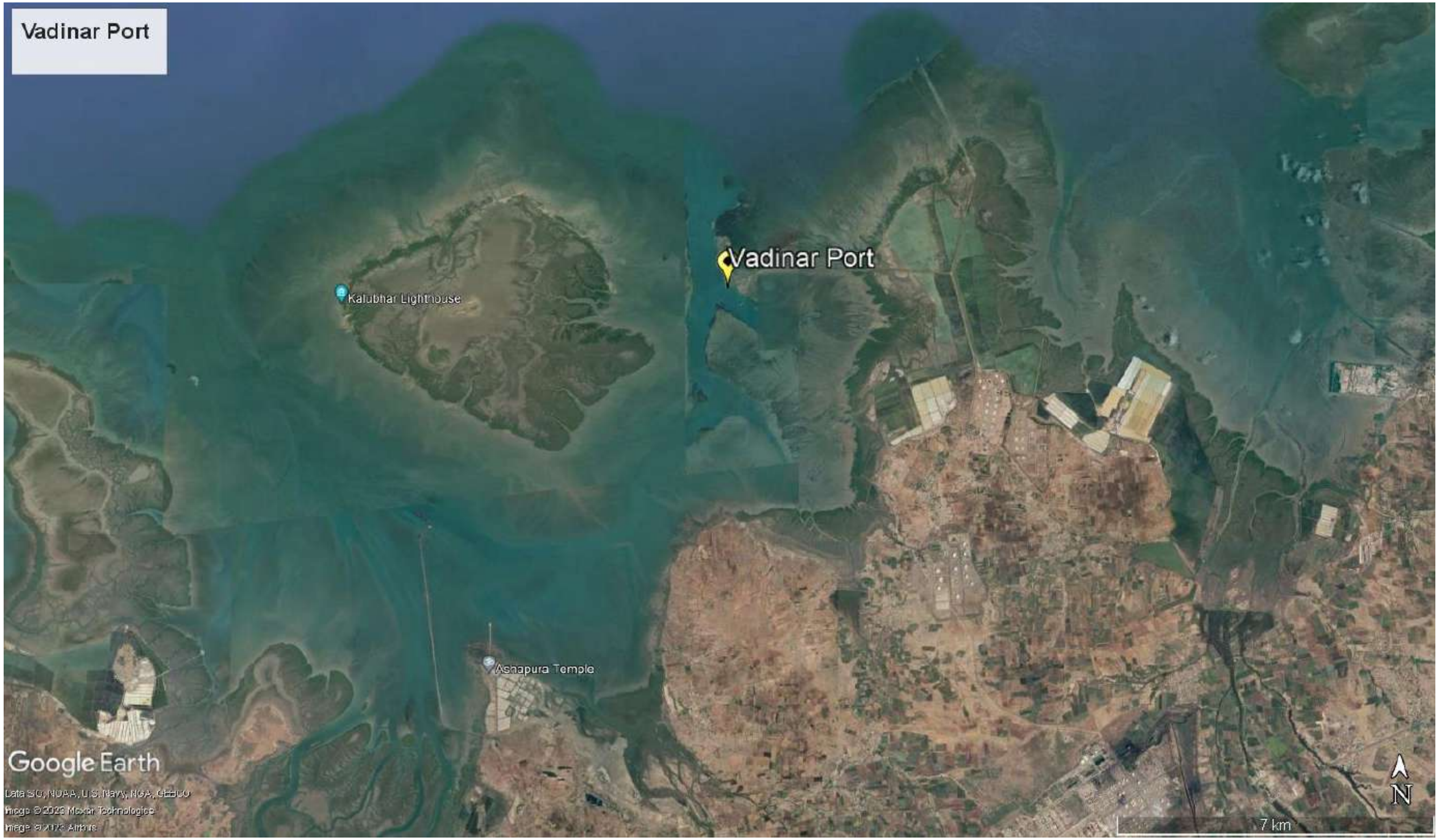
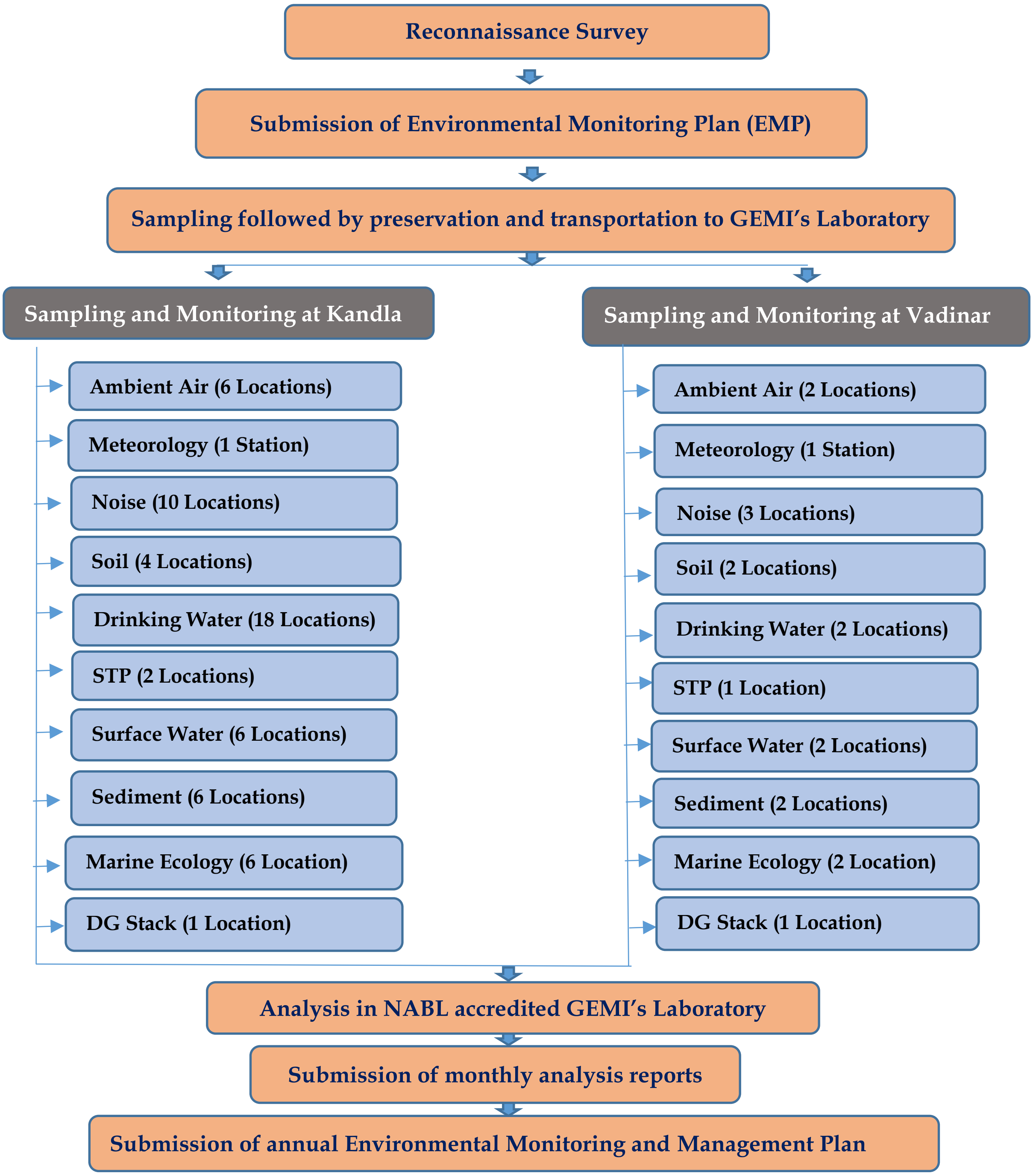


Figure 3: Map of Vadinar Port

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^2		

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 19th April – 16st 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/m²)**	**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/m²)**	**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

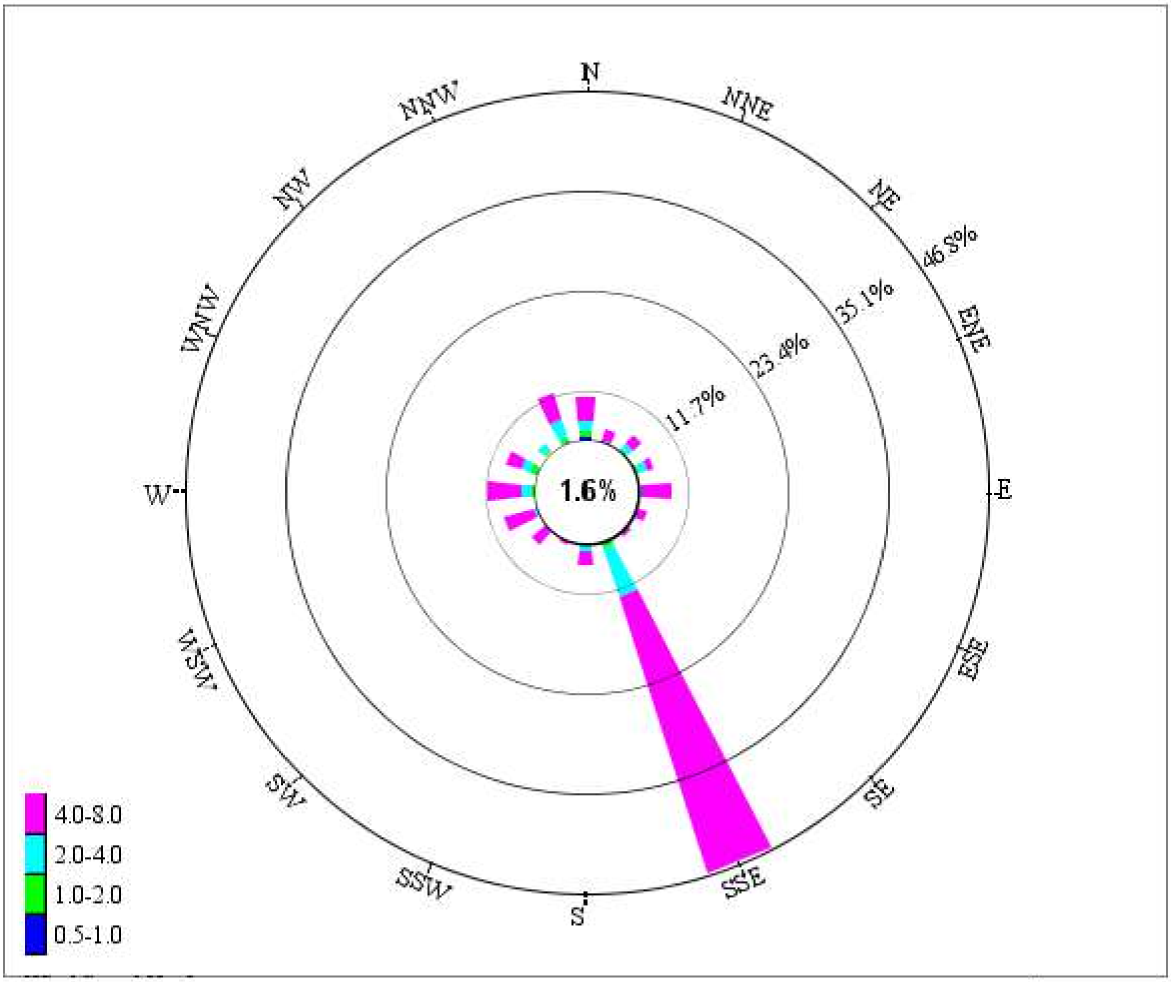
- **Temperature**
  a. Kandla: The ambient Temperature from April to May varies between the range of 26.75-35.23°C for Kandla, with average temperature of 31.31°C.
  b. Vadinar: The ambient temperature for the month of April varies between the range of 25.04-30.62°C for Vadinar, with average temperature 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^2.
  b. Vadinar: The average Solar Radiation was recorded as 110.76 W/m^2
- **Wind rose diagram -**

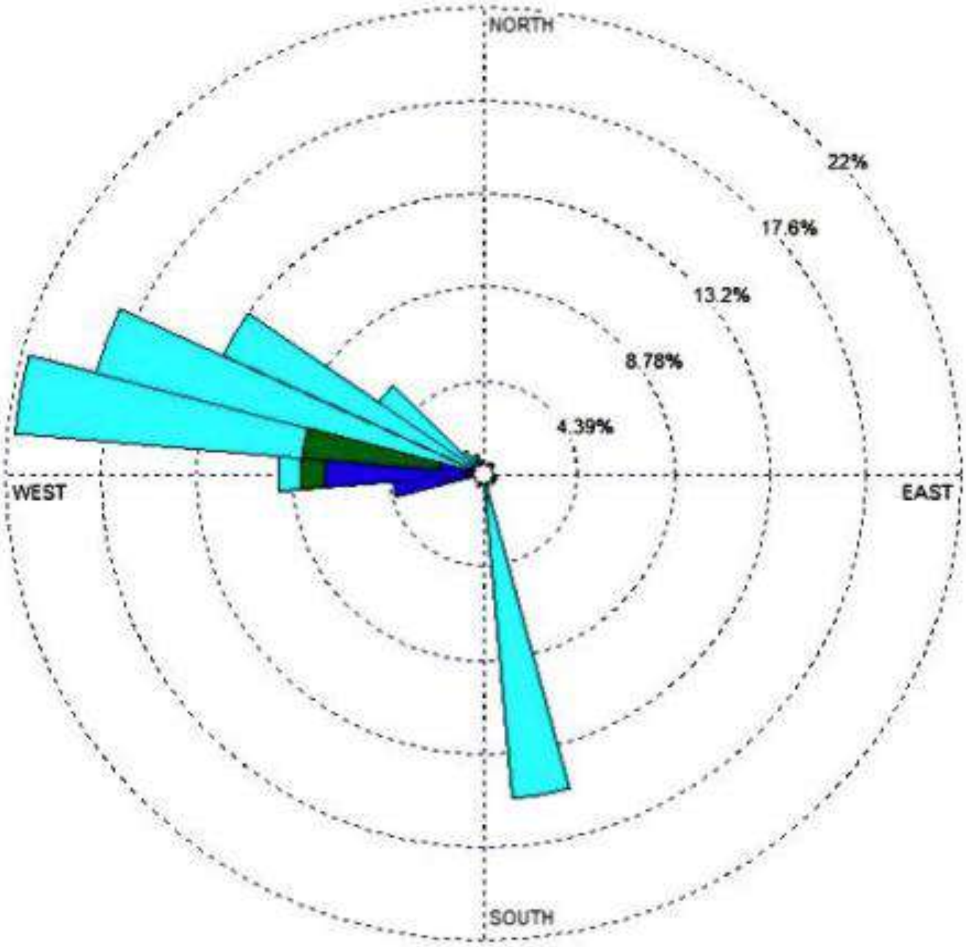
  The wind-rose diagram for the Monitoring period has been drawn on the basis of hourly wind speed and direction data.

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.

<table>
<tr><td>**Wind Rose Plot (April)**
M/s Deendayal Port Authority
Site: Kandla Port (Environment Laboratory)</td><td>**Display: Wind Direction**
Wind Speed</td></tr>
<tr><td colspan="2">

Windrose-> from:21-04-2023 to:16-05-2023 Between: 00:00 & 23:00 hours</td></tr>
<tr><td>Data Period: 21/04/2023 to 16/05/2023</td><td>Modeler: Envirotech Instruments Pvt. Ltd. Delhi.</td></tr>
</table>

Wind Rose Plot (17 April- 16 May 2023) **M/s Deendayal Port Authority** **Site: Vadinar Port (Canteen Area)**	**Display: Wind Direction** **Wind Speed**



Data Period: 20/04/2023 to 16/05/2023	Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

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 17th April- 15th 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	23.029361N 70.22003E	Loading of materials, dry cargo handling, liquid containers, emission from ship
2.		A-2	Oil Jetty No. 7	23.043538N 70.218617E	
3.		A-3	Kandla Port Colony	23.019797N 70.213536E	Vehicular activity, dust emission, Traffic
4.		A-4	Marine Bhavan	23.007653N 70.222197E	Construction activity, road dust emission
5.		A-5	Coal Storage Area	23.000190N 70.219757E	Coal Dust, Vehicular activity
6.		A-6	Gopalpuri Hospital	23.081506N 70.135258E	Residential area, dust emission, vehicular activity
7.	Vadinar	A-7	Admin Building	22.441806N 69.677056E	Vehicular activity
8.		A-8	Vadinar Colony	22.401939N 69.716306E	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

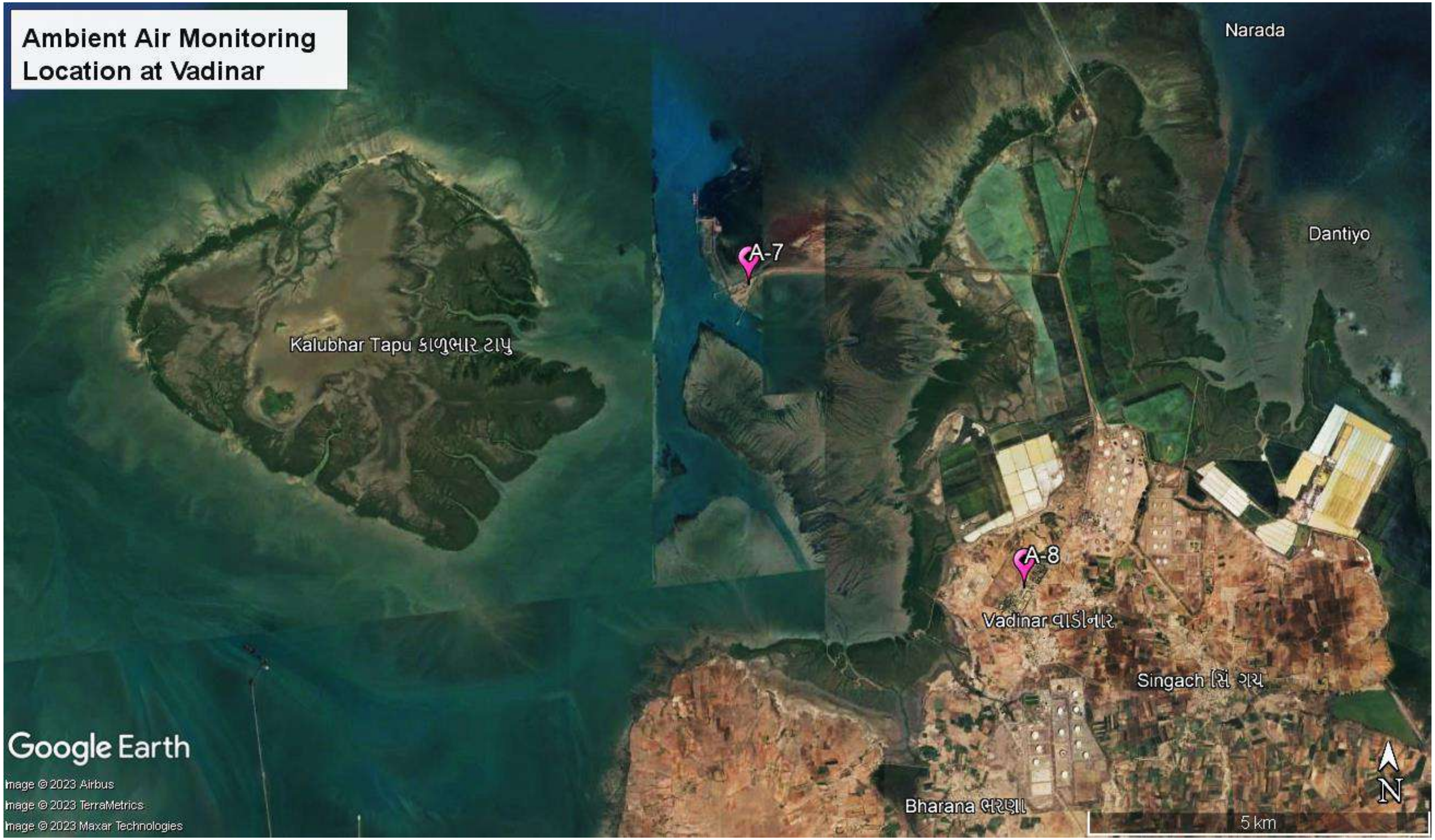


Figure 5: Location Map for Ambient Air Monitoring at Vadinar

Frequency of AAQ Monitoring

The sampling for Particulate matter (PM_{10}, $PM_{2.5}$) and gaseous like SO_x, NO_x, 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_{10}, calibrated 'Respirable Dust Samplers' were used, where Whatman GF/A microfiber filter paper (size: 8" X 10") was used for the collection of PM_{10}. APM- air sampler of the make Envirotech instrument was attached with Respirable Dust Sampler $PM_{2.5}$ 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_2 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, NOx 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_{10}, $PM_{2.5}$, SO_x and NO_x samples of 24-hour duration on two days a week (i.es., 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$_{10}$	µg/m^3	IS 5182 (Part 23): 2006	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-23): 2006	Twice in a week
2.	PM$_{2.5}$	µg/m^3	IS:5182 (Part:24):2019	Fine Particulate Sampler (FPS) conforming to IS:5182 (Part-24): 2019	
3.	Sulphur Dioxide (SO$_x$)	µg/m^3	IS 5182 (Part:2): 2001	Gaseous Attachment conforming to IS:5182 Part-2	
4.	Oxides of Nitrogen (NO$_x$)	µg/m^3	IS:5182 (Part-6): 2006	Gaseous Attachment conforming to IS:5182 Part-6	
5.	Carbon Monoxide	mg/m^3	GEMI/SOP/AAQM/11; Issue no 01, Issue date 17.01.2019: 2019	Sensor based Instrument (Make: Vaibhav Instruments)	
6.	VOC	µg/m^3	IS 5182 (Part 17): 2004	Low Flow Air Sampler	
7.	Benzene	µg/m^3	IS 5182 (Part 11): 2006 RA: 2017	Low Flow Air Sampler	
8.	PAH	µg/m^3	IS: 5182 (Part 12): 2004	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-12): 2004	Monthly
9.	Non-methane VOC	µg/m^3	IS 5182 (Part 11): 2006	Low Volume Sampler	

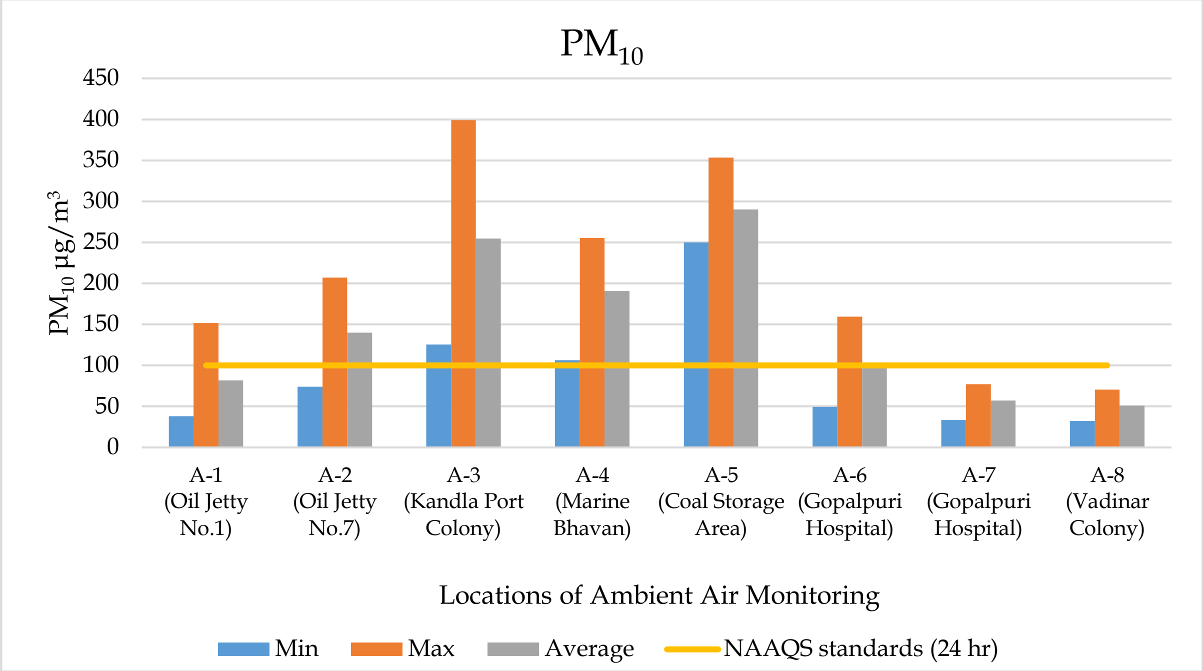
4.3 Result and Discussion:

The summarized results of ambient air quality monitoring for the period from 17th April to 15th 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$_{10}$ for Ambient Air quality monitoring

PM$_{10}$ (µg/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**	**NAAQS standards (24 hr)**
1	17-Apr-2023	86.35	144.87	341.95	255.59	211.81	89.13	56.62	42.63	**100 µg/m^3**
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$_{10}$ (µg/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**	
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$_{10}$ Concentration at Monitoring locations

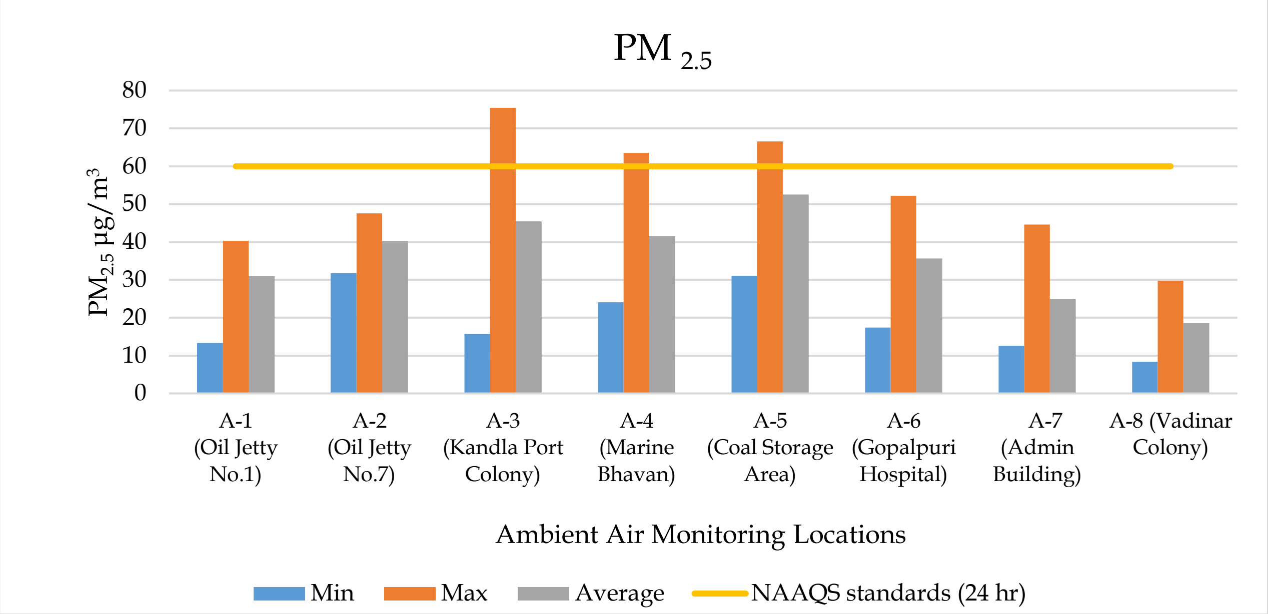
Interpretation:

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

The higher reporting of PM$_{10}$ 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_{10} falls within the stipulated norm of 100 µg/m³. 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 $PM_{2.5}$ for Ambient Air quality monitoring

$PM_{2.5}$ (µg/m³)										
Sr. No	**Location** / **Sampling date**	**Kandla**						**Vadinar**		
		A-1	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**NAAQS standards (24 hr)**
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	

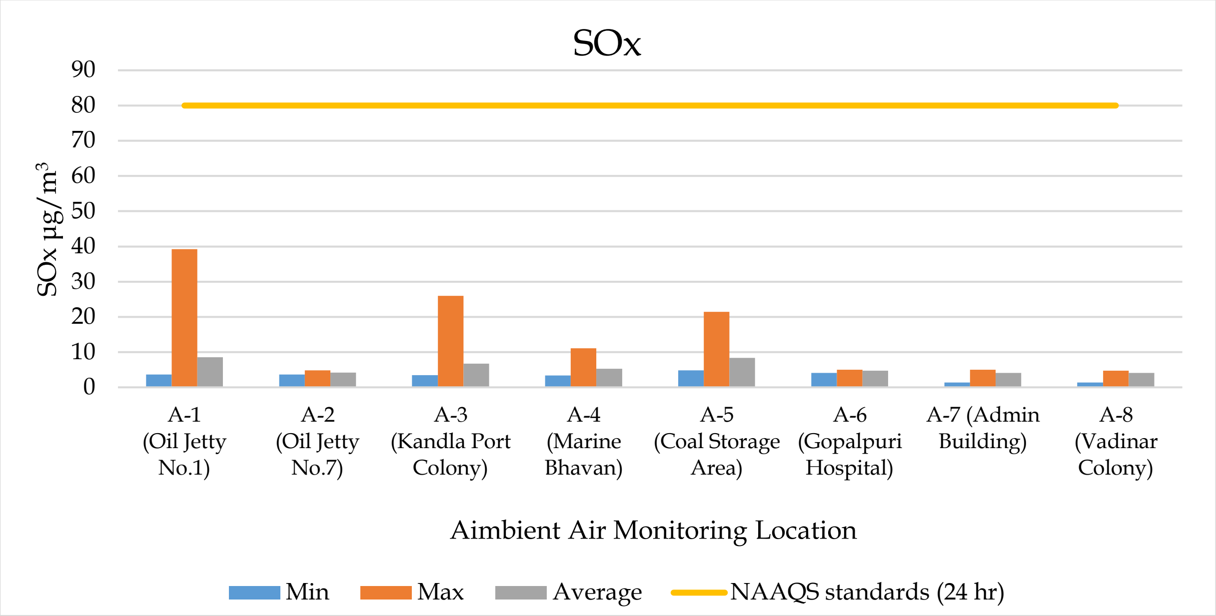


Graph 2: Spatial trend in $PM_{2.5}$ Concentration at Monitoring locations

The highest $PM_{2.5}$ concentration (75.44 µg/m³) was recorded at station A-3, Kandla Port Colony which is above the limit prescribed by NAAQS. Whereas majority of the monitored values of $PM_{2.5}$ at Kandla were reported well below the specified limit of 60 µg/m³. While for Vadinar monitoring station the maximum value for $PM_{2.5}$ observed is, 44.65 µg/m³ at Admin Building (A-7). Similar to values detected for the Respirable Dust i.e., PM_{10}, higher concentration of $PM_{2.5}$ 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 SO_x for Ambient Air quality

SO_x (µg/m³)										
Sr. No	**Location / Sampling date**	Kandla						Vadinar		
		A-1	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**NAAQS standards (24 hr)**
1	17-Apr-2023	5.98	4.8	4.1	3.6	5.33	4.9	4.6	4.6	80 µg/m³
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	



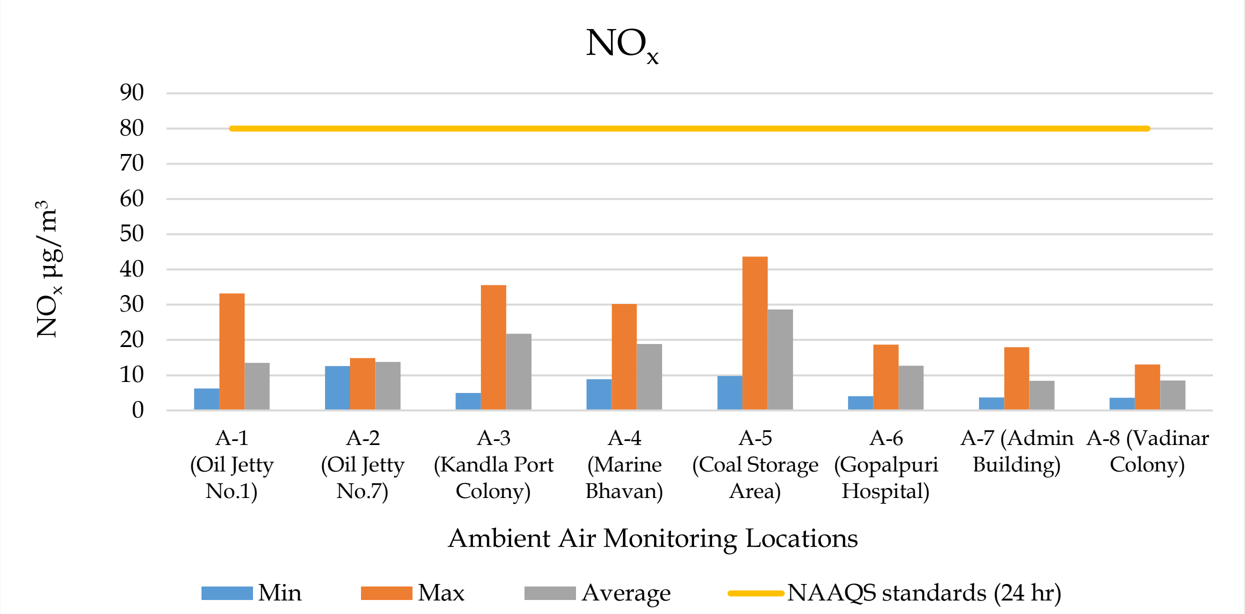
Graph 3: Spatial trend in SOx Concentration at Monitoring locations

The highest SO_x concentration (39.19 µg/m³) was recorded at station A-1, Oil Jetty No.1 area while the lowest SO_x concentration was found to be 3.4 µg/m³ at A-4, Marine Bhavan. From the observed value it is seen that the concentration of SO_x falls within the limit prescribed by NAAQS.

Whereas for Vadinar monitoring station the maximum and minimum value for SO_x observed is, 4.99 µg/m³ and 1.39 µg/m³ at Admin Building (A-7) at different month. The majority of the monitored values of SO_x at Vadinar were reported well below the specified limit of 80 µg/m³.

Table 9: Summarized results of NOx for Ambient Air quality monitoring

NO_x (µg/m³)										
Sr No	Location / Sampling date	Kandla						Vadinar		
		A-1	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**NAAQS standards (24 hr)**
1	17-Apr-2023	9.20	12.85	21.94	19.41	27.76	8.70	8.14	9.72	80 µg/m³
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	

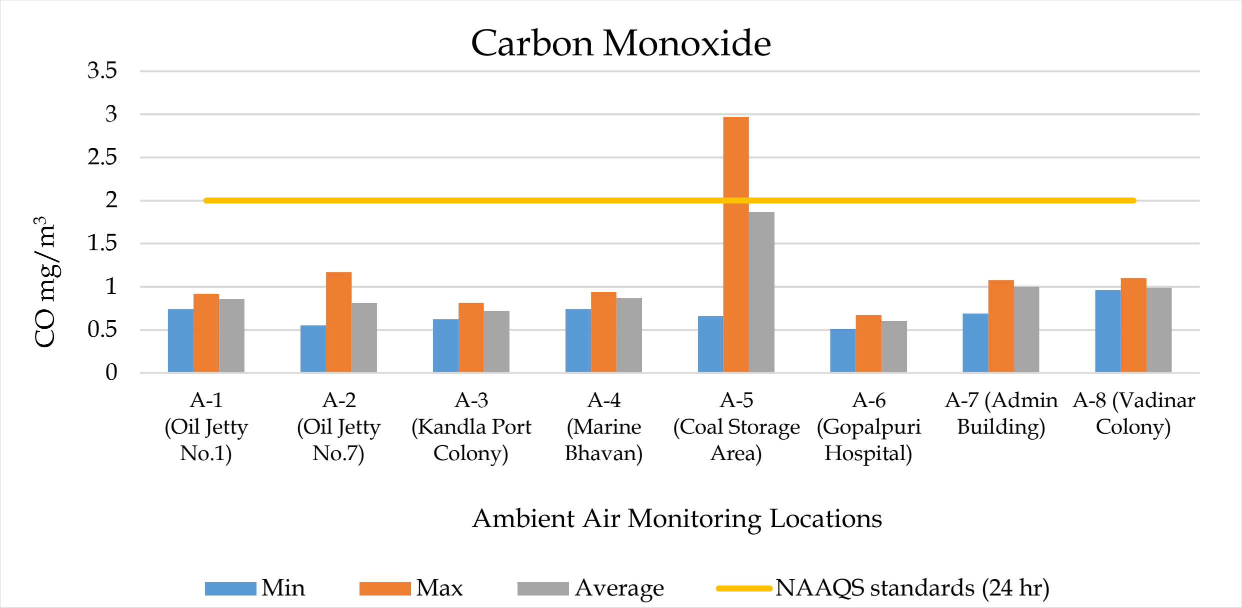


Graph 4: Spatial trend in NOx Concentration at Monitoring locations

The highest NO_x concentration 43.64 µg/m³ was recorded at station A-5, Coal Storage Area. All the monitored values of NO_x are found well below the specified limit of 80 µg/m³. At Vadinar, the concentration of NO_x 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/m³)										
Sr No	Location / Sampling date	Kandla						Vadinar		
		A-1	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**	**A-7**	**A-8**	**NAAQS standards (8 hr)**
1	17-Apr-2023	0.90	0.76	0.62	0.89	1.13	0.66	0.88	0.97	2 mg/m³
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	



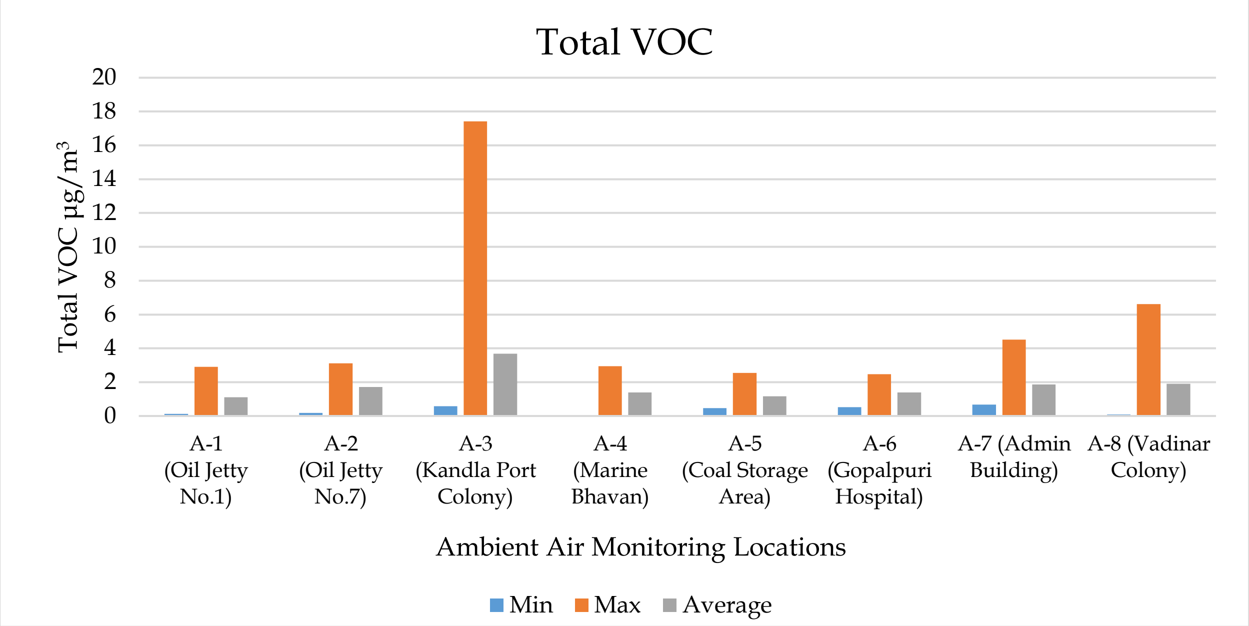
Graph 5: Spatial trend in CO Concentration at Monitoring locations

During the monitoring period, the highest CO concentration i.e., 2.97 mg/m³ was recorded at A-5, Coal Storage Area with mean value 1.87 mg/m³. Whereas other monitoring station were recorded the CO concentration well below the specified limit of 2 mg/m³.

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/m³, 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 ($\mu g/m^3$)									
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
	Minimum	0.13	0.19	0.57	0.04	0.47	0.52	0.68	0.08
	Maximum	2.91	3.11	17.43	2.95	2.54	2.48	4.52	6.62
	Average	1.10	1.71	3.68	1.39	1.17	1.39	1.87	1.91
	Std Dev	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 $\mu g/m^3$) at A-3, Kandla Port Colony. While at Vadinar monitoring station the highest total VOC concentration was observed 6.62 $\mu g/m^3$ at A-8 with mean value 1.91 $\mu g/m^3$. 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 (µg/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 µg/m^3

The Ambient air Monitoring location of Kandla recorded the highest Benzene concentration i.e., 1.43 µg/m^3 at A-3, Kandla Port Colony. While at Vadinar monitoring station the highest Benzene concentration was found to be 0.77 µg/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 µg/m^3.

Table 13: Summarized results of Polycyclic Aromatic Hydrocarbon

Sr No		Kandla						Vadinar	
	Location / Components	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 17th April to 16th 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 (µg/m³)

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 µg/m³ at A-6, Gopalpuri Hospital while the lowest Non-methane VOC concentration was found 0.12 µg/m³ at A-1, Oil Jetty No.1. While at Vadinar monitoring station, the lowest Non-methane VOC concentration was observed 0.09 µg/m³ at A-7, Admin Building. Thus, all monitoring station at Kandla and Vadinar recorded the Benzene concentration well below the specified limit of 5 µg/m³.

4.4 Conclusion:

From the ambient monitoring study conducted for a period (17th April-15th May 2023), it may be concluded that the particulate matter (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 (NO_x, 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-

1. **Ship Emissions:** Ships primarily emit air pollutants through their exhaust stacks. These emissions include sulfur oxides (SO_x), nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), and greenhouse gases (GHGs) such as carbon dioxide (CO_2). The type of fuel used by ships greatly influences the amount and type of emissions produced.
2. **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 NO_x, PM, and CO. Older or poorly maintained equipment tends to generate higher emissions.
3. **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 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.
4. 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	23.043527N 70.218456E
2.		N-2	West Gate No.1	23.006771N 70.217340E
3.		N-3	Canteen Area	23.003707N 70.221331E
4.		N-4	Main Gate	23.007980N 70.222525E
5.		N-5	Main Road	23.005194N 70.219944E
6.		N-6	Marin Bhavan	23.007618N 70.222087E
7.		N-7	Port & Custom Building	23.009033N 70.222047E
8.		N-8	Nirman Building	23.009642N 70.220623E
9.		N-9	ATM Building	23.009985N 70.221715E
10.		N-10	Wharf Area/ Jetty	22.997833N 70.223042E
11.	Vadinar	N-11	Near Main Gate	22.441544N 69.674495E
12.		N-12	Near Vadinar Jetty	22.441002N 69.673147E
13.		N-13	Port Colony Vadinar	22.399948N 69.716608E

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

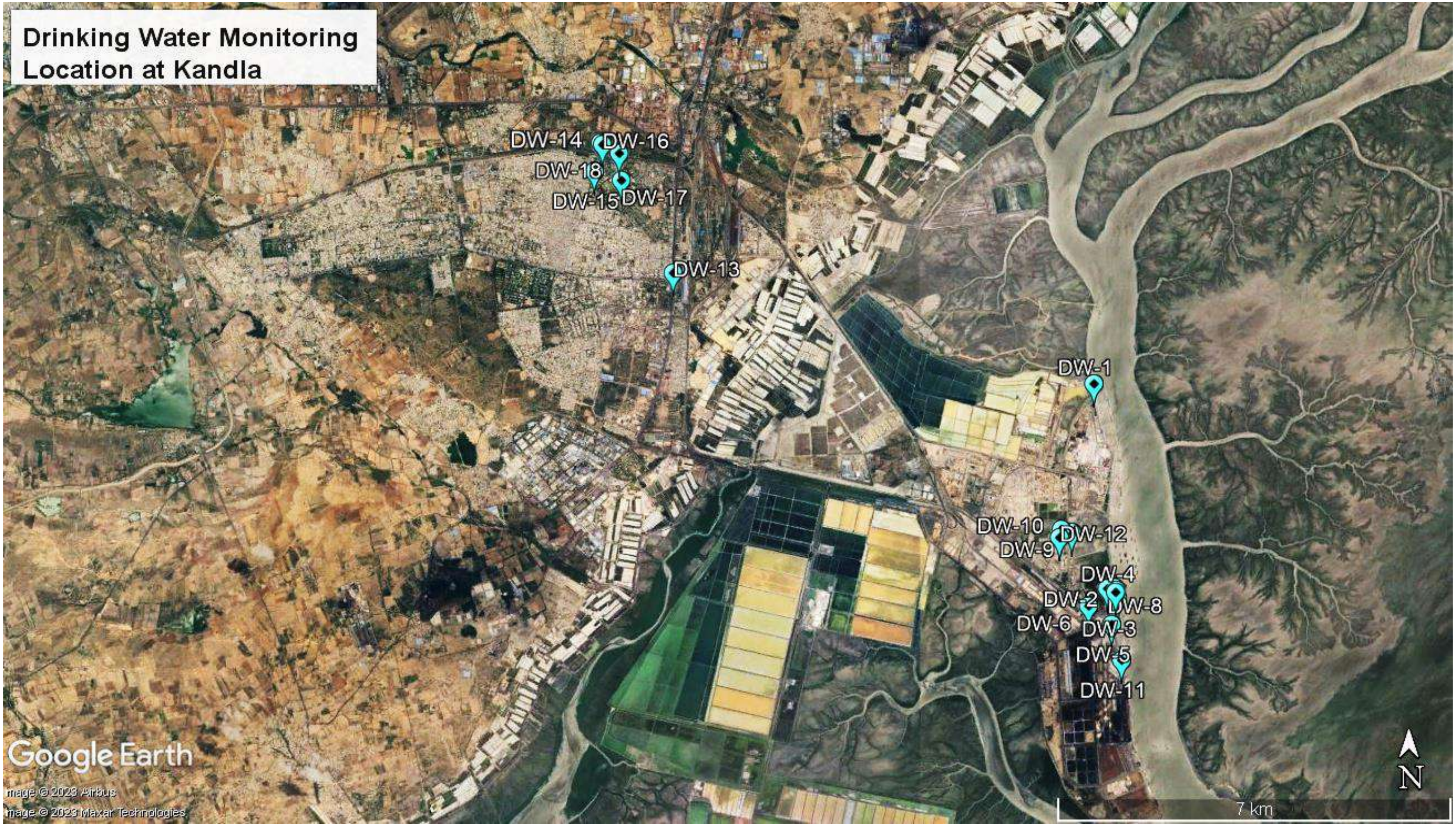

Figure 8: Location Map for Drinking Water Monitoring for Kandla

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, 23rd 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, 23rd Edition (Section-4500-H^+B):2017	pH Meter
2.	EC	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
3.	Turbidity	NTU	APHA, 23rd Edition (Section -2130 B):2017	Nephlo Turbidity Meter
4.	TDS	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with filtration assembly and Oven
5.	TSS	mg/L	APHA, 23rd Edition, 2540 D: 2017	
6.	Chloride	mg/L	APHA, 23rd Edition (Section-4500-Cl-B):2017	Titration Apparatus
7.	Total Hardness	mg/L	APHA, 23rd Edition (Section-2340 C):2017	
8.	Ca Hardness	mg/L	APHA, 23rd Edition (Section-3500-Ca B):2017	
9.	Mg Hardness	mg/L	APHA, 23rd Edition (Section-3500-Mg B):2017	
10.	Free Residual Chlorine	mg/L	APHA 23rd Edition, 4500	
11.	Fluoride	mg/L	APHA, 23rd Edition (Section-4500-F-D):2017	UV- Visible Spectrophotometer
12.	Sulphate	mg/L	APHA, 23rd Edition (Section 4500-SO4-2-E):2017	
13.	Sodium	mg/L	APHA, 23rd Edition (Section-3500-Na-B):2017	Flame Photometer
14.	Potassium	mg/L	. APHA,23rd Edition, 3500 K-B: 2017	
15.	Salinity	mg/L	. APHA, 23rd Edition (section 2520 B, E.C. Method)	Salinity /TDS Meter

Sr. No.	Parameters	Units	Reference method	Instrument
16.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3- B: 2017	UV- Visible Spectrophotometer
17.	Nitrite	mg/L	APHA, 23rd Edition, 4500 NO2-B: 2017	
18.	Hexavalent Chromium	mg/L	APHA, 23rd Edition, 3500 Cr B: 2017	
19.	Manganese	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES
20.	Mercury	mg/L	EPA 200.7	
21.	Lead	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
22.	Cadmium	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
23.	Iron	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
24.	Total Chromium	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
25.	Copper	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES
26.	Zinc	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
27.	Arsenic	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
28.	Colour	mg/L	APHA, 23rd 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 NO3 (QL=1), Nitrite as No2 (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 µS/cm with the average value as 117.38 µS/cm. While at Vadinar, the value of EC ranged from 115-683 µS/cm with the average value as 399 µS/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_x, NO_x, 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

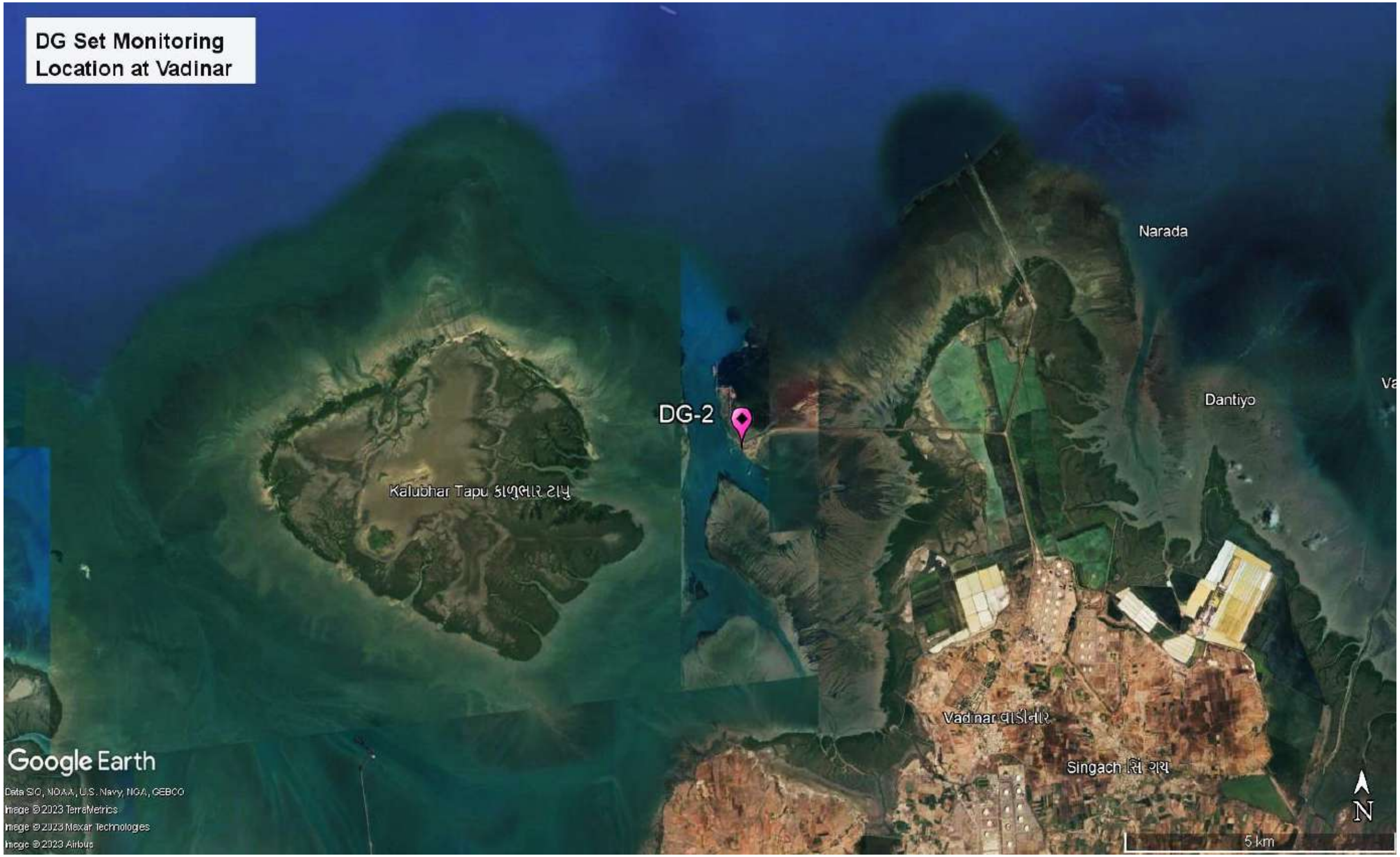

Figure 11: Location Map for DG Set monitoring at Vadinar

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^3	Stack Monitoring Kit
2.	Sulphur Dioxide (SO_2)	mg/Nm^3	Sensor based Flue Gas Analyzer (Make: TESTO, Model 350)
3.	Oxides of Nitrogen (NO_x)	mg/Nm^3	
4.	Carbon Monoxide	mg/Nm^3	
5.	Carbon Dioxide	mg/Nm^3	

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 (NOx), 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^3)
1.	Particulate Matter	150
2.	Sulphur Dioxide (SO2)	40
3.	Oxides of Nitrogen (NOx)	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, 6th 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** (Khori 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	**<4.5** Extremely acidic **4.51-5.50** Very strongly acidic **5.51-6.00** moderately acidic **6.01-6.50** slightly acidic **6.51-7.30** Neutral **7.31-7.80** slightly alkaline **7.81-8.50** moderately alkaline **8.51-9.0** strongly alkaline **>9.00** very strongly alkaline
2.	EC (ppm) (1ppm = 640 µmhos)	**Up to 1.00** Average **1.01-2.00** harmful to germination **2.01-3.00** harmful to crops (sensitive to salts)
3.	Organic Carbon	**Up to 0.2**: very less **0.21-0.4**: less **0.41-0.5** medium, **0.51-0.8**: on an average sufficient **0.81-1.00**: sufficient **>1.0** more than sufficient

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 µs/cm, highest at location S-3 Khori creek (11700 µs/cm) and lowest at S-2 IFFCO Plant (6040 µs/cm); while the average value was 16545 µs/cm. Whereas, at Vadinar highest EC was observed at S-6 i.e., near Jetty Area (6.25 µs/cm) and lowest was observed at S-5 i.e., Near SPM (111 µs/cm), while the average value was 368 µs/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 µs/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 Khori creek (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)

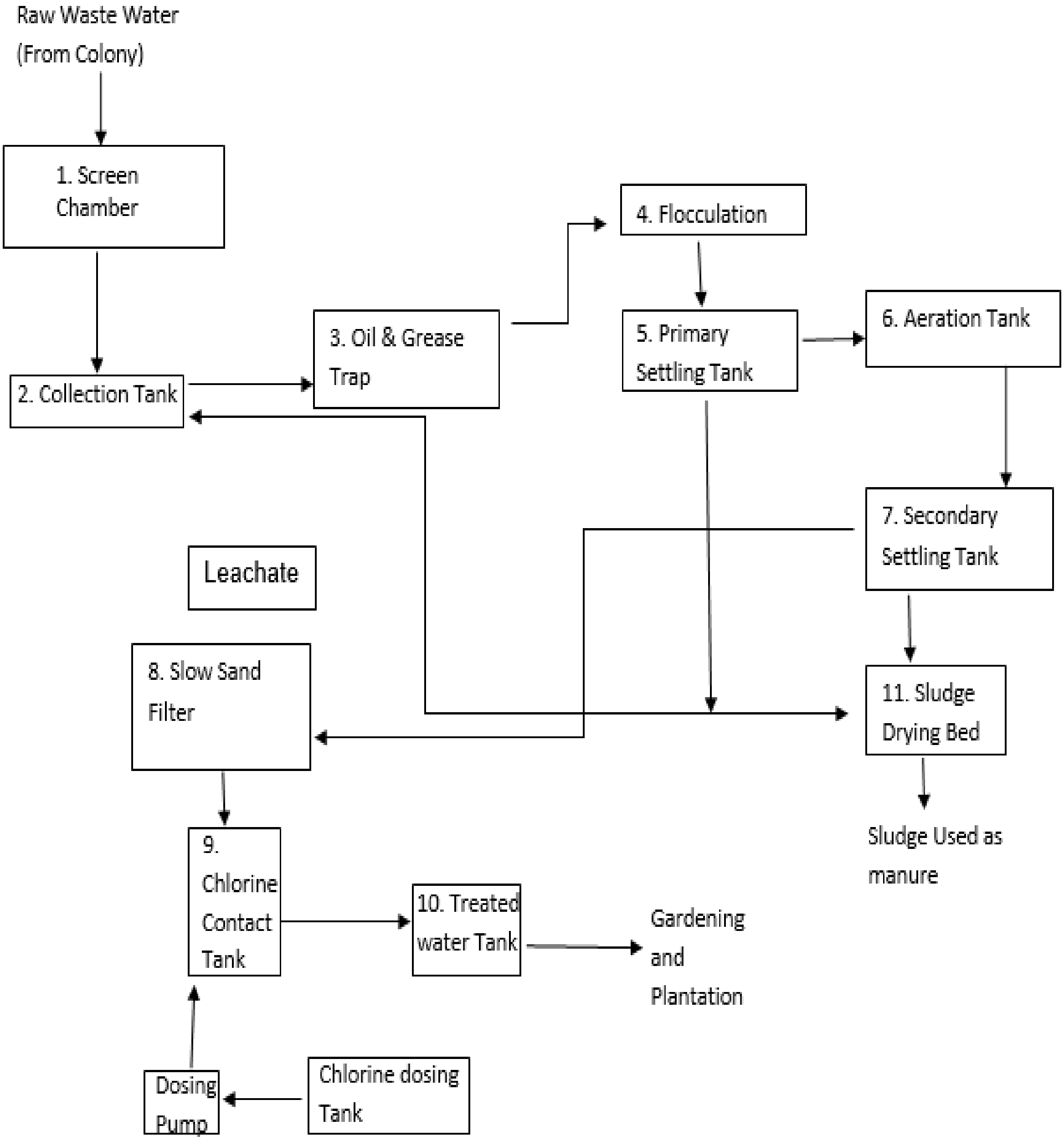

Figure 14: Process flow diagram of Kandla STP

Process Flow Diagram of Gopalpuri Sewage Treatment Plant (STP)

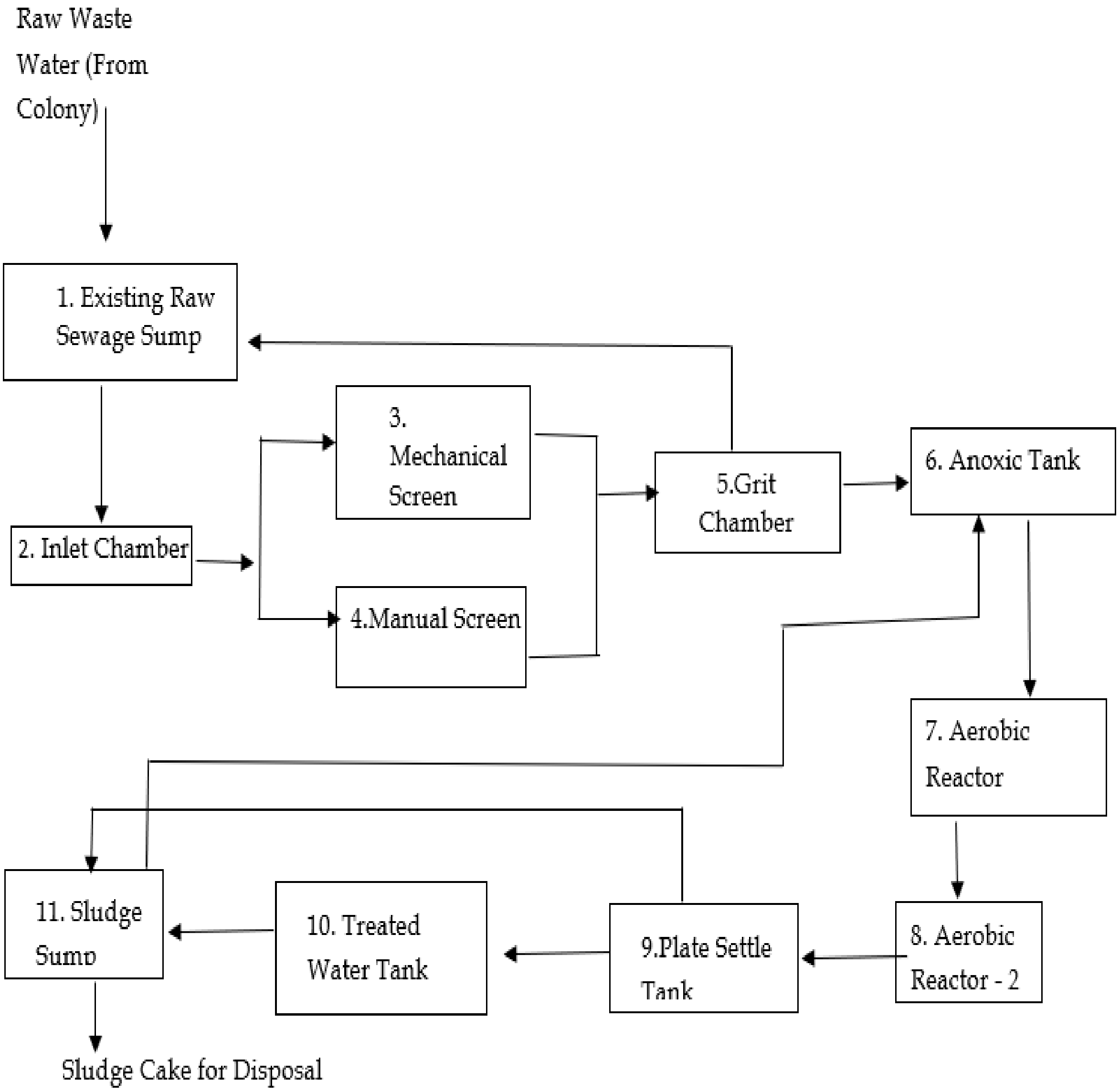

Figure 15: Process flow diagram of Gopalpuri STP

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:

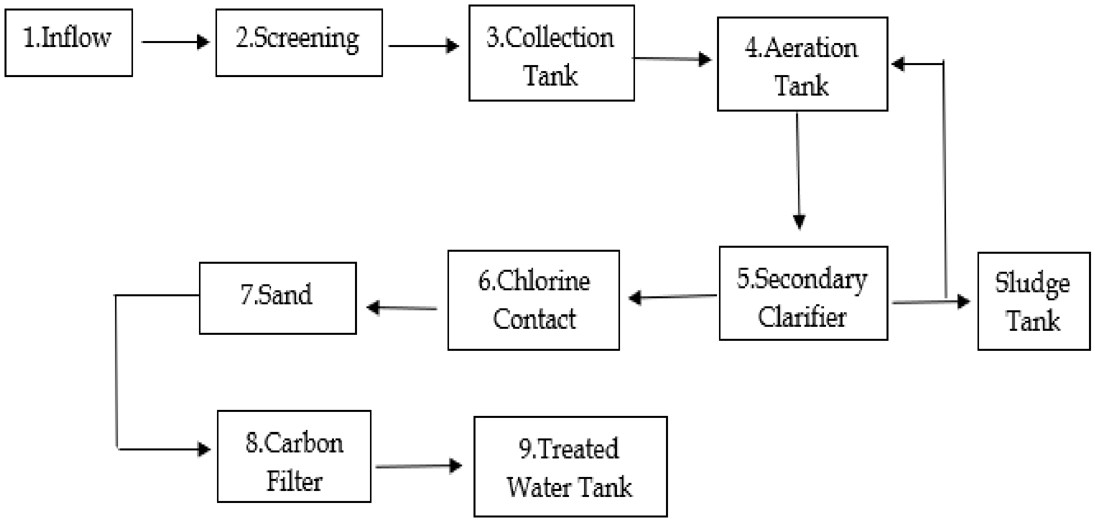

Figure 16: Process flowchart for the Vadinar STP

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, 23rd edition, 4500- H^+ B, 2017	pH Meter
2.	TDS	mg/L	APHA, 23rd Edition, 2540 C: 2017	Vacuum Pump with filtration assembly and Oven
3.	TSS	mg/L		
4.	DO	mg/L	APHA, 23rd Edition, 4500 C: 2017	Titration Apparatus
5.	COD	mg/L	APHA, 23rd 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.

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/H2O2 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	23.017729N 70.224306E
2.		MW-2	Kandla Creek (nr KPT Colony)	23.001313N 70.226263E
3.		MW-3	Near Coal Berth	22.987752N70.227923E
4.		MW-4	Khori Creek	22.977544N 70.207831E
5.		MW-5	Nakti Creek (nr Tuna Port)	22.962588N 70.116863E
6.		MW-6	Nakti Creek (nr NH-8A)	23.033113N 70.158528E
7.	Vadinar	MW-7	Near SPM	22.500391N 69.688089E
8.		MW-8	Near Vadinar Jetty	22.440538N 69.667941E

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

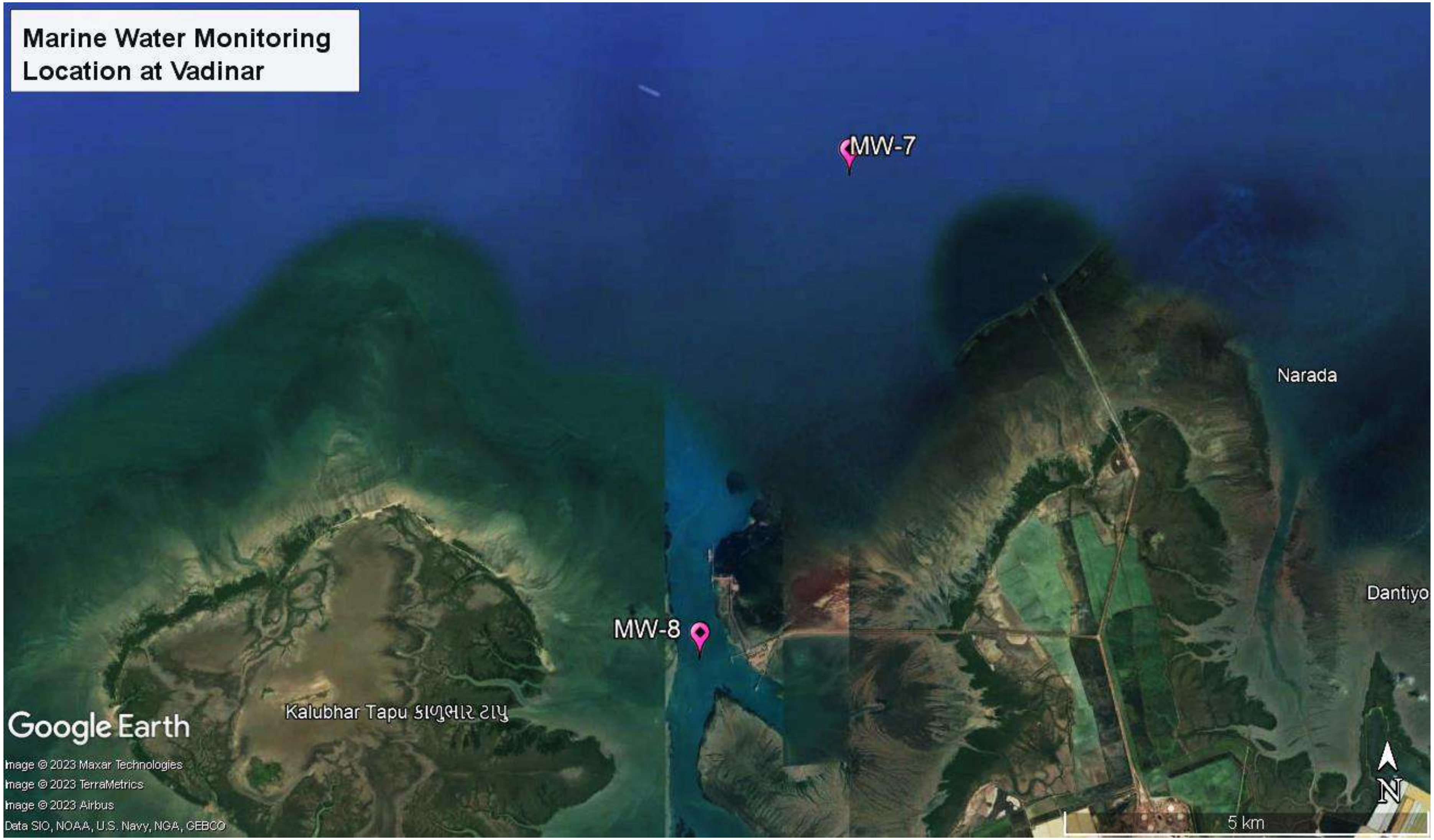


Figure 20: Location Map for Marine Water Monitoring at Vadinar

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, 23rd Edition (Section-2510 B):2017	Conductivity Meter
2.	Dissolved Oxygen (DO)	mg/L	APHA, 23rd Edition, 4500 O C, 2017	Titration Apparatus
3.	pH		APHA, 23rd Edition (Section-4500-H^+B):2017	pH meter
4.	Color	Hazen	APHA, 23rd 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, 23rd Edition (Section-2540 C):2017	Vaccum Pump with Filtration Assembly and Oven
8.	Total Suspended Solids (TSS)	mg/L	APHA, 23rd Edition, 2540 D: 2017	
9.	Particulate Organic Carbon	mg/L	APHA, 23rd 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, 23rd Edition, 4500 C, 2017	UV- Visible Spectrophotometer
13.	Phosphate	mg/L	APHA,23rd 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/m³	-	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 NO3 (QL=1), Nitrite as No2 (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^3.
- **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	23.017729N 70.224306E
2.		MS-2	Kandla Creek	23.001313N 70.226263E
3.		MS-3	Near Coal Berth	22.987752N 70.227923E
4.		MS-4	Khori Creek	22.977544N 70.207831E
5.		MS-5	Nakti Creek (near Tuna Port)	22.962588N 70.116863E
6.		MS-6	Nakti Creek (near NH-8A)	23.033113N 70.158528E
7.	Vadinar	MS-7	Near SPM	22.500391N 69.688089E
8.		MS-8	Near Vadinar Jetty	22.440538N 69.667941E

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 SO4- (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^{4-}	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 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.

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:

$$D = 1 - \sum (p_i \hat{} 2)$$

   Where, ∑ = Summation symbol, pi = 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, ∑ = Summation symbol,
   pi = 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:

$$D_{Mg}=\frac{S-1}{lnN}$$

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:

$$d=\frac{N_{max}}{\mathrm{N}_i}$$

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.

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

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/m³	NIL	3	NIL	NIL	NIL	6	7.21	6.74
5.	Chlorophyll-a	mg/m³	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/m² 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/m² at ME-7 (Near SPM), monitoring station and 32 g/m² 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/m³ 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/m³ 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) recoded 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.es. 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
Bacillaria sp.	460	700	680	750	660	850	650	700
Biddulphia sp.	650	510	-	650	-	-	755	350
Chaetoceros sp.	350	765	680	530	755	550	800	480
Chlamydomonas sp.	150	560	-	-	380	860	420	545
Cyclotella sp.	-	-	800	540	650	880	-	390
Ditylum sp	900	780	390	685	-	350	450	600

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

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
Acartia sp.	-	3	1	4	3	1	2	
Acrocalanus	1	2	7	4	1	1	3	5
Amoeba	6	1		3	6	2	4	1
Brachionus sp.	2	4	2	1		8	5	-
Calanus sp.	1	1	-	3	-	2	2	2
Cladocera sp.	1	-	-	2	1	1	2	3
Copepod larvae	3	8	5	6	5	3	10	3
Cyclopoida	2	4	1	3	2	-	1	1
Diaptomus sp.	4	1	3	1	10	1	1	3
Eucalanus sp.	5	-	1	4	4	8	7	9
Mysis sp.	-	11	8	4	-	2	7	-
Oithona sp.	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
Paracalanus sp.	12	10	13	18	15	15	20	17
Density Unit/L	**38**	**47**	**46**	**55**	**48**	**46**	**66**	**53**
No. of genera	**11**	**11**	**10**	**13**	**10**	**12**	**12**	**10**

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 & Khori 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
Diapatra sp.	1	2	1	6	2	4	1	3
Mollusca sp.	3	1	4	3	1	-	1	-
Odonata sp.	4	1	1	-	1	3	4	5
Coleoptera sp.	1	2	2	3	-	1	3	1
Crustacea sp.	-	1	3	5	1	3	1	-
Hemiptera sp.	3	6	-	2	2	1	-	1
Tricoptera sp.	3	6	4	-	2	5	2	1
Density-Units/l	**15**	**19**	**15**	**19**	**9**	**17**	**12**	**11**
No of genera	**6**	**7**	**6**	**5**	**6**	**6**	**6**	**5**

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 Khori 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

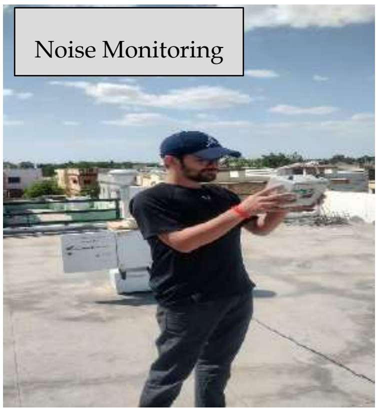
Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	6	7	6	5	6	6	6	5
Individuals	15	19	15	19	9	17	12	11
Shannon diversity	1.68	1.67	1.66	1.54	1.74	1.65	1.63	1.37
Simpson 1-D	0.86	0.81	0.85	0.81	0.92	0.84	0.85	0.76
Species Evenness	0.94	0.86	0.93	0.96	0.97	0.92	0.91	0.85
Margalef	1.85	2.04	1.85	1.36	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

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"We Provide Environmental Solutions"

Annexure -D

Final Report

On

Greenbelt Development for the Deendayal Port Authority at Kandla Port

Submitted to

Deendayal Port Authority
Administrative Office Building
Post Box No.50, Gandhidham (Kachchh)
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Final Report

on

Greenbelt Development for the Deendayal Port Authority at Kandla Port, Kandla

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Introduction

Green vegetation cover surrounding human environment is a vital entity for supply of oxygen, food, fodder and medicine for the survival of all living being, and also it has played an important role in maintaining ecological balance, climate regulation, biodiversity conservation, retention of soil moisture, control of soil erosion, increasing soil fertility, maintaining pleasant micro climate of the region, etc. In addition, vegetation cover also absorbs various pollutants from the environment and thus helps in effective pollution control. However, due to the various types and extent of economic development like industrialization, mining, infrastructural development, etc. has reducing and fragmenting natural vegetation cover day-by day all over the world. The infrastructural and industrial development leads to influence the life of all the living organisms in two directions: either upwards or downwards. In the upward mode, human being gets opportunities for luxuriant life with easy accessibility to the resources while in downward, the quality of ecosystem services gets affected. Most of the industrial and infra-structural developmental activities generate pollution of one or other types with varying magnitudes, which makes susceptible to all the organisms, nevertheless, the power of resistance of each organism helps themselves to overcome the hazards caused by such pollutants.

Therefore, development of green belts alongside of industries, mines, thermal power station, roadsides, and other development unit is an effective mechanism to rejuvenate vital vegetation cover for safeguarding health of human and other living being. Green belts in and around urban and industrial areas are important to the ecological health of any given region. Greenbelt is the raw of trees planted along the industrial units, mines, roadside for reducing the pollution originating from these operations (Flemming, 1967; Hanson and Throne, 1970; Warren, 1973; Ganguly, 1976). Greenbelt has developed considering following factors; (i) physical characteristics of the green belt eg. Distance from the source, width, and height and leaf surface area density (ii) aerodynamic properties eg. Wind speed through greenbelt and effective height of the incident air stream (iii) deposition velocity of the pollutant and (iv) atmospheric stability conditions (CPCB, 2000).

As per the National Forest Policy (NFP-1988), it is necessary to encourage the planting of trees alongside of roads, railway lines, rivers and streams and canals, and on other unutilized lands under state/corporate, institutional or private ownership. NFP give emphasis on the green belt developments. It says – Green belts should be raised in urban/industrial areas as well as in arid tracts. Such a programme will help to check erosion and desertification as well as improve the microclimate.

Green infrastructure serves to provide on ecological framework for social, economic and environmental health of the surroundings. The main components of this approach include storm water management, climate adaptation, less heat stress, more biodiversity, food production, better air quality, sustainable energy production, clean water and healthy soils, as well as the more anthropocentric functions such as increased quality of life through recreation and providing shade and shelter in and around infrastructure and industrial areas. Green infrastructure is thought to be effective in such scenarios, where green plants from a surface capable of absorbing air pollutants and act as a sink for pollutants. Leaves with their vast leaf area in the tree canopy, absorbs pollutants on their surface. Thus, effectively reduce their concentrations in the ambient air. Often the absorbed pollutants are incorporated in metallic streams and thus the air is purified. Plants grown in such a way as to function as pollutant sinks are collectively referred to as green infrastructure or green belts. Apart from functioning as a pollutant sink, green belts would also provide other benefits like aesthetic improvement and providing possible habitats for birds and animals along with maintain the soil moisture regime with the soil microorganisms and improve the Soil quality and ground water recharge. The greenbelts has helps in improving the ecology, maintenance of biodiversity, mitigation of dust pollution and fugitive emission, control of noise pollution, provide fresh air, mitigates soil erosion, increasing aesthetic values of an area and overall improvement of the landscape.

Rationale

Deendayal Port in Kachchh District of Gujarat State (formerly Kandla Port Trust), operated by Deendayal Port Authority (DPA), is a gateway Port to the hinterland in the western and northern states of India. It is one of the 11 major Ports of India situated at 22°59'39.77'' N latitude and; 70°13'20.14'' E longitude on Kandla creek at Gulf of Kachchh. The inclusion of Karachi Port in Pakistan after India's partition and heavy traffic congestion at the then Bombay Port gave impetus for promoting Deendayal Port during the year 1950s. In 1955, Deendayal Port acquired the status of a major Port in India. Because of its proximity to the Gulf countries, large quantities of crude petroleum and other assorted cargo are imported through Deendayal Port. The Port presently has 14 jetties, six oil terminals, and several allied facilities for handling dry and liquid cargo. Regular expansion/developmental activities such as the addition of jetties, allied Special Economic Zones (SEZ hereafter), industrial parks and ship bunkering facilities are underway to cope with the increasing cargo handling demands. Shri Mansukh Mandaviya, Minister of State for Ports, Shipping and Waterways (I/C) appreciated the efforts taken by Deendayal Port and added that it is indeed the major achievements in the challenging (COVID) times and it is significant indication that economy is bouncing back to achieve pre-COVID times.

Major commodities handled by the Deendayal Port are Crude Oil, Petroleum product, Coal, Salt, Edible Oil, Fertilizer, Sugar, Timber, Soya bean, Wheat. This major achievement can be attributed to the user-friendly approach of port with the Shipping fraternity / stakeholders and constant consultations with them to improve ease of doing business. An assortment of liquid and dry cargo is being handled at Deendayal Port. The dry cargo includes fertilizers, iron crap, steel, food grain, metal products, ores, cement, coal, machinery, sugar, wooden logs, salt extractions, etc. The liquid cargo includes edible oil, crude oil and other petroleum products. DPA created a new record by handling 127.10 million metric tonnes of cargo during FY 2021-22 compared to 117.566 MMT in FY 2020-21, with a growth of 8.11%. Incidentally, DPA is the only major Indian Port to handle more than 127 MMT cargo throughput, and it has also registered as the highest cargo throughput in its history. The Port has handled 3151 vessels during FY 2021-22 compared to 3095 vessels in FY 2019-20. 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 September 2021. Deendayal Port is a natural harbour located on the eastern bank of North-South trending Kandla creek at an aerial distance of 145 km from the Gulf's mouth.

Being located at the inner end of the Gulf of Kachchh (GoK), Deendayal Port has a fragile marine ecosystem with a vast expanse of mangroves, mudflats, creek systems and allied biota. The Port location is marked by a network of major and minor mangrove-lined creek systems with a vast extent of mudflats. The coastal belt in and around the Port has an irregular and dissected configuration.

There are no perennial or seasonal rivers in Gandhidham taluka where the part is located. Total rainy days during the monsoon season is limited to only 15-20 days and used to be erratic. Freshwater input into the near coastal waters is relatively meagre and appears to have less influence on the ambient coastal water quality except during monsoon months, during which freshwater through flash floods get discharged in the near coastal waters. The annual average humidity is 60%, which increases to 80% during the southwest monsoon (June to September) and decreases to 50% during the months of November and December. The drought phenomenon is common with two drought years in a cycle of 5 years.

The coastal belt in and around the Kandla region is characterized by a network of creek systems and mudflats covered by sparse halophytic vegetation, creek water and salt-encrusted land mass, which forms the major land forms. The surrounding environment in a radius of 10 km from the Port is mostly built-up areas consisting of salt works, human habitations and Port related structures on the west and north, creek system, mangrove formations and mudflats on the east and south. The Deendayal Port and its surroundings have mangroves, mudflats and creek systems as major ecological entities.

DPA is committed towards environment protection since its establishment and has taken many initiatives towards increasing green cover and greenbelt development in various areas under DPA through intensive plantation activities and developing greenbelt around its established port and jetty areas and human habitations.

In order to enhance and strengthen Greenbelt Development, the DPA has approached GUIDE to develop the greenbelt area within the port area in phase wise manner. It was finalised to raise 5000 plants at a suitable site during the first phase.

Project Site

Based on observation made by the GUIDE Team and Officials from Deendayal Port Authority, a site at adjacent to Berth 11-12 (Wood log site) have been selected on the peripheral boundary of two sides.

The area proposed for green development of Deendayal Port is barren land without any vegetation. The soil of the area is black muddy highly saline soil and with saline ground water. The area is very dry and hot during the summer. The highest temperature used to be recorded in this area.

Scope of Works

The overall objective is to Development Greenbelt at Deendayal Port. The following activities of the Greenbelt development have been carried out:

1. To make an inventory of suitable sites for greenbelt development in and around the Deendayal Port at Kandla.
2. To carryout Soil and Moisture Conservation (SMC) of the selected sites.
3. Identification of suitable native species of plants for the greenbelt plantation.
4. Adopting plantation technique of plant saplings.
5. Regular monitoring (survival and growth) of the plantation.
6. Suggest measures for management and improvement of the greenbelt.

Approach and Methodology for Greenbelt Development

Following steps have been adopted for greenbelt development:

- Removal of exotic/unwanted plants plant species from the entire area demarcated for green belt development: The entire selected site have been cleared by removing unwanted weeds and material such as stones, plastics etc.by JCB and also with labours.

- Landscaping of the area and land preparation Trench line of 2.5x 2.5 ft. have been dig out through JCB along the boundary adjacent to birth 11 & 12 wood log area up to approximately 5000 ft.
- Soil and moisture conservation work since the port area is highly saline, SMC work was very much essential for better survival of the plants. Eight dumper of fertile soil from the field have been added.

- Identification of native species of plants for plantation in greenbelt as per the site suitability the site was very challenging for greenbelt development since the water and soil is highly saline with the extreme climatic condition, the selection of plant species for plantation has been made very carefully. 40 % of plants have been selected as native species for plantation where as 60% species of *Conocarpus*.
- Procurement of sapling of identified species or Nursery management or seeding of tree/shrub species all the saplings were procured where of 3-4 ft. in height from reliable nursery. All saplings were of tree species.

- Installation of irrigation facilities was not feasible therefore activity was planned preferably through tankers. The watering of the plantation have been schedule as per the seasons which is given in table. Regular watering as per the scheduled have been provided by the water tanker under the supervision of team expert
- Use of Manure, preferably organic fertilizer for enhancing soil fertility best quality organic manure of 12,500 kg have been provided to the saplings for better growth and survival. Weed management and trench repairing have been carried out periodically also as and when it required.

- Regular monitoring and management of the saplings by a qualified team from GUIDE the selected site is wood log site hence, the wood log used to roll down on a path for water tanker while uploading and downloading the wood log. The regular visit to the site has been made for monitoring and clearing the road for water tanker for irrigation. Gap filling were also made during the period.

Plantation Techniques:

- Site development for a plantation includes clearance for weeds and it involves, bush cutting, soil and moisture conservation works in 'nalas', construction of bunds or check dams, marking of pits for planting of saplings etc.

- After clearing the land sites for digging of pits, plantation have been marked on ground using a measuring tape to ensure the desired spacing.

- Pits of the size 45 cm x 45 cm and 45 cm depth have been dug for tree plantation. Pits have been deep enough to ensure that the roots of the plants do not curl up once the planting material is placed in it.

- Since the soil is highly saline, a fertile soil around 6 dumper have been added for better survival of plants

- Organic manure around 12,500 kg. Have been given for better growth and survival.

- The pit have been filled a little above the ground level so that after the earth settles the upper surface of the pit is level to the ground thus avoiding any water logging.

- The plantation has been out in two phase since the some areas were blocked by wood logs.

- Around 4100 saplings have been planted during the month of September 2022 at available plantation area.

- The remaining and gap filling of 1500 saplings have been planted after the clearance of the area during the month of Feb.2023. A total number of 5000 plantations, were completed in the area.

Selection of Plant Species for Plantation:

Various indigenous tree species suitable for the area have been identified and selected for plantation in suitable areas based on the assessment of soil quality, available water facility, and other environmental parameters.

Number of Sapling:

Approximate numbers of saplings to be required for the greenbelt are as follows:

- Peripheral plantation adjacent to birth 11-12 (along the boundary of the wood log area both sides): 5000 saplings

Management and Monitoring of Greenbelt:

The plantation within the identified site have been managed and monitored for a period of one year from June 2022 to June 2023 The management of plantation includes appropriate irrigation of the plantation in regular intervals, during summer and winter periods and if required even during monsoon with dry spells.

Watering have been made through tanker service at given schedule during the different seasons. (Table 1)

The all plants are growing very well and reached more 4-6 ft. height. The survival of plants have been noted very high as 98% during June 2023.

Table: 1 Time Schedule for Watering

Sr. No.	Month & Year	Number of Time
1	September 2022	4 times/month
2	October 2022	5 times/ month
3	November 2022	8 times/ month
4	December 2022	8 times/ month
5	January 2023	8 times/ month
6	February 2023	8 times/ month
7	March 2023	12 times/ month
8	April 2023	12 times/ month
9	May 2023	12 times/ month
10	June 2023	2 times/ month (end of the project 4th June 2023

Table: 2 List of Plants for Plantation at Site for Greenbelt Development

SI. No.	Scientific Name	Local Name	No. of Plant
1	*Conocarpus lancifolius*	Conocarpus	3500
2	*Ficus religiosa*	Piplo	100
3	*Azadirachta indica*	Limblo	200
4	*Peltophorum pterocarpum*	Pletoforam	300
5	*Millettia pinnata*	Karanj	300
6	*Cassia fistula*	Garmalo	100
7	*Delonix regia*	Gulmahor	300
8	*Mimusops elengi*	Borssalii	200

Fig. 1 Before Plantation

Fig. 2 Map of Plantation Area

Fig. 3 Digging Out Trench for Plantation

Fig. 4 Transportation of Plants to Site

Fig. 5 Fertile Soil for Better Survival of Plants

Fig. 6 Plantation Pits of Soil Filling

Fig. 7 Organic Manure for Better Growth and Survival

Fig. 8 Regular Watering of the plants by tanker

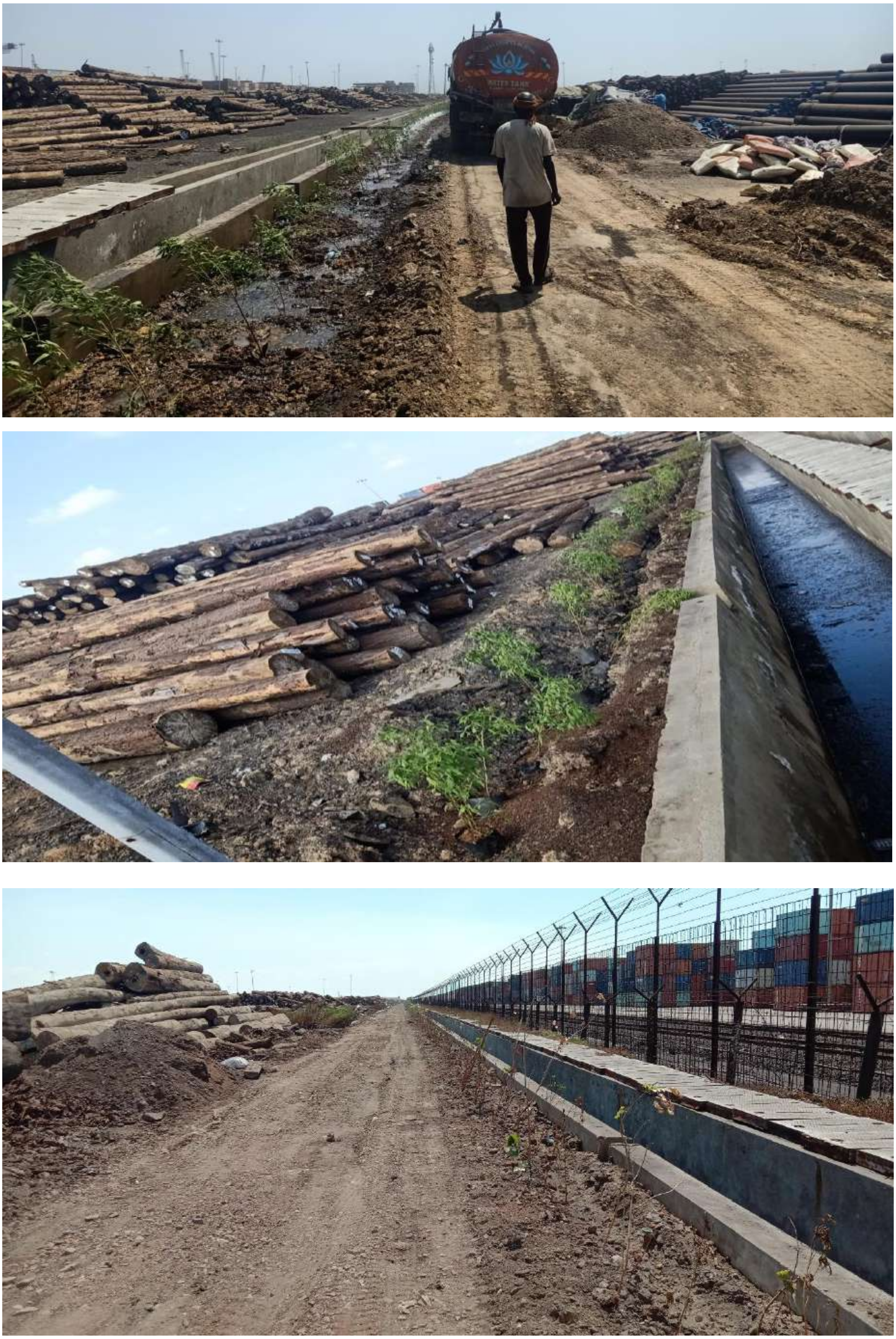

Fig. 9 Plantation in October 2022

Fig. 10 Plantation in December 2022

Fig. 11 Plantation in February 2023

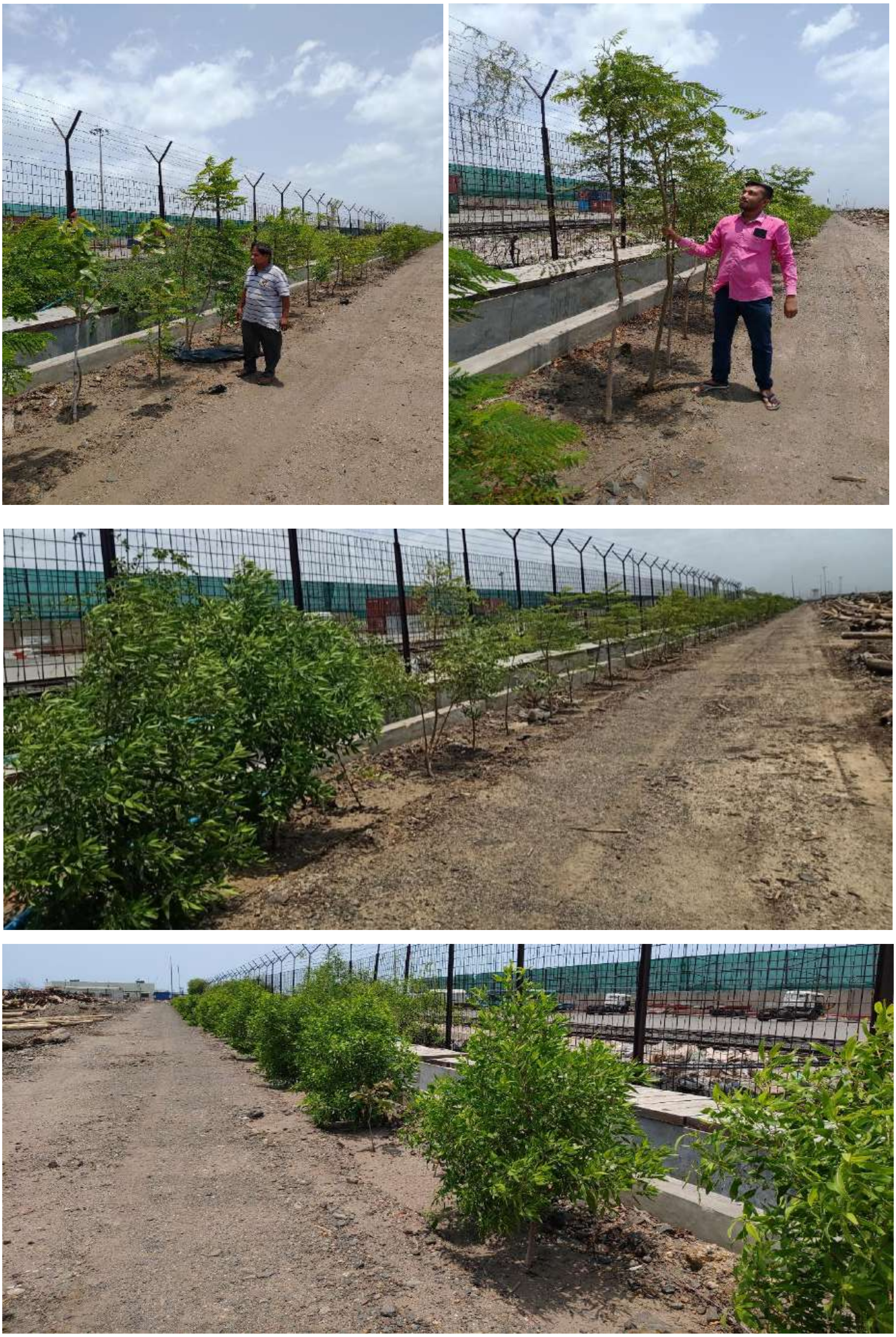

Fig. 12 Plantation in May 2023

Annexure -E

Final Report
(2021-2022)

Studies on Dredged Material for presence of Contaminants

(As per EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016- specific condition no. vii)

DPA Work order No. EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021.

Submitted by

Gujarat Institute
Of Desert Ecology

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Submitted to

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Project Team

Project Co-Ordinator **:** Dr. V. Vijay Kumar, Director

S. No	Name & Designation	Role	Expertise
Scientific Personnel			
1.	Dr. K. Karthikeyan Principal Scientist	Principal Investigator	Ph.D. in Environmental Sciences – Experience in water and soil studies.
2.	Dr. G. Jayanthi Scientist	Co- Investigator	PhD in Botany; Research experience with Post-Doctoral experience
3.	Dr. Krushnakant D Baxi Scientific Officer	Co- Investigator	Ph.D in Zoology (Marine Biology) with 5 years of experience
Technical Staff			
4.	Mr. T. Dhananjayan Sr. Scientific Assistant	Team Member	M.Sc. in Environmental Sciences; Analytical experience in soil, water analysis
5.	Ms. Dipti Parmar Jr. Scientific Assistant	Team member	M.Sc. in Environmental Sciences; Experience in soil and water analysis.

Dr. V. Vijay Kumar
Director

Gujarat Institute
of Desert Ecology

Certificate

This is to state that the **Final Report** of the work entitled, **"Studies on Dredged Material for the Presence of Contaminants"** has been prepared in line with the Work order issued by DPA vide No.EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021 as per the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016, Specific Condition No. vii. The work order is for a period of Three years from November 2021 – October 2024 for the above-mentioned study.

This Final report is for the project period from November 2021 – October 2022.

Authorized Signatory **Institute Seal**

CONTENTS

List of tables given in the report

List of figures given in the report

Abbreviations

µg	microgram
AAS	Atomic Absorption Spectrophotometer
Avg	Average
BDL	Below Detectable Limit
C	Celcius
Cd	Cadmium
cm	Centimetre
Cr	Chromium
CWPRS	Central Water and Power Research Station
DPA	Deendayal Port Authority
g/L	Grams per litre
GIS	Geographical Information System
GoK	Gulf of Kutch
GPS	Global Positioning System
GUIDE	Gujarat Institute of Desert Ecology
HCl	Hydrochloric acid
Hg	Mercury
HNO_3	Nitric Acid
$K_2Cr_2O_7$	Potassium Dichromate
kg	kilogram
km	Kilometer
KOH	Potassium Hydroxide
m	meter
max	maximum
min	Minimum
ml	millilitre
MoEF & CC	Ministry of Environment, Forests & Climate Change
Pb	Lead
pH	Potential of Hydrogen
PHc	Petroleum Hydrocarbon
ppm	Parts per million
ppt	Parts per thousands
TOC	Total Organic Carbon
TP	Total Phosphorus

Snapshot of the project “Studies on Dredged Materials for the presence of Contaminants”

Deendayal Port Authority intends to develop seven integrated facilities to meet the increasing cargo handling demands of the port. Ministry of Environment, Forests and Climate Change (MoEF & CC), New Delhi, while according environmental clearance to these developmental initiatives, among other conditions, stipulated to carry out “Studies on dredged materials for the presence of contaminants” as per the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016, Specific Condition No. vii and the task of carrying out the study was given to Gujarat Institute of Desert Ecology (GUIDE), Bhuj during September 2017 and the study encompasses a detailed study of various physical, chemical and biological characteristics of the sediment. This report covers the study conducted for the period from November 2021 – October 2022.

The data of the present study is detailed out as snapshot below:

S. No	Components of the study	Remarks
1	MoEF & CC sanction letter and details	MoEF & CC’s clearance to seven integrated project and specific conditions thereof. Ref. No. F. No. 11-82/2011-IA III; letter dated 19th December 2016. Specific condition No. vii.
2	Deendayal Port letter sanctioning the project	No. EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021.
3	Duration of the project	Three years (01.11.2021 – 30.10.2024)
4	Period of survey carried out for various components	1st Season study (Winter) 2nd Season study (Summer) 3rd Season study (Monsoon)
5	Survey area within the port limit	Dumping locations of dredged materials as suggested by the CWPRS
6	No of locations sampled within the port limits	Three sampling locations, *i.e.*, Two locations in sub-tidal and one creek location during all the three seasons
7	**Components of the report**	
7.1	Sediment quality (Physico-	The maximum concentration of heavy metals in the

	chemical)	sediment samples were in the order of Nickel, Lead, Cadmium, Chromium, Zinc, Copper, Manganese and Cobalt.
7.2	Sediment quality (Biological)	Shannon Diversity Index ranging from 0.598 - 1.39 during Season 1, 0.444-1.547 during 0.444-1.54 Season 2 and during Season 3 the indices was in the range of 0.00-1.22 indicated very low diversity during all the three seasons. Similarly, the evenness values ranged between 0.641 – 1, 0.634 to 0.960 and 0 to 0.98 during Season 1, 2 and 3 respectively. In case of Simpson's Index, it ranged between 0.353 - 0.74, 0.273 to 0.776 and 0 to 0.67 indicated low to moderate diversity almost during all the seasons.
7.3	Water quality (Physico-chemical)	During all the three seasons, notably the Copper and Cadmium levels were found Below Detection Limit in the water samples. In case of Petroleum hydrocarbon from all the three locations during all the three seasons recorded values which were within the Permissible limits prescribed by CPCB, i.e. 100 µg/L.
7.4	Water quality (Biological)	Shannon Index ranged between 1.27-2.72, 1.784-3.004 and 2.18 to 2.93 during Season 1, Season 2 and Season 3 indicated moderate to slightly higher level of diversity status of Phytoplankton species composition during the year. Simpson dominance index showed the range from 0.579 to 0.926, 0.782 to 0.940 and 0.86 to 0.94 which was not having much difference. In case of Zooplankton, t*he Shannon-wiener diversity index* (H') fluctuated between 0.69 to 2.46, 2.42 to 3.22 and 2.29 to 3.34, indicated a moderate to high level of diversity in case of Zooplankton during the study period.

		Range of Simpson Index was 0.37 to 0.90 during Season 1, 0.42-0.91 during Season 2 and 0.87 to 0.95 during Season 3 with no major variation in the indices.
7.5	Management plan	The significant points elaborated in the Management Plan chapter of this report includes that the dredging should be undertaken in such a way that it does not harm the marine organisms breeding especially the ones which are economically important. In case of technical application, use of suction dredger instead of bucket dredger can be a better option and dewatering of the fines suspended matter through sediment traps can be followed and utmost necessary aspect is that the dredging activity areas should be screened for the presence of presence of RET Species which are indigenous to the Gulf of Kachchh region.

Chapter 1 Background

Deendayal Port Authority is a Chief seaport in Gulf of Kutch and one among the twelve major ports of India which is located in the on West Coast in the District of Kutch, Gujarat state located around 256 nautical miles southeast of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). Deendayal Port's journey has started in the year 1931 with construction of RCC Jetty and as of today Deendayal Port has risen to the No. 1 port in India since 2007-08 till date, continuing to be in the same position for the past 14 years and as the largest port of India in terms of volume of cargo handled.

Deendayal Port Authority caters the maritime trade requirement of many hinterland states and is well connected by the network of rail and road and serves as a gate way port for export and import of northern and western Indian states of Jammu & Kashmir, Delhi, Punjab, Himachal Pradesh, Haryana, Rajasthan, Gujarat and parts of Madhya Pradesh, Uttaranchal and Uttar Pradesh. About 35% of the country’s total export takes place through the ports of Gujarat in which the contribution by Deendayal port is considerable.

The growth of this port has been contributed not only owing to handling of crude oil imports but also in taking relevant measures to boost non-POL cargo. An assortment of liquid and dry cargo is being handled at Deendayal 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. Deendayal Port Authority has shown consistent increase in case of traffic being handled every year and is growing at a fast rate year by year. The port handled a total cargo of 105 MMTPA during 2016-17, 110 MMTPA during 2017-18, 115 MMTPA during 2018-19, 122.5 MMTPA during 2019-2020 and 117.5 MMTPA during 2020-21. During the year 2016, Deendayal Port created history by handling 100 MMT cargos in a year, which is the first of its kind for the Major port category to achieve the milestone.

Especially the cargo traffic handled by the port comprises of Iron scrap, steel, food grains, ore, timber logs, salt extractions, POL products, edible oils and broad range of chemicals compounds. Containerized cargo traffic through this port has also shown a significant growth during the last few years. The dry cargo traffic at the port has been increasing steadily every year at a much faster pace with an average annual rate of growth of around 11.94%. The Port has presently fourteen (14) jetties and six oil terminals and many other allied facilities to handle both dry and liquid cargo. Regular expansion/developmental activities such as addition of jetties, Special Economic Zones, industrial parks, go downs, ship repairing and bunkering facilities and railway lines are underway in order to cope with the increasing cargo handling demands.

Further, a regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. The port has high commercial importance in the Indian maritime trade as it handled 36.1 million tons (17%) of cargo out of total cargo of 213.1 million tons of the maritime cargo of India during 2015. DPT is well connected by the network of rail and road and serves as a gate way port for export and import which caters the maritime trade requirement of many hinterland states including northern and western Indian states of Jammu & Kashmir, Delhi, Punjab, Himachal Pradesh, Haryana, Rajasthan, Gujarat and parts of Madhya Pradesh, Uttaranchal and Uttar Pradesh.

DPT has taken up various activities including Special Economic Zone establishment and proposal to develop a multipurpose cargo terminal and a container terminal at the creek mouth. This entails regular vessel movement, and capital and maintenance dredging of different proportions. Development of multipurpose cargo terminal at Tekra off Tuna and construction of railway over-bridge at the inner end of Nakti creek is sanctioned by the ministry. The cargo terminal will come up very close to the mouth of the Nakti creek and it envisages capital and maintenance dredging to the tune of 12657175 and 1898576 m^3, respectively.

As part of its ongoing expansion, Deendayal Port Authority has taken up Development of 7 Integrated facilities which include development of oil jetty and ship bunkering terminal at old Kandla, a multi-purpose oil terminal near Tuna, upgradation of barge handling facility at Kandla, construction of one rail over bridge and strengthening of existing oil jetties.

1.1. **EC conditions**

The Ministry of Environment, Forest and Climate Change (MoEF & CC), has put up some conditions while according Environmental and CRZ clearance. One of the conditions is to carry out the *"Study on Dredged Material for presence of contaminants"* as accorded by the MoEF&CC,GoI dated 19/12/2016 - Specific condition no. vii)" which states that ***"Dredged materials should be analyzed for presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted and the findings should be shared with the Gujarat SPCB and Regional Office of the Ministry"***.

1.2. Need of the study

In this regard, DPT has assigned the task of carrying out this particular study to Gujarat Institute of Desert Ecology (GUIDE), Bhuj. GUIDE has received the Work order for this Dredging project with project time period being Three years (01.11.2018 – 31.10.2021). This study on Evaluation of dredging contaminants was conducted Three times in a year at two different dumping locations with the methodical investigation of evaluating physical and chemical characteristics of the bottom sediment from the dumping locations with special reference to pollutants such as heavy metals and petroleum hydrocarbon. Further, the study had objectives including the understanding of the productivity of the sediment and the water by analyzing the planktonic and benthic fauna. Further, based on the results obtained, the management plan is also elaborated which spells out the possible options for managing the dredged materials.

1.3. Selection of sampling locations for 2022-2022

DPT has assigned the study on the presence of contaminants in the dredged materials for the year 2017-18 based on the locations for the dumping has been suggested by Hydraulic & Dredging Division to DPT on the e-mail dated 24th October 2018. 1. In line with the study conducted during 2017-18, the extension of the study was given in 2018 for a period of three years, *i.e.*, from 2018-2021 and 2021-2024 and the GPS locations of all the locations are mentioned in Table 1.

Table 1: GPS Co-ordinates of sampling locations (2021-22)

Station	Latitude	Longitude
Location 1 (Offshore)	22° 51' 00" N	70° 10’ 00" E
Location 2 (Phang creek)	23° 04' 28" N	70°13’ 28" E
Location 3 (Cargo jetty)	22°56' 31" N	70 13' 00" E

1.4. Port environment

The fast industrialization and economic growth in the world has resulted in increased pollution in various environmental matrices such as Air, Water and Soil. The marine environment receives a vast quantity of dredge spoils, sewage waste, industrial effluents and river runoff, markedly affecting the composition and quality of the aquatic environment. The coastal waters are highly at the risk of various pollution due to increase human settlement, establishment of industries, ports and harbours that use seawater and discharge solid and liquid wastes directly into the environment. In general, ports are economic instruments for trade and a vital component in the nation’s economy, however, such activities also involves dredging, large-scale construction and its continuous expansion which could affect the marine ecosystems in its vicinity. In a port environment, activities like dredging, continuous movement of vessels and human create major impacts at the marine/coastal environment in its vicinity.

1.5. Study Area

Deendayal port is located at Gandhidham taluka of Kutch district, Gujarat which is the nearest major habitation with a population of 2.49 lakhs as per the 2011 census. The coastal environs in and around the port jurisdiction is characterized by a network of creek systems and mudflats which are covered by sparse halophytic vegetation like scrubby to moderately dense mangroves, creek water and salt-encrusted landmass as major ecological entities. The surrounding environment in a radius of 10 km 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.

1.6. Aim and objectives of the study

The present project is designed considering the scope of work given in the EC conditions with the specific objectives as detailed below and considering the general environmental setting of the entire Gulf. Coastal waters often reveal significant temporal, spatial and seasonal changes with reference to sediment and water environmental and other ecological aspects and such variations should be clearly understood for assessing the prevailing status of a coastal water body. This report covers the monitoring results for the period from November 2021 - October 2022 with specific objectives as follows:

1. To characterize the bottom sediment samples from the dumping grounds for physico-chemical characteristics.
2. To understand the biological characteristics of the marine sediment for benthic faunal density and diversity.

3. To study the physico-chemical characteristics of the marine water from the dumping locations.
4. To estimate the primary productivity (pigments) and the plankton community structures (phytoplankton and zooplankton) in the marine water samples collected near the dumping grounds.
5. To compare the characteristics of the sediment estimated during different seasons to understand the pattern.
6. To suggest suitable management plan for management of the dredged materials.

1.7. Approach Strategy

The work is designed in such a way with an initial reconnaissance survey to understand the sampling location. For this purpose, pre-fixed sampling locations as prescribed by CWPRS were considered and sampling techniques for water and sediment for all the characteristics including physical, chemical and biological aspects were well planned as per standard protocol.

1.8. Sampling frequency

The samples for each season for collection of water and sediment to study different characteristics were sampled at both the locations thrice during the study period. This detailed report represents the outcome of all the Three seasons study in which the first season sampling was conducted for a period of 3 days during January 2022, the second season study was conducted for a period of 3 days during April 2022 and the final season study was conducted for a period of 3 days during September 2022 as per the locations details mentioned in the map as Figure 1 and the glimpses during the sampling locations are presented in Figure 2.

Figure 1: Map showing locations sampling during 2021-22

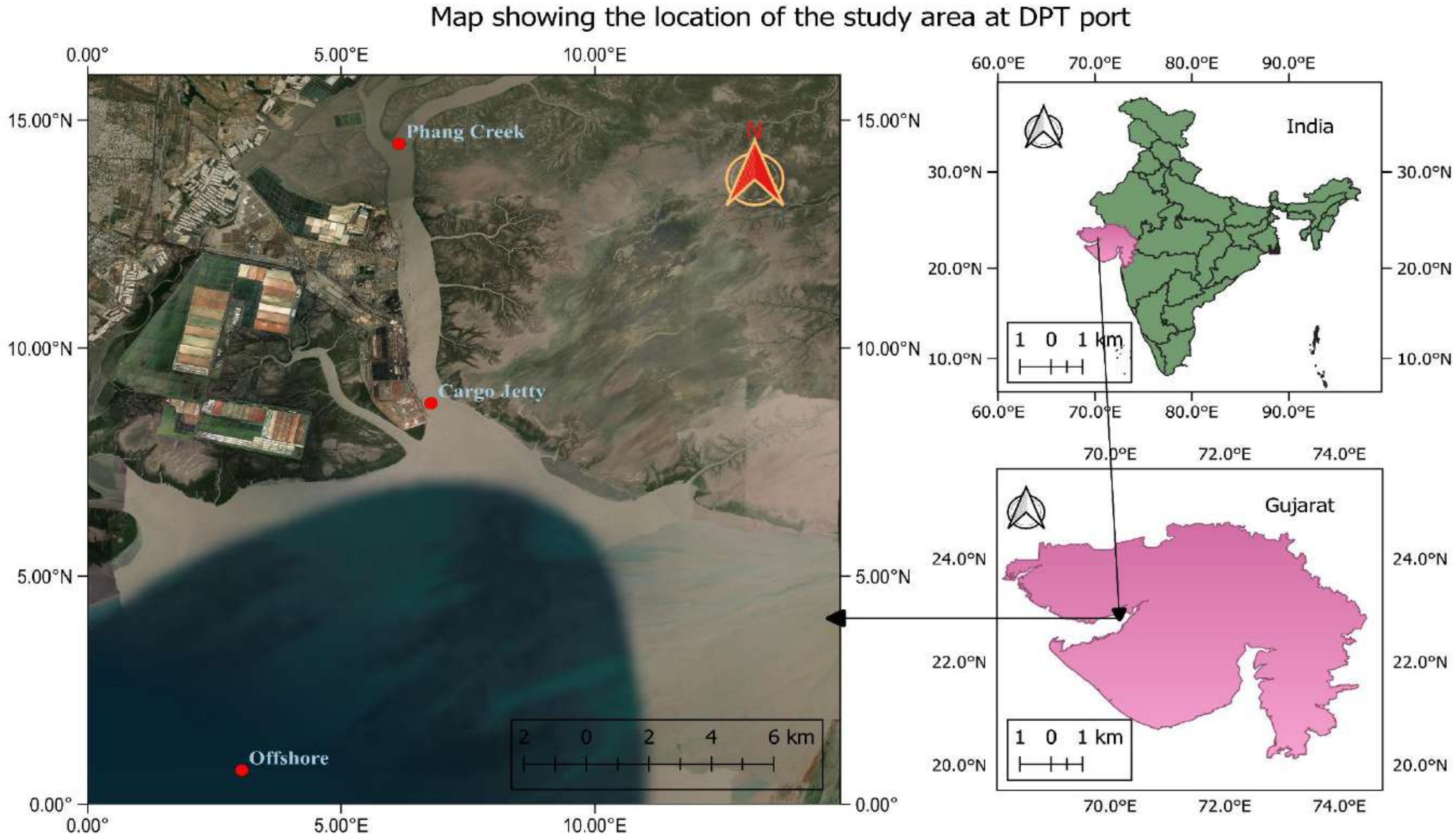

Figure 2: Photograph during Sub-surface water sampling at the sampling

locations

Chapter 2 Sediment Quality (Physico-chemical)

2.1. Background

Sediments, in general, have strong tendency to accumulate contaminants, especially heavy metals and they possess a very high physico-chemical stability and studying their characteristics usually indicates the optimum health of the marine system (Leoni and Sartori 1996). Sediment characteristics are a determinant factor in contamination of dredged marine environments. This is due to the retention and adsorption of contaminants to sediments by contaminants that have settled on the bottom of marine water bed. Such behavior of adsorption of sediment is highly influence by the sediment texture which is the relative proportions of each class including sand, silt and clay and are commonly referred as soil separates.

For the purpose of sediment characterization, the samples from the study area were collected employing standard methodology and the analysis of the samples were also performed as per standard protocol and the data of sediment analysis is presented in this Chapter. The sediment samples were collected in pre-fixed stations using a Van-veen type of grab sampler. After collection, the sediment samples were preserved with Rose Bengal and formalin to avoid decomposition of samples and processed for analysis and the samples after collection were brought to the laboratory on the same day of collection and air dried and used for further analysis for the test parameters (Table 2).

Table 2: Physico-chemical and biological characteristics of sediment samples

S. No	Physico-chemical and Biological parameters
1	pH (1: 10 suspension)
2	Salinity (ppt)
3	Petroleum Hydrocarbon (µg/kg)
4	Magnesium (mg/kg)
5	Sand (%)
	Silt (%)
	Clay (%)

6	Total organic carbon (%)
7	Phosphorus (mg/kg)
8	Sulphur (mg/kg)
9	Nickel (mg/kg)
10	Lead (mg/kg)
11	Cadmium (mg/kg)
12	Chromium (mg/kg)
13	Zinc (mg/kg)
14	Copper (mg/kg)
15	Manganese (mg/kg)
16	Cobalt (mg/kg)
17	Macrobenthos Biomass (g/m^2,wet wt) Population (no/m^2) Total Group (no.) Major Groups

2.2. Materials and Methods

2.2.1. pH and Salinity (1: 10 suspension)

pH of the sediment is the measure of H^+ ion activity of the sediment water system. It indicates whether the sediment is acidic, neutral or alkaline in nature. Since ions are the carrier of electricity, the electrical conductivity (EC) of the sediment water system rises according to the content of soluble salts. The measurement of EC can be directly related to soluble salts concentration of the sediment at any particular temperature. Ten gram of the finely sieved sediment will be dissolved in 100ml of distilled water to prepare a leachate. This will be subjected to vigorous shaking using a rotator shaker for 1 hour to facilitate proper homogenization of the suspension. The suspension will be allowed to settle for two 2 hours and the supernatant after filtration will be used for the analysis of pH and salinity using the pH and EC meter (Make: Systronics 361) and Refractometer (Make: Atago). Each sample will be analysed in triplicates and the mean values will be taken into consideration.

2.2. 2. Textural analysis (Sand/Silt/Clay)

Sediments will be collected using Van Veen grab whereas intertidal sediments will be collected using a handheld shovel. After collection, the scooped samples will be transferred to polythene bags, labeled and stored under refrigerated conditions. The sediment samples will be thawed, oven dried at 40ºC and ground to a fine powder before analyses.

For texture analysis, specified unit of sediment samples will be sieved using sieves of different mesh size as per Unified Sediment Classification System (USCS). Cumulative weight retained in each sieve will be calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves. The percent retained will be calculated from the weight retained and the total weight of the sample. The cumulative percent will be calculated by sequentially subtracting percent retained from 100%.

2.2.3. Total organic carbon

Total organic carbon is the carbon stored in sediment organic matter which enters the sediment through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, sediment biota etc. Total Organic carbon in the sediment is oxidized with potassium dichromate in the presence of concentrated sulphuric acid. Potassium dichromate produces nascent oxygen, which combines with the carbon of organic matter to produce CO_2. The excess volume of $K_2Cr_2O_7$ is titrated against the standard solution of ferrous ammonium Sulphate in presence of H_3PO_4 using Ferroin indicator to detect the first appearance of unoxidised ferrous iron and thus volume of $K_2Cr_2O_7$ can be found out which is actually required to oxidize organic carbon.

Procedure

Percentage of Total organic carbon in the sediment/sediment will be determined by oxidizing organic matter in the sediment samples by chromic acid and estimating excess chromic acid by titrating it against ferrous ammonium sulphate with ferroin as an indicator. The detailed step-by-step procedure is as follows:

One gm of 0.5 mm sieved sediment will be weighed and put into 500 ml conical flask and to which 10 ml of 1N $K_2Cr_2O_7$ will be added with pipette and swirled. Immediately using a burette, 20 ml Conc. H_2SO_4 will be added and mixed gently until sediment and reagents are mixed. The reaction will be allowed to proceed for 30 min in a marble stone to avoid the damage caused due to release of intense heat due to reaction of sulphuric acid. Further, 200 ml of distilled water will be added slowly and 10 ml of concentrated Orthophosphoric acid and about 0.2 gm NaF will be added and allowed the sample and reagent mixture to stand for 1.5 hrs because the titration end point is better visible in a cooled solution. One ml of ferroin indicator will be added into the conical flask just before the titration and then titrated the excess K_2Cr_2O with 0.5 N Ferrous Ammonium Sulphate till the color flashes from yellowish green to greenish and finally brownish red at the end point. Simultaneously a blank test will be also run without sediment sample.

2.2.4. Total Phosphorus

Phosphorus in sediment is commonly performed by Bray's extraction method and in this method, specific colored compounds are formed with the addition of appropriate reagents in the solution, the intensity of which is proportionate to the concentration of the element being estimated. The color intensity is measured spectrophotometrically. In spectrophotometrically analysis, light of definite wavelength (not exceeding say 0.1 to 1.0 nm in band width) extending to the ultraviolet region of the spectrum constitutes the light source. The photoelectric cells in spectrophotometer measure the light transmitted by the solution.

Fifty ml of the Bray's extractant will be added to 100 ml conical flask containing 5 gm of sediment sample and shaken for 5 minutes and filtered. Exactly 5 ml of the filtered sediment extract will be taken with a bulb pipette in a 25 ml measuring flask and 5 ml of the molybdate reagent with an automatic pipette will be added and diluted to 20 ml with distilled water and shaken well. Further, to this, 1 ml of the dilute Stannous Chloride solution will be added and volume made upto 25 ml mark and shaken thoroughly. The mixture will be kept for color development and after 10 minutes the readings will be taken in the spectrophotometer at 660 nm wave length after setting the instrument to zero with the blank prepared similarly but without the sediment.

2.2.5. Total Sulphur

Sulphur in the sediment extract was estimated turbidimetrically using a spectrophotometer. The standards of sulphur were prepared in series such as 2, 4, 6, 8 and 10 ppm working solution from stock solution. In this, 25ml of solution was added in the volumetric flask separately to each flask and 2.5 ml of conditioning reagent solution was also added followed by 5 ml of extraction solution was added. To this mixture, 0.2-0.3 gm of barium chloride was also added and shaken well and made-up to 25 ml with distilled water and the readings were taken at 340nm spectrophotometer.

The sample was analysed by taking 5g of marine sediment into a 100ml conical flask, to which, 25 ml of 0.15 % CaCl2 solution was added and shaken for 30 minutes. Then this was filtered through Whatman no. 42 filter paper and then 5 ml of sample aliquot was taken in a 25 volumetric flask, to which 2.5 ml of conditioning reagent and 0.2 to 0.3 g of barium chloride powder was added and made up to 25 ml distilled water and shaken well for 2 minutes and the absorbance was read in the same manner as standard solutions.

2.2.6. Heavy metals

Heavy metals are of concern especially as it relates to the environment are Cadmium (Cd), Lead (Pb), Chromium (Cr), Nickel (Ni), Cobalt (Co),Copper (Cu), Zinc (Zn), Manganese (Mn) etc. For the release of mineral elements from sediment and sediments, wet oxidation of samples are generally performed. Wet oxidation employs oxidizing acids (Tri / Di-acid mixtures).

Sediment sample will be weighed to 1.0 gm and taken in 100ml beaker covered with a watch glass and 12 ml of Aqua regia in (1: 3 HNO3 : HCl) will be added and the beaker will be kept in digestion for 3 hours at 100^0c on a hot plate using sand bath and the samples will be evaporated to near dryness and the samples will be kept cool for 5 mins and then 20 ml of 2% nitric acid will be added and kept for 15 minutes in hot plate for digestion and remove from hot plate and cooled and filtered using Whatman No. 42 mm filter paper and then the final make up to 50 ml with 2 % nitric acid will be made. The extracted sample will be then aspirated to an AAS.

2.2.7. Petroleum Hydrocarbons

Sediment after refluxing with KOH-methanol mixture will be extracted with hexane. After removal of excess hexane, the residue will be subjected to clean-up procedure by silica gel column chromatography. The hydrocarbon content will be then estimated by measuring the fluorescence as per standard method.

2.3. Results

Like water, sediment matrix is also an important entity in quantifying the pollutant concentration of an environment and in fact in comparison to the water quality characteristics sediment characteristics reflects the long term quality of that particular system. Various pollutants gets accumulated in the sediments over long period of time according to their chemical persistence and the physical-chemical and biochemical characteristics of the substrata which help in drawing sources of contamination. Furthermore, sediments also act as a sinks and sources of contaminants in aquatic systems, chemical analysis for characterization of sediments also provides environmentally significant information about natural and anthropogenic influence on the water bodies. In addition, sediment strata also serve as an important habitat for the benthic macro invertebrates whose metabolic activities contribute to aquatic productivity. All these points add up an value to sediments which indicates the ecological health of the marine environment and hence measuring such strata will help us in deriving to a conclusion on the overall environment. Hence, in the present project, the physico-chemical characteristics of the marine sediment collected from the study area was used to ascertain the nature of the marine environment of the coast.

2.3.1. Physico-chemical characteristics of the sediment during Season 1

2.3.1.1. pH (Hydrogen Ion)

pH values in marine sediments, increasing or decreasing free proton concentrations in pore waters. However, these processes are generally depending with cycles of carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron and manganese and are associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and dissolution of calcium carbonate marine water and sediments. In the present investigation of pH average values were recorded to be 8.52±0.11 in the Offshore, 8.77±0.12 in the Cargo jetty and 8.67±0.09 in the Phang Creek among all the stations comparably, the maximum concentration of pH was recorded to 8.93 at 2A in the Cargo jetty and the minimum concentration of pH was recorded to be 8.42 at control-1 in the Offshore (Fig-3)

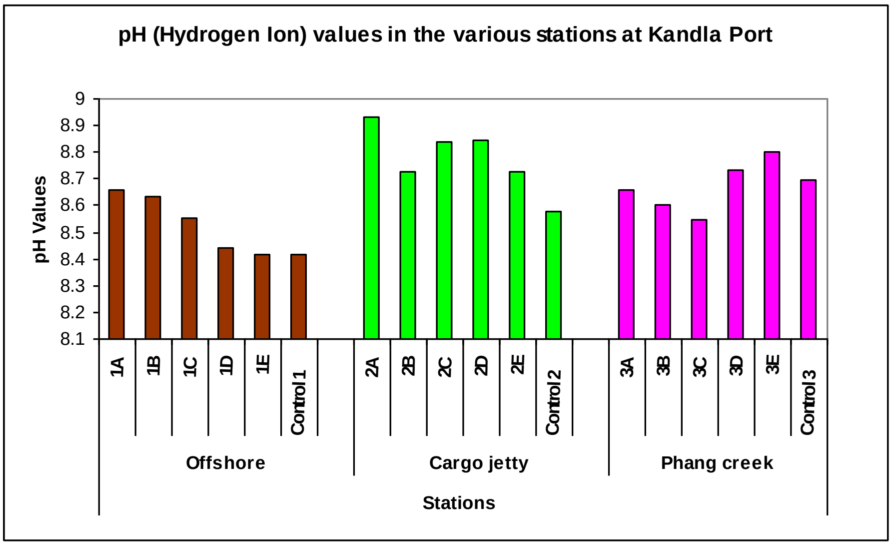

Fig. 3. pH (Hydrogen ion) values in the various stations during Season 1

2.3.1.2. Salinity

In the marine water and sediment salinity typically varies from 0 to 36 in most estuaries with hyper salinity occurring in many semienclosed bays. As well as, salinity variable water temperature typically oscillates in diurnal and seasonal cycles in response to atmosphere temperature. In the study, during season first examination was observed the highest concentration of salinity was found to be 26.56 ppt at 2D site (Cargo Jetty) and the lowest concentration of salinity was found to be 13.76 ppt at 1A site (Offshore) and mean ±SD of 17.58±2.96ppt, 22.63±2.43 ppt and 21.28±1.42ppt in the Offshore, Cargo jetty and Phang Creek respectively and all the data shown in the (Fig-4).

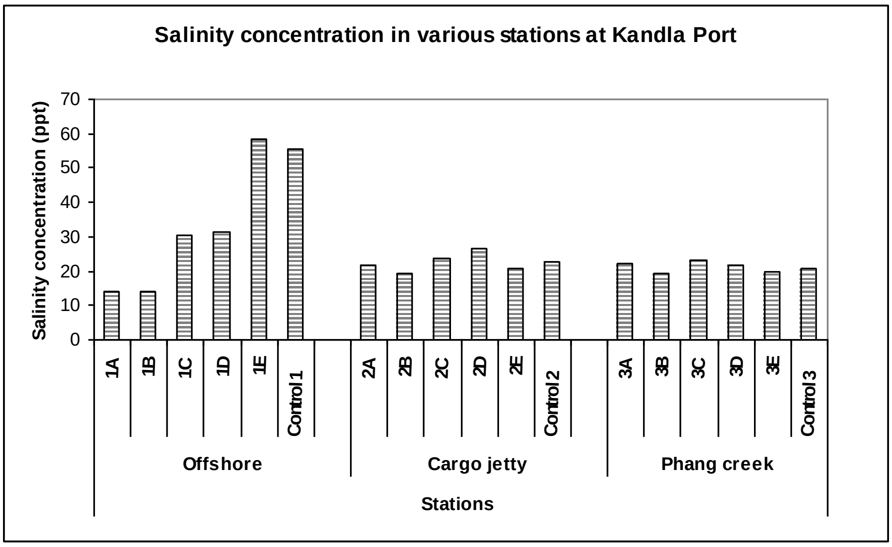

Fig.4. Salinity concentration in various stations during Season 1

2.3.1.3. Petroleum hydrocarbons

Petroleum hydrocarbons (PHCs) contaminating marine environmental it is mainly compounds of three classes such as alkanes, olefins, and aromatics. Moreover, the petroleum hydrocarbons are less solubility in marine water and adsorbing by particulate matter showing a long-term persistence on the bottom of sediments and it is a significant negative impact on benthic aquatic communities in the marine ecosystem, In the first season, the PHC ranged between 18.77 to 41.46 µg/kg, the maximum was observed to be 41.46 µg/kg at 1A (Offshore site) and minimum was observed to be 18.77 µg/kg at Control -2 (Cargo Jetty site) (Fig-5).

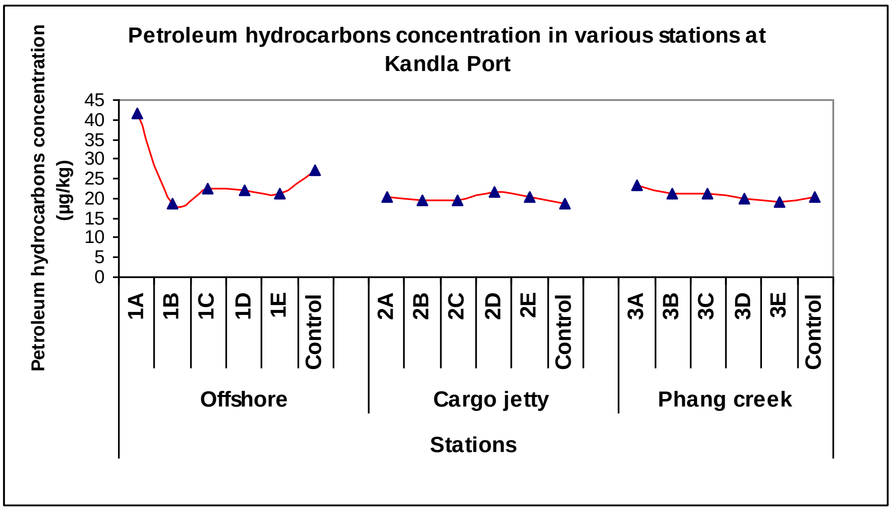

Fig. 5. Petroleum hydrocarbons concentration in various stations during Season 1

2.3.1.4. Magnesium

Ocean flux of dissolved magnesium into marine sediment from the overlying ocean is widely driven by molecular diffusion that occurs as pore water magnesium is depleted during authigenic mineral formation in the sediment column, as well as the direct burial of seawater as pore water that results from sediment accumulation on the seafloor. During the first season, determination of magnesium in the different station in the study area was in the Average ± SD of 565.89±163.56 mg/kg (Offshore site), 459.08±66.06 mg/kg (Cargo jetty) and 493.16±41.67 mg/kg (Phang Creek) and the maximum and minimum was 721.71 mg/kg at 1D (Offshore site) and 319.3mg/kg at 1B (Offshore site) respectively among all the stations results shown in the (Fig-6).

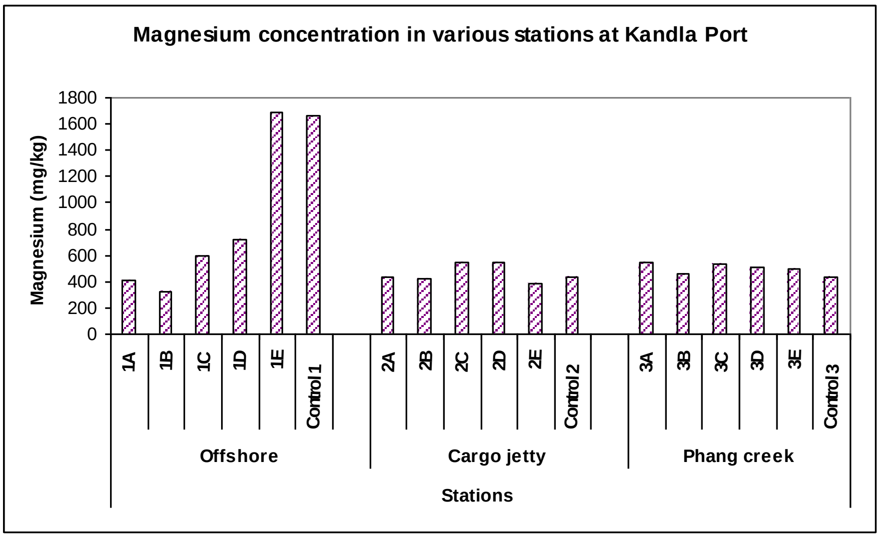

Fig. 6. Magnesium concentration in various stations during Season 1

2.3.1.5. Sediment Texture

One of the most important of these factors is sediment texture which (Sand, Silt and Clay) to marine benthic groups, in the study was investigated in different stations sediment texture, in which highest sediment texture percentage was observed of sand 91.8% at 1A (Offshore) , silt 39.6% 2E (Cargo jetty) and clay 74.6% at 3A (Phang Creek) and lowest concentration of sand 12.2% at 3A (Phang Creek), Silt 3.9% at 1A (Offshore) and Clay 3.7% at 1B (Offshore site) among all the stations data shown in the (Fig-7).

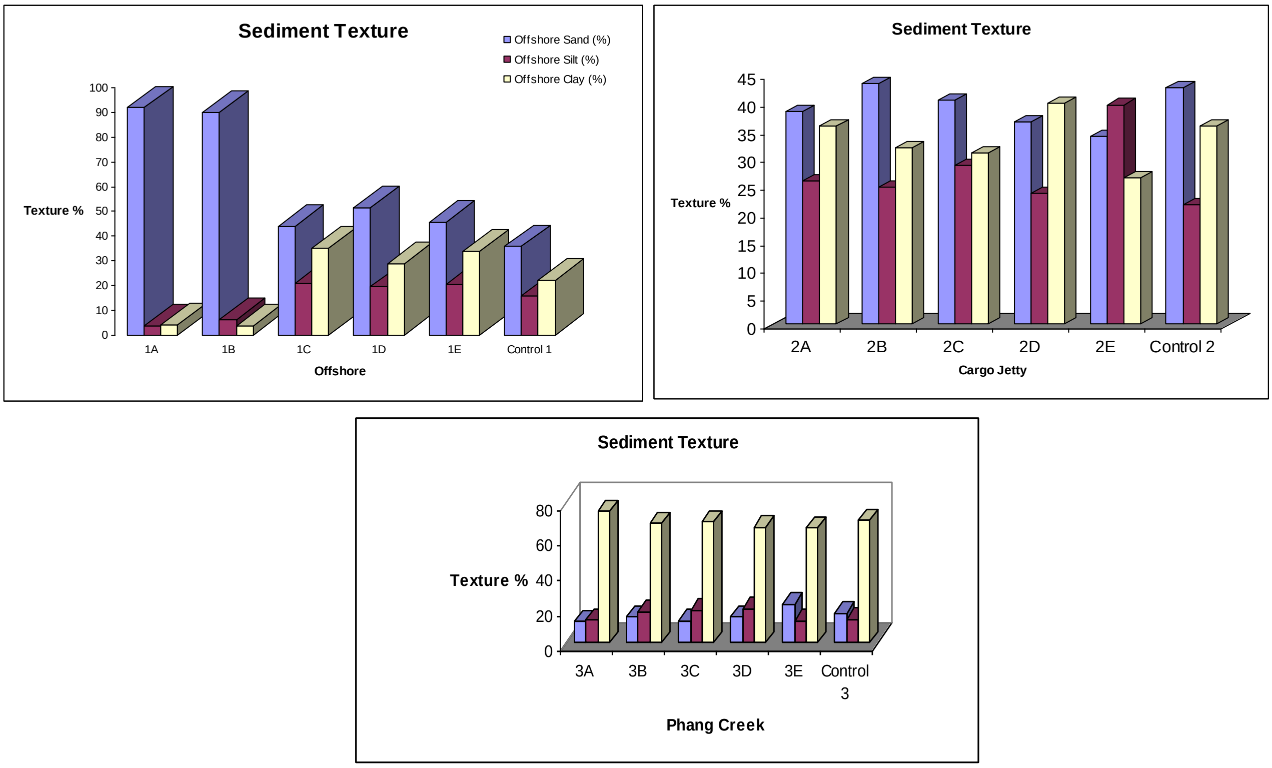

Fig.7. Sediment texture content in various stations during Season 1

2.3.1.6. Total organic Carbon

The organic carbons in marine sediment are mainly coming from decomposition from animals, plants and anthropogenic sources such as chemical waste, fertilizers and organic – rich wastes enrich the marine environment and that organic load settling to the bottom sediments from water column, in the path way that TOC values increasing and it is affecting the faunal communities. During first season, that TOC concentration ranged between 0.21 to 1.56 % all the stations (Fig-8).

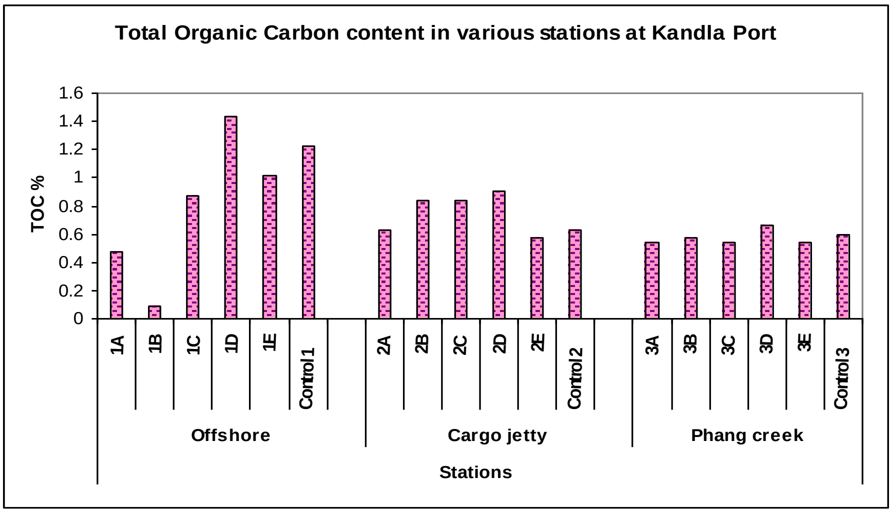

Fig.8. Total organic carbon content in various stations during Season 1

2.3.1.7. Phosphorus

Phosphorus (P) is an essential nutrient for life that plays a key role in regulating primary productivity in some marine systems. During season first, the maximum concentration of phosphorus was found to be 38.17 mg/kg at 2A (Cargo jetty) and the minimum concentration of phosphorus was found to be 16.12 mg/kg at 3A (Phang Creek) and the average ±SD being 27.28±5.36mg/kg in Offshore, 31.13±4.58 mg/kg in Cargo jetty and 19.93±3.71 mg/kg in Phang Creek among all the results shown in (Fig.9).

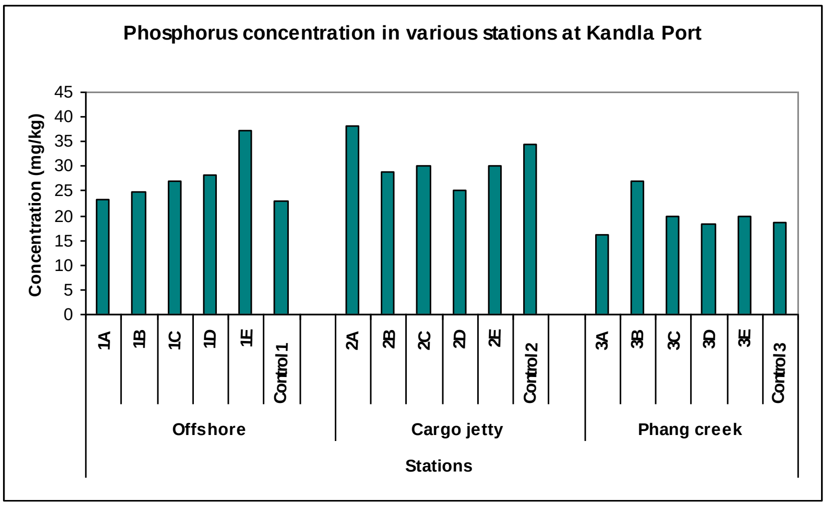

Fig.9. Phosphorus concentration in various stations during Season 1

2.3.1.8. Sulphur

Sulphur is a most significant primary source in sediments, the oxidation of sulphur and subsequent processing of oxidation intermediates. However, the sulphur cycle of marine sediments is primarily driven by the dissimilatory Sulphate reduction to sulfide by anaerobic microorganisms. In present study aimed to examine for sulphur concentration variables in different seasons, during the first season, the maximum concentration of sulphur was recorded to be 101.58 mg/kg at Control site (Offshore site) and the minimum concentration of sulphur was recorded to be 38.7mg/kg at 1B (Offshore site) (Fig.10).

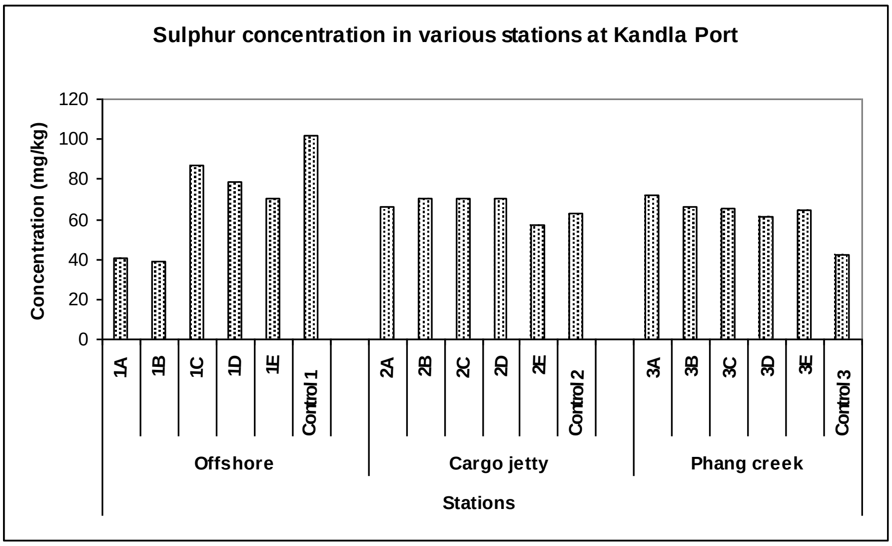

Fig.10. Sulphur concentration in various stations during Season 1

2.3.1.9. Heavy metals

Nickel (Ni), Lead (Pb), Cadmium (Cd), Chromium (Cr), Zinc (Zn), Copper (Cu) and Cobalt (Co) concentrations have been determined in bottom sediment samples during first season in different stations in the study area. The highest concentration of Ni was observed to be 75.75 mg/kg at 2A (Cargo Jetty) and the lowest concentration of Ni was observed to be 17.6 mg/kg at 1A (Offshore site) and lead concentration ranged between 2.3 - 4.85 mg/kg in the Offshore, 1.6-20.35mg/kg in the Cargo jetty and 4.75-13.65mg/kg in the Phang Creek and mean±SD being 3.58±1.8 mg/kg, 10.38±7.18mg/kg and 8.82±3.29mg/kg of Offshore, Cargo jetty and Phang Creek respectively. Furthermore, the maximum and minimum concentration of Cd was recorded to be 2.15gm/kg at 3E (Phang Creek) and 0.3mg/kg at 1C (Offshore) respectively and the Zinc concentration ranged from 7.45 to 58.95 mg/kg among all the stations and followed by concentration of cobalt maximum was 29.5 mg/kg observed at 2A (Cargo jetty) and minimum was 4.5 mg/kg observed at 1A (Offshore), whereas, the chromium and copper metals were observed BDL among all the stations and different sampling sites. Metals concentrations were shown in Fig.11.

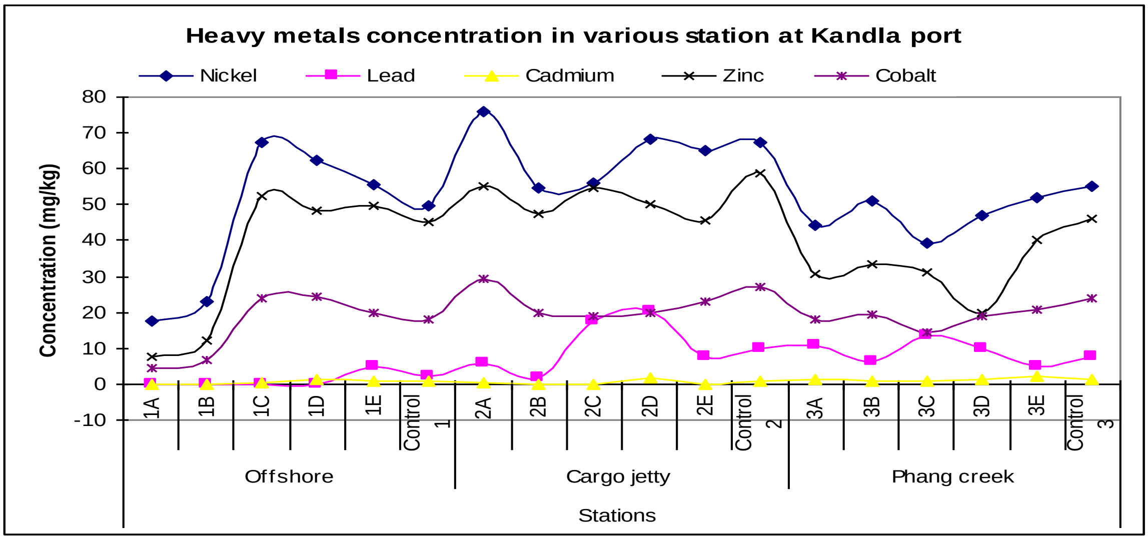

Fig.11. Heavy metals concentration in various stations during Season 1

2.3.2. Physico-chemical characteristics of the sediment samples during Season 2

2.3.2.1. pH (Hydrogen Ion)

pH values in marine sediments, subatomic concentrations in seawater and deposited in the sediment core. However, these processes are generally depending with cycles of carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron and manganese and are associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and dissolution of calcium carbonate marine water and sediments. In the present investigation pH average values were recorded to be 7.95±0.11 in the offshore, 8.04±0.08 in the cargo jetty and 7.71±0.34 in the Phang creek. Among all the stations, the maximum concentration of pH was recorded to be 8.17 in the cargo jetty station and the minimum concentration of pH was recorded to be 7.02 in the Phang creek station Fig.12

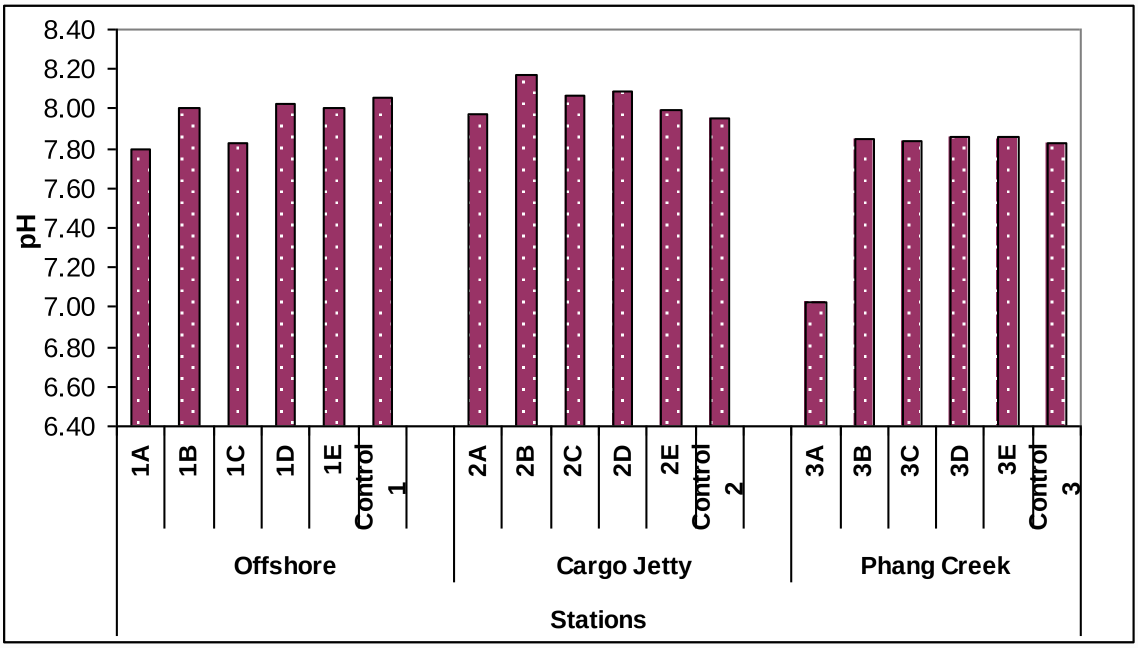

Fig .12. pH values in the various stations at Deendayal Port during Season 2

2.3.2.2. Salinity

In the marine water and sediment, salinity typically varies from 0 to 36 ppt in most estuaries with hyper salinity occurring in many semi-enclosed bays. As well as, salinity concentration is associated with water temperature typically oscillates in diurnal and seasonal cycles in response to atmospheric temperature. In this study, during season two, salinity was observed to the highest concentration of 24.73 ppt in the phang creek station and the lowest concentration of salinity was found to be 7.78 ppt in the offshore station and mean ±SD salinity of 9.63±2.89ppt in the offshore station, 21.73±1.30ppt in the cargo jetty station and 22.36±2.01ppt in phang creek station. Among all the stations values shown in Fig.13.

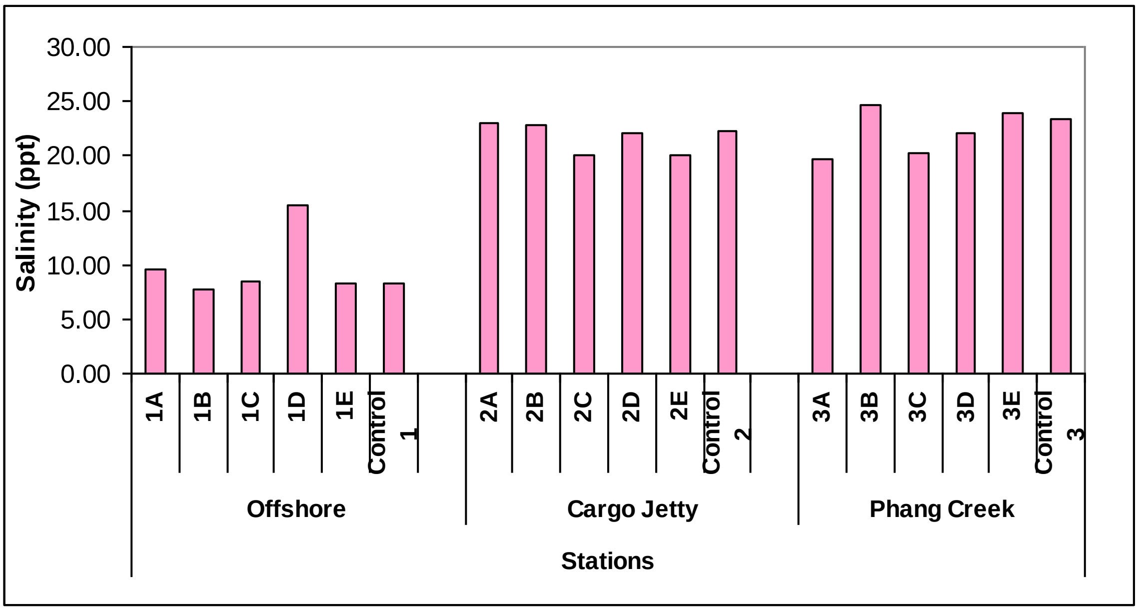

Fig.13 Salinity concentration in the various stations during Season 2

2.3.2.3. Sediment Texture

One of the most important physical characteristics is sediment texture which (Sand, Silt and Clay) to marine benthic groups, in the study was investigated in different stations sediment texture, in which highest sediment texture percentage was observed of sand 54.80 % in the cargo jetty, silt 68.80% in the offshore station and clay 55.30% in the cargo jetty and lowest sediment texture percentage was observed of sand 10.10% in the phang Creek, silt 14.20% in the cargo jetty and Clay 10.60% in the offshore stations and among all the stations and the data shown in the Fig.14.

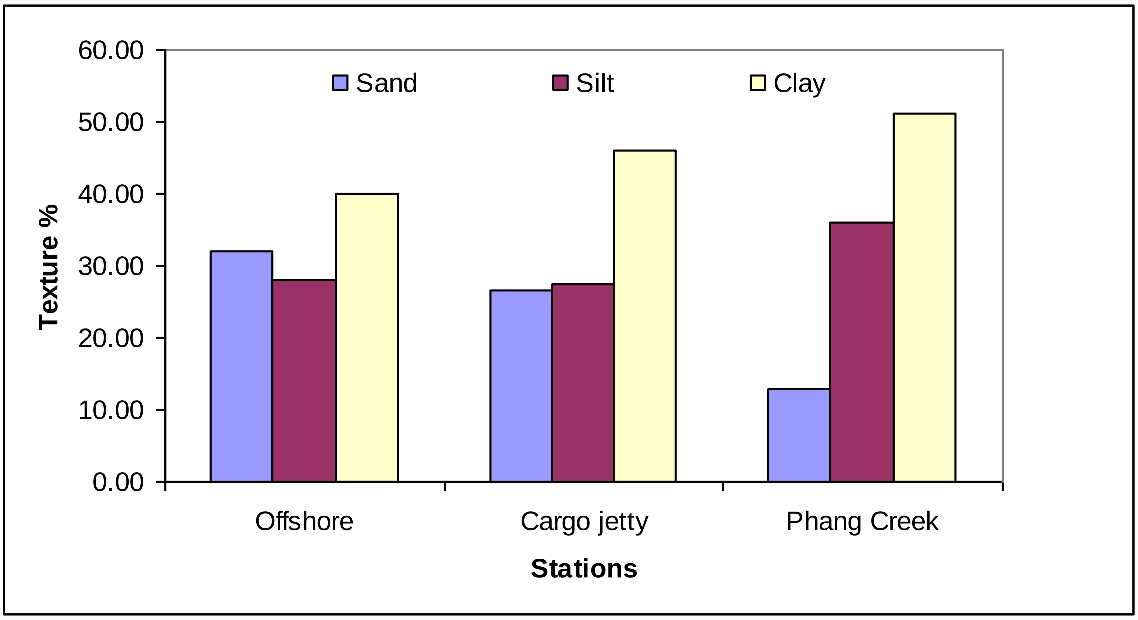

Fig.14. Sediment texture values in various stations during Season 2

2.3.2.4. Total organic Carbon

The organic carbon in the marine sediment are mainly coming from decomposition from animals, plants and anthropogenic sources such as chemical waste, fertilizers and organic – rich wastes which enrich the marine environment and that organic load settling to the bottom sediments from water column, in the path way that TOC values increasing and it affects the faunal communities. During season two, that TOC mean ±SD % of 0.41±0.17% in the offshore station, 0.69±0.21% in the cargo jetty station and 0.67±0.09 % in phang creek station, among all the station TOC concentration shown in the Fig .15.

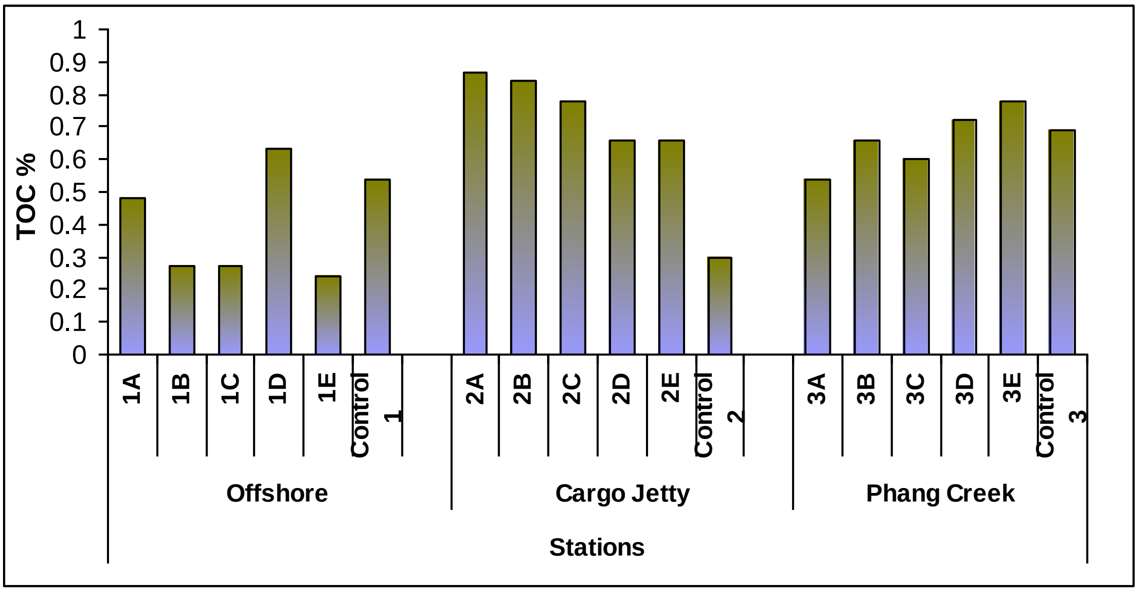

Fig.15. Total organic carbon in various stations at Deendayal port during Season 2

2.3.2.5. Organic matter

In the marine sediment organic matter is the major reservoir of organic carbon, which is a chemical, physical and biological effect of degradation to produce the organic matter in marine environment. Moreover, composed of material derived from the various planktons and benthic species that comprise the ecology of primary producers and consumers in overlying surface sediment. In the study, during season two, determined the organic matter ranged between 0.41 to1.50 % among all the stations data shown in the Fig.16.

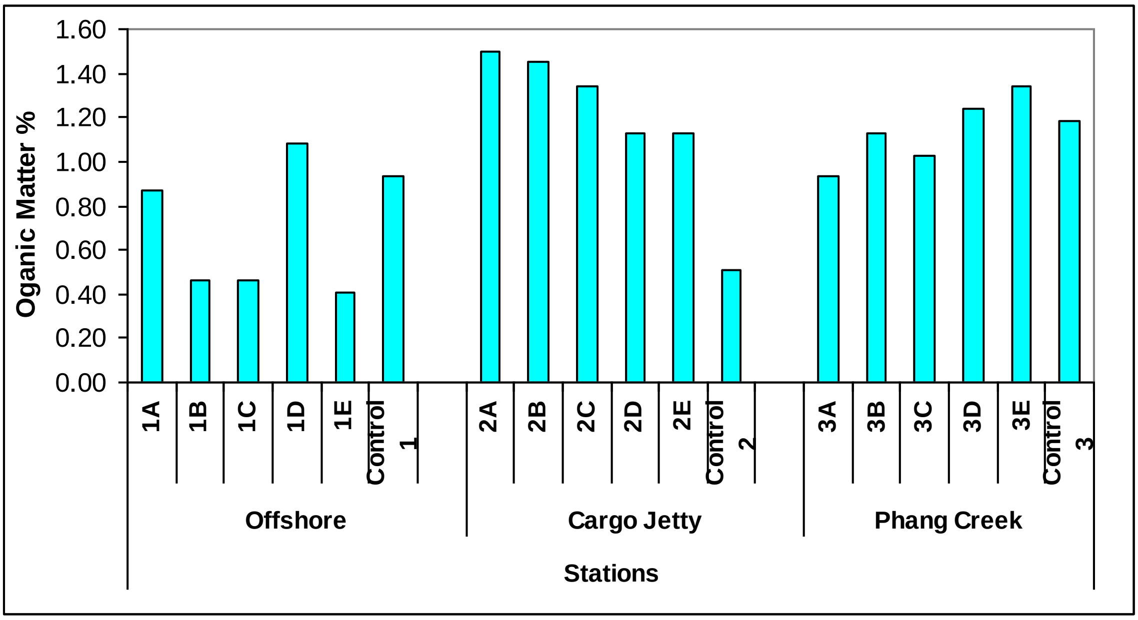

Fig.16. Organic matter concentration in various stations during Season 2

2.3.2.6. Phosphorus

Phosphorus (P) is an essential nutrient for life that plays a key role in regulating primary productivity in the marine systems. During season two, the maximum concentration of phosphorus was found to be 93.17 mg/kg in the Cargo jetty station and the minimum concentration of phosphorus was found to be 2.70 mg/kg in the offshore station and the average ±SD being 10.09±4.17 mg/kg in offshore, 30.28±31.16 mg/kg in cargo jetty and13.82 ±4.10mg/kg in phang creek.

2.3.2.7. Sulphur

Sulphur is a most significant primary source in sediments, the oxidation of sulphur and subsequent processing of oxidation intermediates. However the sulfur cycle of marine sediments is primarily driven by the dissimilatory sulfate reduction to sulfide by anaerobic microorganisms. In the present study, we aimed to examine the sulphur concentration which varies in different seasons, during season two, the maximum concentration of sulphur was recorded to be 28.08mg/kg in the phang creek and the minimum concentration of sulphur was recorded to be 13.0mg/kg in the offshore station, among all stations data shown in Fig.17.

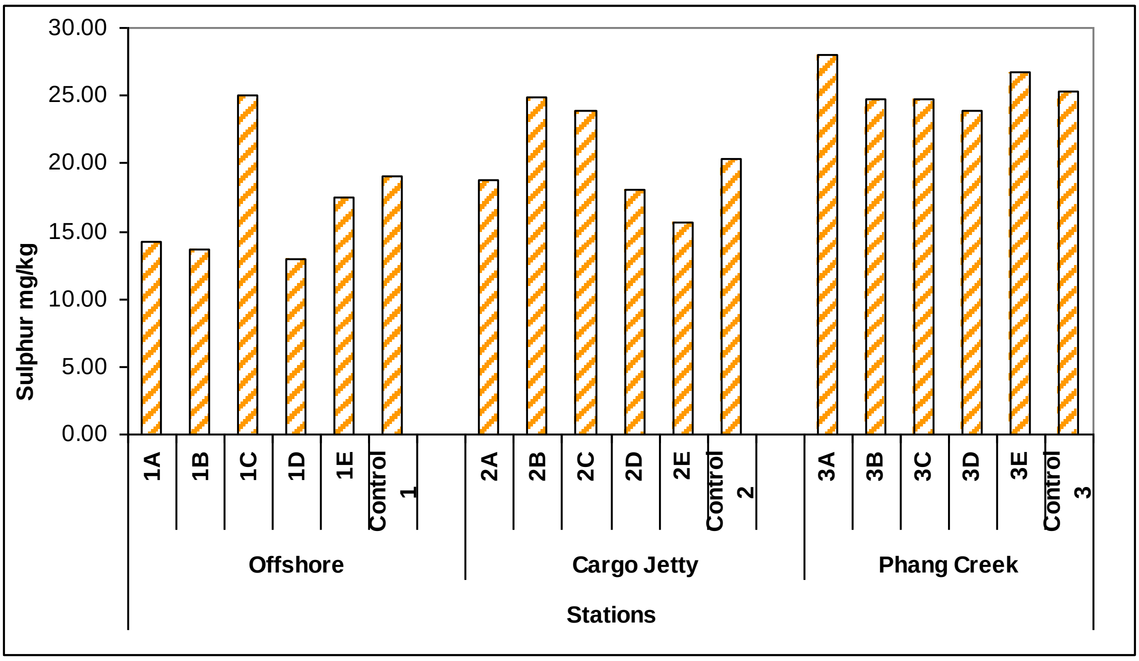

Fig.17. Sulphur concentration in various stations during Season 2

2.3.2.8. Petroleum hydrocarbon

Petroleum hydrocarbon (PHc) contaminating the marine environment which comprises mainly of three classes of groups such as alkanes, olefins, and aromatics. Moreover, the petroleum hydrocarbons has less solubility in marine water and adsorbing by particulate matter showing a long-term persistence on the bottom of sediments and it cause a significant negative impact on benthic aquatic communities in the marine ecosystem. During season two, various stations the PHC ranged between 1.25 to 2.26µg/kg and the maximum was observed to be 2.26µg/kg in the offshore stations and minimum was observed to be 1.25µg/kg in the cargo jetty station Fig.18.

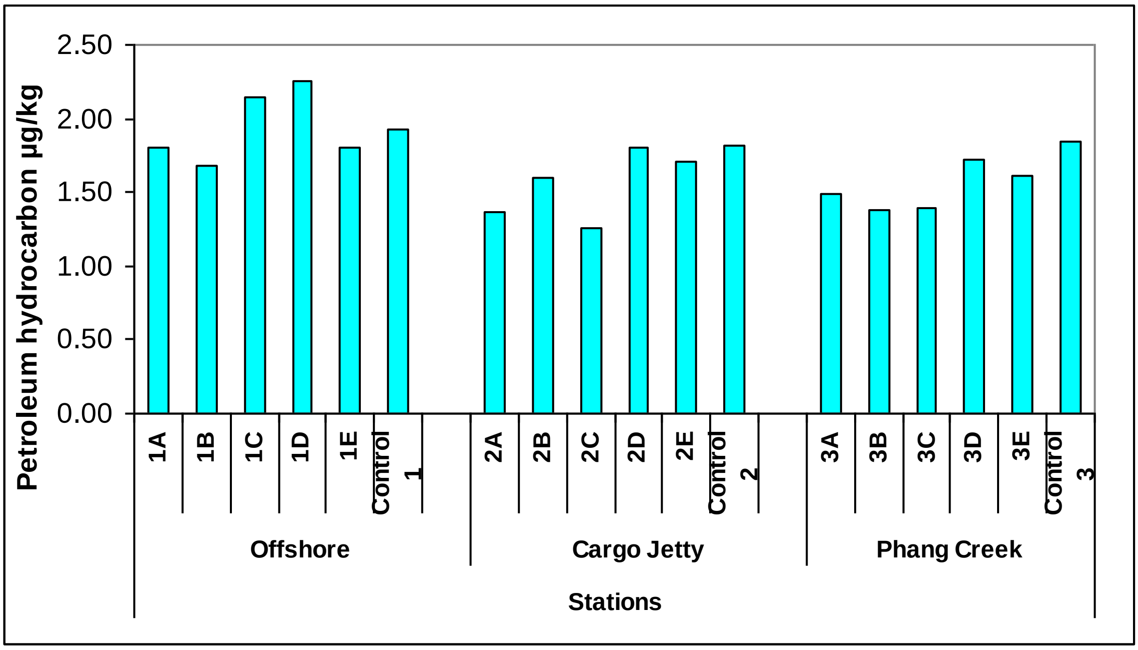

Fig. 18. Petroleum hydrocarbon concentration in various stations during Season 2

2.3.2.9. Heavy metals

The maximum concentration of heavy metals in the sediment samples for the metals such as Nickel, Lead, Cadmium, Chromium, Zinc, Copper, Manganese and Cobalt are in the levels 29.34 mg/kg, 1.44 mg/kg, 0.70 mg/kg, BDL, 21.43 mg/kg, 0.38 mg/kg, 1.50 mg/kg and 8.55 mg/kg respectively. Whereas, the mean concentration of the metals were in the Cargo Jetty location where in the range of 60.46 mg/kg, 9.64 mg/kg, 0.47 mg/kg, BDL, 42.06 mg/kg, 1.02 mg/kg, 3.27 and 33.73 for the metal species Nickel, Lead, Cadmium, Chromium, Zinc, Copper, Manganese and Cobalt respectively. In case of the creek system, the metal concentrations were observed in the range as 24.58 - 32.24 mg/kg for Nickel, 8.56- 13.57 mg/kg for Lead, 0.57-2.15 mg/kg for Cadmium, 0.11 -0.21 mg/kg for Chromium, 28.56-42.80 mg/kg for Zinc, 0.87 - 2.24 mg/kg for Copper, 3.56 - 10.28 mg/kg for Manganese and 9.85 - 18.75 in case of cobalt metal. During the second season, determination of magnesium in the different station in the study area was in the Average ± SD of 449.53±155.33 mg/kg (Offshore site), 397.62±75.65 mg/kg (Cargo Jetty) and 467.60±29.75 mg/kg (Phang Creek) and the maximum and minimum was 612.48 mg/kg at Control site and 218.56 mg/kg at 1B (Offshore site) respectively.

2.3.3. Physico-chemical characteristics of the sediment characteristics during Season 3

2.3.3.1. pH (Hydrogen Ion)

pH values in marine sediments, subatomic concentrations in seawater and deposited in the sediment core. However, these processes are generally depending with cycles of carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron and manganese and are associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and dissolution of calcium carbonate marine water and sediments. In the present investigation of pH average values were recorded to be 7.65±0.11 in the offshore, 7.53±0.07 in the cargo jetty and 7.75 ±0.15 in the Phang creek among all the stations comparably, the maximum concentration of pH was recorded to 7.91 (Fig.19) at 3B in the Phang creek and the minimum concentration of pH was recorded to be 7.42 at 2A in the cargo jetty.

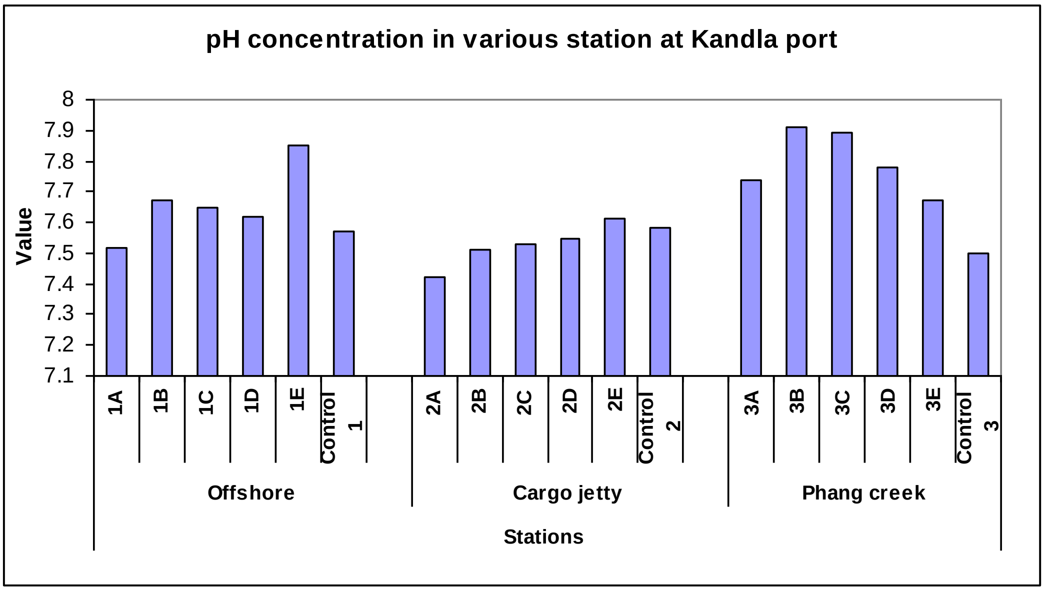

Fig .19. pH values in the various stations during Season 2

2.3.3.2 Salinity

In the marine water and sediment salinity typically varies from 0 to 36 in most estuaries with hyper salinity occurring in many semi-enclosed bays. As well as, salinity variable water temperature typically oscillates in diurnal and seasonal cycles in response to atmosphere temperature. In the study, the highest concentration of salinity was found to be 32.24 ppt at 3E Phang creek station and the lowest concentration of salinity was found to be 7.95 ppt at 1E (Offshore) and mean ±SD of 9.26±0.96 ppt, 13.92±2.61 ppt and 22.19±7.17 ppt in the offshore, cargo jetty and Phang creek respectively and all the data shown in the (Fig-20).

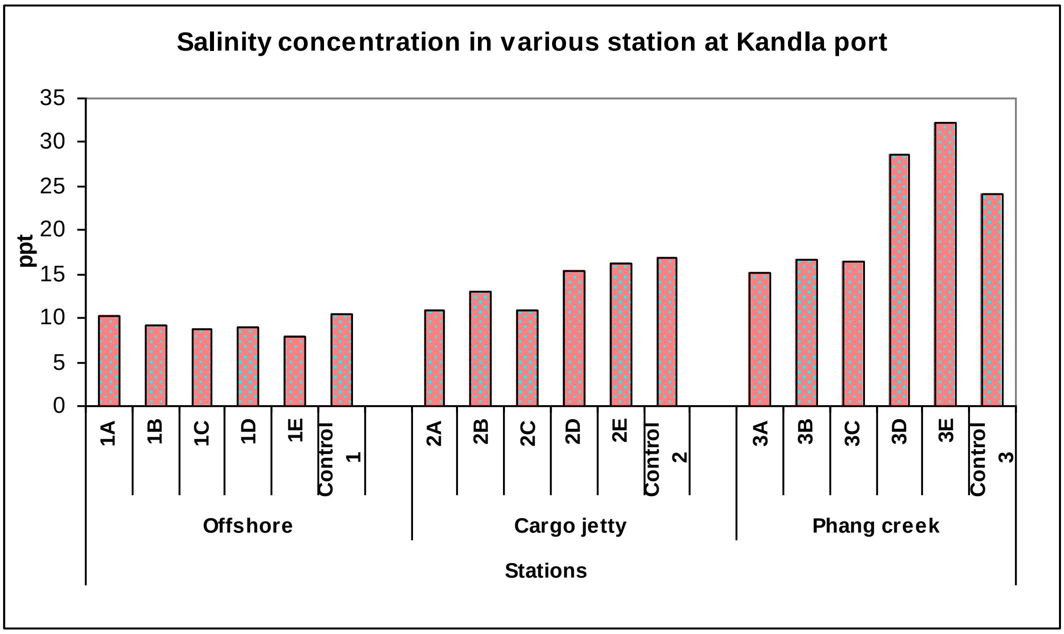

Fig.20. Salinity concentration in the various stations during Season 2

2.3.3.3. Sediment Texture

One of the most important of these factors is sediment texture which (Sand, Silt and Clay) to marine benthic groups, in the study was investigated in different stations sediment texture, the average range of sediment texture percentage was observed of sand, silt and clay, 7.10, 30.12 and 62.78% in the offshore station, 36.87, 24.33 and 38.80% in the cargo jetty and 9.17, 33.02 and 57.82% in the phang creek station among all the stations data shown in the (Fig-21).

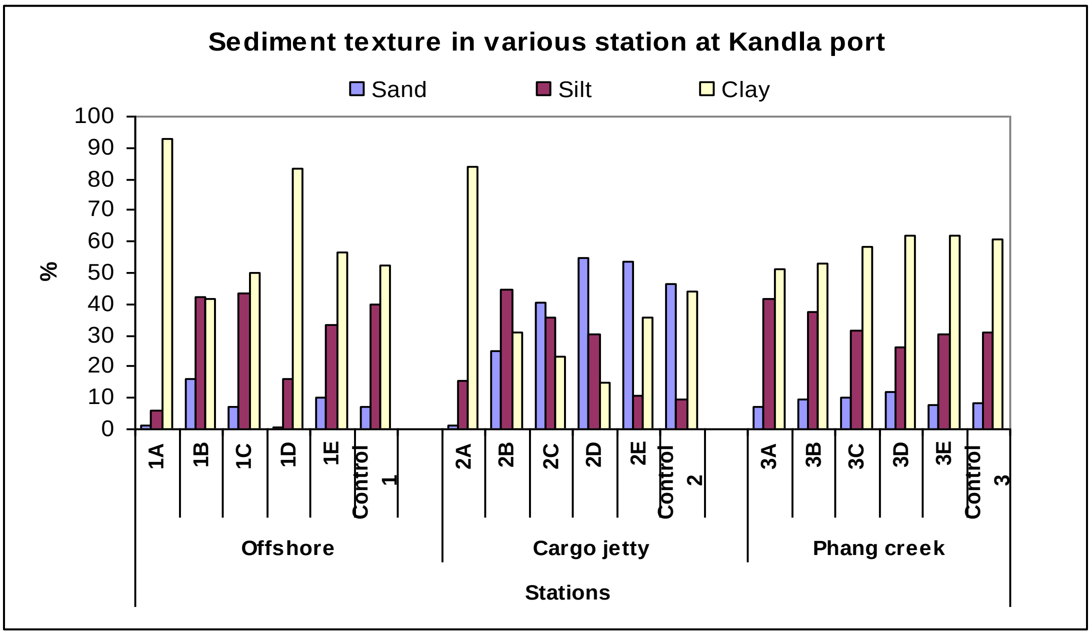

Fig.21. Sediment texture average values in various stations during Season 2

2.3.3.4. Total organic Carbon

The organic carbon in the marine sediment is mainly coming from decomposition from animals, plants and anthropogenic sources such as chemical waste, fertilizers and organic – rich wastes which enrich the marine environment and that organic load settling to the bottom sediments from water column, in the path way that TOC values increasing and it affects the faunal communities. During season three, that TOC mean ±SD % of 0.22±0.07% in the offshore station, 0.49±0.18% in the cargo jetty station and 0.52±0.16 % in Phang creek station, among all the stations.

2.3.3.5. Organic matter

In the marine sediment organic matter is the major reservoir of organic carbon, which is a chemical, physical and biological effect of degradation to produce the organic matter in marine environment. Moreover, composed of material derived from the various planktons and benthic species that comprise the ecology of primary producers and consumers in overlying surface sediment. In the present study during the third season, the organic matter ranged between 0.25 - 0.57%, 0.31-1.18% and 0.62-1.34% in the Offshore, Cargo jetty and the creek locations respectively as shown in the Fig.22.

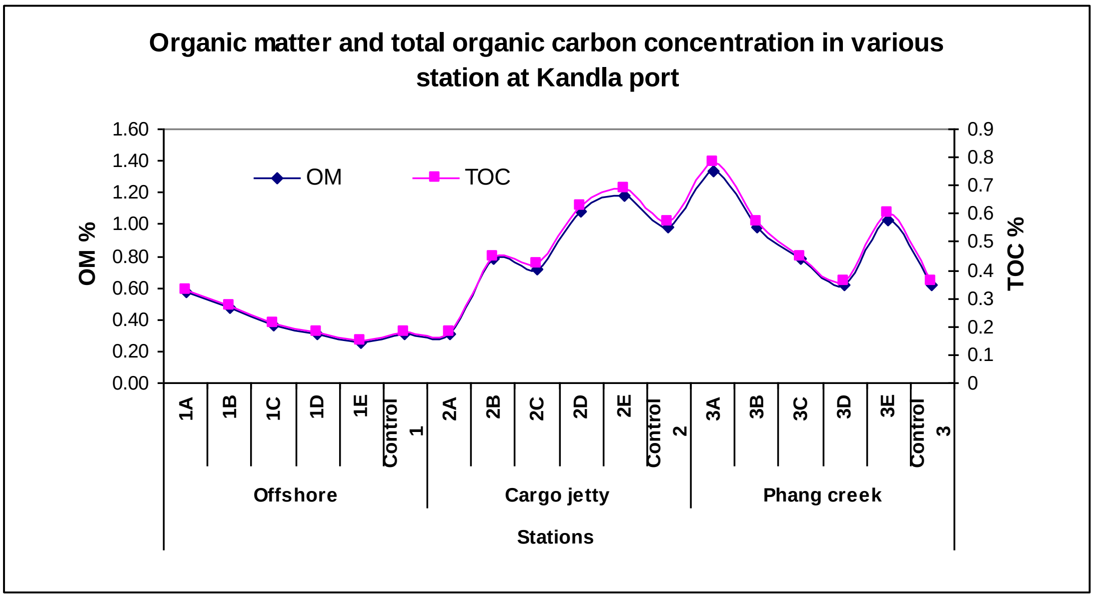

Fig.22. Organic matter concentration in various stations during Season 2

2.3.3.6. Phosphorus and Sulphur

In marine sediment, the Phosphorus (P) is an essential nutrient for life that plays a key role in regulating primary productivity in some marine systems. Moreover, the Sulphur (S) are microbial dissimilatory sulfate reduction to sulfide is a predominant terminal pathway of organic matter mineralization in the anoxic seabed. Chemical or microbial oxidation of the produced sulfide establishes a complex network of pathways in the sulfur cycle, leading to intermediate sulfur species and partly back to sulfate. In the present study, the highest concentration of Phosphorus found to be 98.96 mg/kg at 2A in the cargo jetty station, in the sulphur found to be 29.68 mg/kg at 3E in the Phang creek station and among all the station phosphorus and sulphur data shown in (Fig-23).

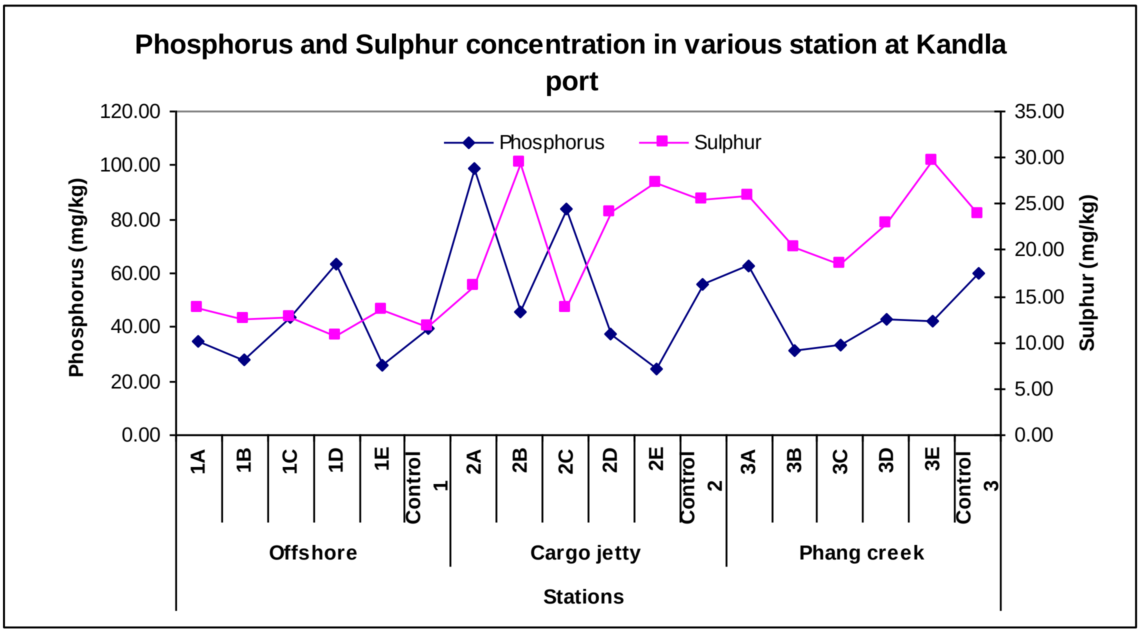

Fig.23. Sulphur concentration in various stations during Season 2

2.3.3.7. Petroleum hydrocarbon

Petroleum hydrocarbons (PHCs) contaminating marine environmental it is mainly compounds of three classes such as alkanes, olefins, and aromatics. Moreover, the petroleum hydrocarbons is less solubility in marine water and adsorbing by particulate matter showing a long-term persistence on the bottom of sediments and it is a significant negative impact on benthic aquatic communities in the marine ecosystem, the PHC ranged between 1.54 to 2.88 µg/kg, the maximum was observed to be 2.88 µg/kg at 1E offshore station and minimum was observed to be 1.54 µg/kg at Control -3 phang creek (Fig-24).

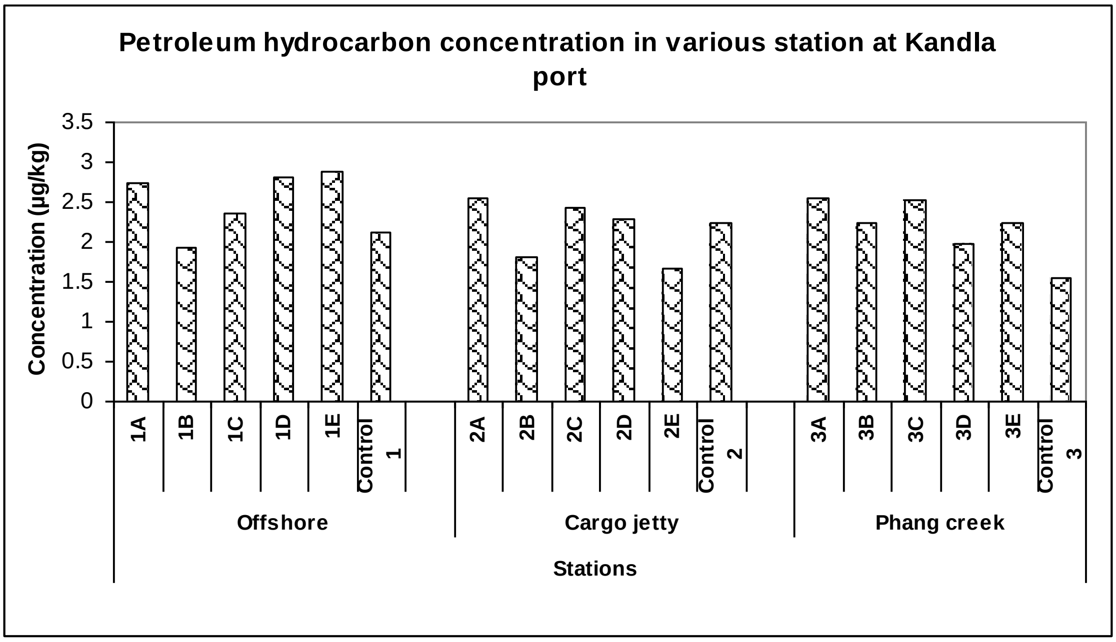

Fig. 24. Petroleum hydrocarbon concentration in the various stations during Season 2

2.3.3.8. Magnesium

Ocean flux of dissolved magnesium into marine sediment from the overlying ocean is widely driven by molecular diffusion that occurs as pore water magnesium is depleted during authigenic mineral formation in the sediment column, as well as the direct burial of seawater as pore water that results from sediment accumulation on the seafloor. During the Third season, determination of magnesium in the different station at Kandla port, that average ± SD magnesium concentration was 277.33±48.98 mg/kg (Offshore station), 262.94±10.7 mg/kg (Cargo jetty) and 297.23±59.95 mg/kg (Phang Creek).

2.3.3.9. Heavy metals

In the study present heavy metal contents in the sediment samples in various stations at Kandla Port by determined the concentrations of heavy metals (Ni, Pb, Cd, Cr, Zn, Cu, Mn and Co). During season three, the highest concentration of zinc was observed to be 128.05 mg/kg at 2D cargo jetty station and chromium and copper was observed below detectable limits (BDL) among all the stations data shown in the (Fig-25). In case of manganese, the Cargo Jetty recorded a value of 0.89-2.21 mg/kg with the mean concentration of 1.75 mg/kg. In case of another sub-tidal location, *i.e.*, Cargo jetty, the average concentration recorded to be 2.48±0.80 mg/kg and in the creek location, the minimum concentration of 2.87 mg/kg was recorded and the maximum concentration of manganese recorded was 4.52 mg/kg.

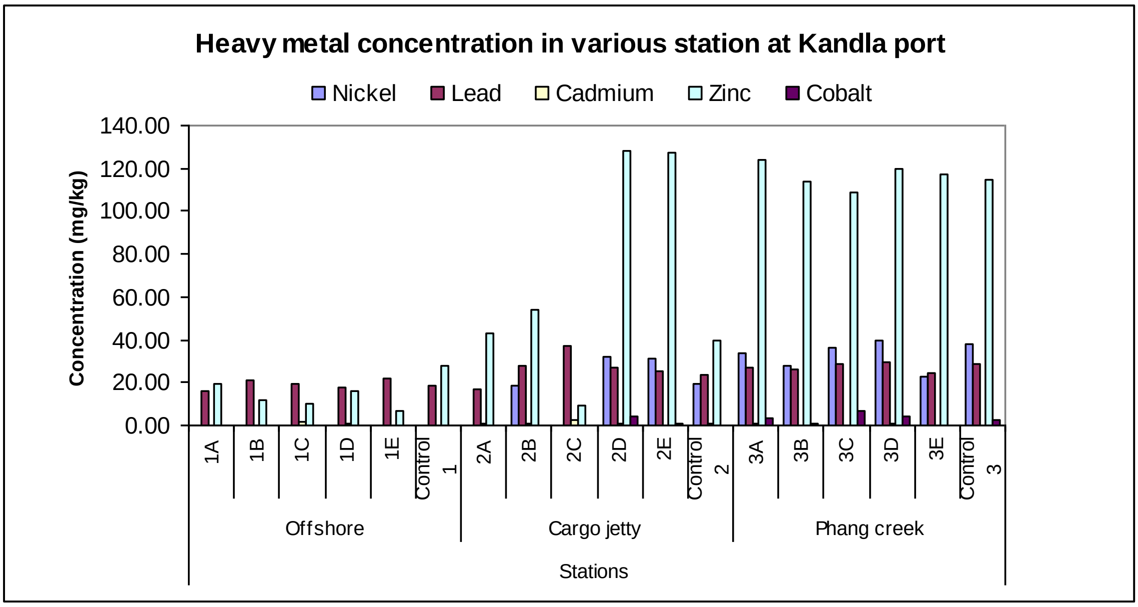

Fig. 25. Heavy metal concentration in the sediment samples during Season 2

Table 3: Comparison of the physico-chemical characteristics of the sediment samples of the present study (2021-2022) with the previous year data

Parameters	Period of study (in year)								
	2019-2020			2020-2021			2021-2022 (Present study)		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
pH (1: 10 suspension)	7.74	7.58	7.57	7.85	7.78	8.1	8.52	8.77	8.67
Salinity (ppt)	12.75	17.87	17.83	15.70	21.24	10.67	17.58	22.63	21.28
Petroleum Hydrocarbons (µg/L)	0.69	1.24	7.42	3.24	3.57	1.50	25.55	20.01	20.87
Magnesium (mg/kg)	410.11	455.61	384.68	369.79	488.93	302.24	565.89	459.08	493.16
Sand (%)	22.28	10.08	10.79	32.81	16.58	59.52	61.90	39.23	15.48
Silt (%)	42.88	5.98	18.22	19.43	21.98	19.27	15.46	27.35	15.88
Clay (%)	34.83	83.93	70.99	47.74	61.42	21.22	22.64	33.42	68.63
Total organic carbon (%)	0.45	0.27	0.26	0.35	0.35	0.27	0.95	0.86	0.70
Phosphorus (mg/Kg)	6.74	8.79	10.76	19.68	16.45	12.04	27.28	31.13	19.93
Sulphur	5.57	11.05	0.35	18.63	18.42	13.61	69.57	66.10	62.06
Nickel (mg/Kg)	32.46	16.34	46.94	26.02	24.94	21.88	45.84	64.53	48.18
Lead (mg/Kg)	18.40	BDL	BDL	17.95	20.53	50.07	3.58	10.38	8.82
Cadmium (mg/Kg)	0.50	BDL	1.16	1.50	0.911	BDL	0.79	1.08	1.27
Chromium (mg/Kg)	31.80	BDL	50.51	14.28	13.16	29.5	BDL	BDL	BDL
Zinc (mg/Kg)	46.62	21.96	86.73	73.00	74.75	83.59	35.90	51.98	33.45
Copper (mg/Kg)	19.65	8.25	26.76	9.46	14.41	23.7	BDL	BDL	BDL
Cobalt (mg/Kg)	1.87	BDL	4.42	12.05	8.77	19.93	16.25	23.10	19.28

Note: BDL denotes Below Detection Limit.

During the last three years, i.e., 2019-20, 2020-21 and 2021-22, the consolidated mean values of the sediment quality is shown in Table 3. The pH level ranged from 7.58 – 8.77 during three years among all the station. In the present study, pH was observed significance level when compare to previously results and followed by the most important proportion of sediment texture such as sand, silt and clay varied from 10.08-61.90%, 5.98-42.88% and 21.22-83.93% respectively. All the other characteristics observed during the last three years trend is shown in Table 3.

Chapter 3 Sediment Quality (Sub-tidal Fauna)

3.1. Introduction

The word Benthos comes from the ancient Greek language (βένθος (bénthos) meaning 'the depths (of the sea)'), also called benthon. It is the community of organisms which are mostly live on, in, or near the bottom part of a sea, river, lake, pond or stream and create one typical zone called Benthic zone. Benthos mostly used algae, small microscopic fauna and organic matter (runoff from land) in their diets. Majority affected factors of benthic community are depth of water, salinity, temperature, types of substrates, pre-predation ratio and suddenly change in environmental condition. Now a days different anthropogenic activities affected water ecosystems of earth including substratum habitat. Most of these animals lack a backbone and are called invertebrate animals. Benthic organisms, play an important role as a food source for fish and other higher level of organisms.

Generally benthic community include Mollusca (Gastropods and Bivalves), Coral, Sponges, different types of worms (mostly polychaetes and nematode), Crustacean crabs, other crustaceans, Echinoderms, oysters etc. Some benthos are important predators and scavengers for particular food chain system. The benthic community mainly prefer hard, sandy, muddy and soft bottoms as a living habitat. By the size, Benthos mainly divided into 3 types Macrobenthos (> 1 mm), Meiobenthos (< 1 mm or > 0.1 mm) and Microbenthos (< 0.1 mm). These animals also divided into two types Phytobenthos and Zoobenthos also added base on location Endobenthos, Epibenthos, Hyperbenthos are divided. The benthic community can be considered a black box diverting organic matter into either metabolites or the geosphere (burial) (Wikipedia). The sediments of benthic zone play an important role in providing nutrients for the organisms that live in the benthic zone. The up-down movement of the bottom sediments mainly occurred by these benthic organisms results in a rise of the oxygen concentration of water and hence the overall productivity of the water bodies rich in high level.

The study was conducted in winter season at 3 sites of Deendayal Port Authority with the locations namely, Offshore, Cargo Jetty and Phang Greek.

3.2. Methodology

To studying the benthic organisms, triplicate samples were collected at each station using Van veen grab which covered an area of $0.04m^2$. The wet sediment was sieved with varying mesh sizes (0.5 mm-macrofauna) for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution for easy spotting at the time of sorting. The number of organisms in each grab sample was expressed as number/ meter square (No/m^2). All the species were sorted, enumerated, and identified to the advanced taxonomic level possible with the consultation of available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al.* (1999) for crustaceans; SubbaRao *et al.* (1991) and Ramakrishna (2003) for molluscs.

Further, the data were treated with univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clarke and Warwick, 1994).

a) Shannon – Wiener index

In the present study, the data were analyzed for diversity index (H') by following Shannon – Wiener's formula (1949):

$H' = -\sum^{S} Pi \log 2\ Pi\ldots\ldots\quad i = 1$

which can be rewritten as

$$H' = \frac{3.3219\ (N\ \log N - \sum ni - \log ni}{N}$$

where, H'= species diversity in bits of information per individual

ni = proportion of the samples belonging to the ith species

(number of individuals of the ith species)

N = total number of individuals in the collection and

$\sum$ = sum

b) Species richness(S) was calculated using the following formula given by Margalef (1958)

c) Margalef index (d)

$d = (S-1) / \log N$

d) Pielou's evenness index

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\text{In}S}$$

Where, J' = evenness; H' = species diversity in bits of information per individual and S = total number of species.

3.3. Results and Discussion

3.3.1. Species Composition, Population density and Biomass during Season 1

Location 1 – Offshore site

The six stations selected for collection of samples (1A, 1B, 1C, 1D, 1E and 1- control). Total Five groups of Benthic community recorded in all stations of Offshore region and they are Bivalves, Crustaceans, Gastropods, Nematode and Polychaeta worms. Number of Density and Biomass expressed in (nos/m^2), (gm/m^2) respectively.

Highest population density of benthic organisms recorded in station 1A (725 nos/m^2), whereas lowest in station 1C (225 nos/m^2). The density range of all stations varied from (225 nos/m^2) to (725 nos/m^2). Bivalves and Polychaeta worms (Annelids) were more abundant among all benthos animals (Table 4). The high biomass value (expressed wet weight) of benthic fauna was observed in station 1A (4 gm/m^2) and low value in 1D (0.053 gm/m^2) (Table 4).

Location 2 - Cargo Jetty site

In Cargo Jetty, frequently observed Benthic groups were Crustaceans animals then Bivalves, Gastropods and Polychaeta worms. The population density range (50 to 700 nos/m^2) recorded between all stations (2A, 2B, 2C, 2D, 2E & 2-control) during assessment period. High and Low density recorded in station 2D (700 nos/m^2) and 2A (50 nos/m^2) respectively. The Biomass value indicated high in station 2D (2.9 gm/m^2) and low in control site (0.017 gm/m^2) (Table 4).

Location 3 - Phang Creek site

Six Stations of Phang Creek were selected for study namely (3A, 3B, 3C, 3D, 3E & 3-control). In this Creek area mainly represented macrofauna were Bivalves, Gastropods & *Polychaete worms* (Annelida). The population density was highest in station 3E and Control point (950 nos/m^2) same way other side lowest recorded in 3A (575 nos/m^2). Station (3C) comprises high wet wt (9.6 gm/m^2), whereas low recorded in station of control point (1.5 gm/m^2).

Overall result of macrofauna community showed high population density and biomass observed in Phang Creek region followed by Offshore and Cargo Jetty. Table 4 showed high population values of Bivalves and Polychaetes worms recorded in Phang Creek region where muddy environment preferred for benthic community. This was might be due to relatively stable and non-polluted environment provided by muddy Creek area of Phang Creek further added that very low level of predation pressure on benthic community. One more reason is might be comparatively less anthropogenic activities in that area. Abundant species in the Phang Creeks are *Pirenella cingulata, Umbonium vestiarium, Optediceros breviculum, Tellina sp., Clypeomorus bifasciata etc.* The percentage of occurrence (Table 4) revealed highest was Bivalves (83.33%) and Polychaeta worms (83.33%) then followed by Gastropoda (61.11%), Crustaceans (55.55%) and Nematoda worms (11.11%). Compared to three sites low density and biomass observed in Cargo Jetty that indicated some pollution level or uncomfortable environment for some benthic organisms. More detail status of Population density, Group composition and Biomass of benthic community of all selected sites are depicted in Table 4 and Figure 26. In all stations highest percentage composition recorded by Bivalves-mollusca (42%) followed by Polychaetaes worms (25%), Gastropods (19%), Crustaceans animals (12%) and Nematoda (2%) as shown in Figure 27. Phytoplankton abundance and their size, Zooplankton composition, Distribution of zooplankton, water currents, ebb and flow tides, water churning process are main reason for Biomass fluctuation. In Bivalves most commonly -frequently observed species are *Saccostrea sp., Mactra sp, Meretrix sp, Crassostrea sp, Donax sp.* etc . In Crustacea most commonly observed species are Crabs and Mysis development stage. Main Gastropods families recorded Trochidae, Cerithidea, Turritellidae, Mitridae and Bucciniae etc. *Nereis* sp, *Capitella* sp, *Nephtys* sp. like polychaeta's are frequently observed in samples. During microscopic work, more numbers of the broken bivalve's debris plat items and broken gastropods are frequently observed.

Diversity indices of Benthic Community

Table 5 shows various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.598 - 1.39) indicated very low to near moderate diversity. Highest diversity indices were recorded in Station 1B-Offshore (1.39) where all groups of benthos presented. The evenness values ranged between (0.641 to 1). The highest evenness value is 1 in station 2A-Cargo Jetty and the lowest evenness index value (0.641) is station 3E and Control-3 of Phang Creek where the population density was very high recorded. Simpson's Index value ranged between (0.353) to (0.74) indicated the bigger the value of D, the lower the diversity. Evenness value 1 of station 2A-Cargo Jetty showed very less number or no faunal diversity that is why no evenness or no richness.

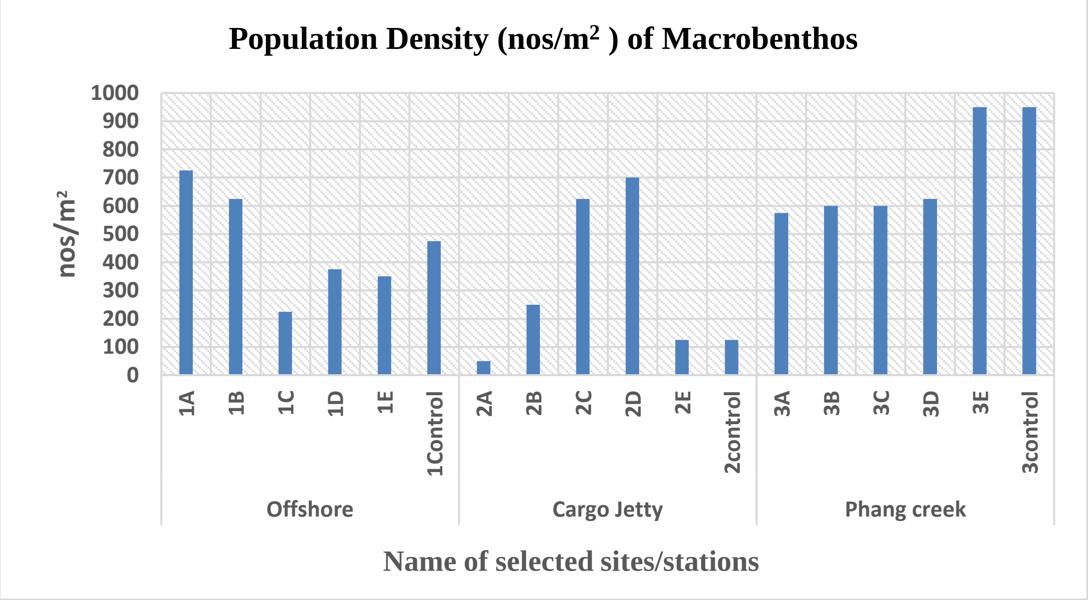

Fig. 26. Population density of Macrobenthos in various sites during Season 1

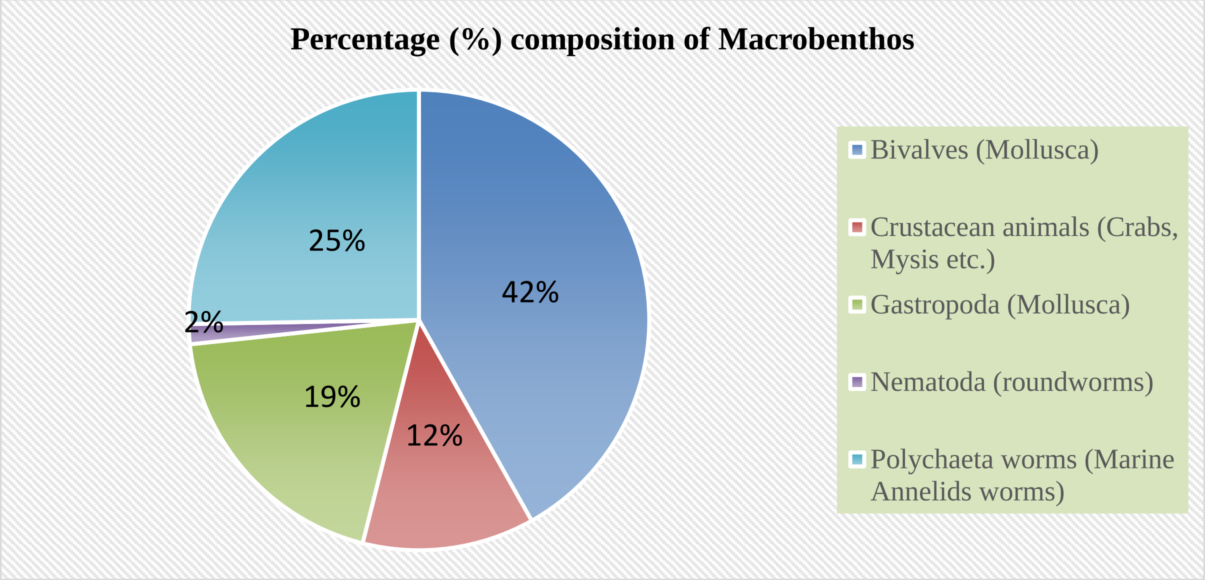

Fig. 27. Percentage composition of Macrobenthos during Season 1

Table 4. Macrobenthos distribution in different sites of Deendayal Port during Season 1

Name of Station	**Offshore**						**Cargo Jetty**						**Phang Creek**						**% Occurrence**
Benthic Group	**1A**	**1B**	**1C**	**1D**	**1E**	**1-Control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Control**	
Bivalves (Mollusca)	125	300	150	125	125	125	0	50	125	200	0	0	225	225	200	250	750	750	83.33 %
Crustacean animals (Crabs, Mysis etc.)	0	50	25	0	25	0	25	50	250	500	50	75	0	0	25	0	0	0	55.55 %
Gastropoda (Mollusca)	75	75	0	0	0	0	25	75	250	0	0	0	200	250	275	250	125	125	61.11 %
Nematoda (roundworms)	50	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.11 %
Polychaeta worms (Marine Annelids worms)	475	175	50	250	200	300	0	75	0	0	75	50	100	125	100	125	75	75	83.33 %
Population Density (No/m^2)	725	625	225	375	350	475	50	250	625	700	125	125	575	600	600	625	950	950	-
Biomass (Wet wt gm/m^2)	4	0.15	0.3	0.053	0.5	0.3	0.17	0.9	2.0	2.9	0.6	0.017	3.1	1.6	9.6	2.1	2.9	1.5	-

Table 5: Diversity indices in various station of Deendayal port (Benthos) during Season 1

	Offshore						**Cargo Jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1-CON**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-CON**	**3A**	**3B**	**3C**	**3D**	**3E**	**3- CON**
Taxa_S	4	5	3	2	3	2	2	4	3	2	2	2	3	3	4	3	3	3
Individuals (Nos/m^2)	725	625	225	375	350	425	50	250	625	700	125	125	525	600	600	625	950	950
Dominance D	0.474	0.294	0.506	0.555	0.459	0.584	0.5	0.26	0.36	0.591	0.52	0.52	0.365	0.357	0.350	0.36	0.646	0.646
Shannon	0.999	1.39	0.848	0.636	0.876	0.605	0.693	1.36	1.05	0.598	0.673	0.673	1.04	1.05	1.15	1.05	0.653	0.653
Simpson	0.525	0.705	0.493	0.444	0.540	0.415	0.5	0.74	0.64	0.4082	0.48	0.48	0.6349	0.6424	0.6493	0.64	0.353	0.353
Evenness	0.679	0.804	0.778	0.944	0.800	0.916	1	0.980	0.957	0.909	0.980	0.980	0.949	0.961	0.793	0.957	0.641	0.641
Menhinick	0.149	0.193	0.200	0.103	0.160	0.097	0.283	0.253	0.120	0.076	0.179	0.179	0.131	0.123	0.163	0.120	0.097	0.097
Margalef	0.456	0.614	0.369	0.169	0.341	0.165	0.256	0.543	0.311	0.153	0.207	0.207	0.319	0.313	0.469	0.311	0.292	0.292

3.3.2. Species Composition, Population density and Biomass during Season 2

Location 1 - Offshore site

Data collection was done at six sites (1A, 1B, 1C, 1D, 1E and 1- control). A Total of 4 groups of Benthic community were recorded in all stations at Offshore sites and they are Bivalves, Crustaceans, Gastropods (Mollusca) and Scaphopoda (Mollusca). Data on Density and Biomass expressed in (Nos/m^2), (gm/m^2) respectively.

Highest population density of benthic organisms was recorded in station 1E-Offshore (2350 nos/m^2), whereas lowest in station 1D-Offshore (1425nos/m^2). The density range of all stations varied from 1425 nos/m^2 to 2350 nos/m^2. Bivalves and Gastropoda were more abundant among all the benthic organisms (Table 6). The highest biomass value (expressed wet weight) of benthic fauna was observed in station 1B-Offshore (8.41 gm/m^2) and lowest value was 1E-Offshore (4.14 gm/m^2) (Table 6).

Cargo Jetty

In Cargo Jetty, frequently observed Benthic groups were Bivalves-Gastropods than Scaphopoda (Mollusca), and Razor clam (Bivalves). The population density range of 1100 to 4000 nos/m^2 was recorded between all the stations (Cargo Jetty2A, 2B, 2C, 2D, 2E & 2-Control) during the study period. Highest and Lowest density were recorded in station 2E-Cargo Jetty (4000 nos/m^2) and 2B-Cargo Jetty (1100 nos/m^2) respectively. The Biomass value indicated a highest value in station 2A- Cargo Jetty (13.86 gm/m^2) and lowest in 2B-Cargo Jetty (5.08 gm/m^2) (Table 6 and Fig. 28).

Phang creek

Six Stations of Phang creek were selected for the study namely 3A, 3B, 3C, 3D, 3E and 3-control-Phang creek. In this Phang creek benthic organisms were represented by Bivalves, Gastropods & *Razor clam* (Mollusca). The population density was highest in station 3Control-Phang creek (3400 nos/m^2) and on the other side, lowest density was recorded in 3A-Phang creek (1200 nos/m^2). Station 3D-Phang creek comprises highest wet wt (11.81 gm/m^2), whereas low at was recorded in 3A-Phang creek (0.87 gm/m^2).

Overall result of macrofaunal community showed highest population density in 2E-Cargo Jetty (400 nos/m^2) and biomass observed in 2A-Cargo Jetty (13.86 gm/m^2). Table 6 showed highest population values of Bivalves in 2E- Cargo Jetty (2800 nos/m^2) and lowest value comprised by Scaphopoda 50 nos/m^2 at 2D and 2-Control (Cargo Jetty). Optediceros breviculum (Common name Mangrove snail-Small Gastropoda shell) was only recorded at 3B and 3-Control site of Phang Creek. The Muddy habitat of Phang creek is preferred for many benthic organisms**.** This might be due to relatively stable and less polluted environment provided by muddy creek area of Phang creek further added that very low level of predation pressurs on benthic community and also might be due to lesser anthropogenic activities in that area. Table 6 showed that average population density and biomass higher in Cargo Jetty area where mostly rocky or covered with coral base providing a unique habitat for gastropod, bivalves and other benthic organisms.

Frequently found species at all sites were *Pirenella cingulata, Umbonium vestiarium, Optediceros breviculum, Tellina sp., Clypeomorus bifasciata, Cly Pholas orientalis, Dentalium sp Dosinia sp, Donax sp, Anadara sp, Turris sp etc*. The percentage of occurrence (Table 6) revealed highest group present was Gastropoda (100%), Bivalves (94.44%) then followed by Razor clam (55.55%), Scaphopoda (38.88%) and others. *Lowest percentage of occurrence by Pirenella cingulata (5.55%). Compared to three sites, lowest density and biomass was observed at Offshore area (Table 6 and Figure 29) which indicated pollution level or stressful environment, monsoon effect and also might be some chemical and biological changes in water. Detail status of Population density, Group composition and biomass of the benthic community of all selected sites were depicted in (Table 6) and (Figure 28).* In all the stations, highest percentage composition recorded by Bivalves (53%) followed by Gastropoda (23%), Razor clam (7%), *Optediceros breviculum* (5%), Scaphopoda (3%) and 1% comprises by Polychaete, Pirenella cingulata(gastropods) and Crustacean (Figure 29.). Phytoplankton abundance and their size, zooplankton Body composition, pathcy distribution of zooplankton, water currents, ebb and flow tides, and water churning process, changing in structure of muddy, rocky and sandy habitats are the main reasons for biomass and density fluctuation in Benthic cummunities. In Crustacean most commonly observed species are Crabs and attached Barnacles. Main Gastropods families recorded Trochidae, Cerithidea, Turritellidae, Mitridae and Bucciniae etc. *Nereis sp*, *Capitella sp*, *Nephtys sp*. like polychaete were observed in samples. More number of the broken bivalves, debris, plat items and broken gastropods are frequently observed in the Microscope.

Diversity indices of Benthic Community

Table 7 shows various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.444-1.547) indicated very low to near moderate diversity. Highest diversity indices was recorded in Station 3B-Phang creek (1.547) where moderate value of density and biomass of benthos and other side in 1A-Offshore diversity indices value was 0.444 where only two groups were present. The evenness values ranged between (0.634 to 0.960). The highest evenness value is 0.960 observed in station 1C-Offshore and the lowest evenness index value 0.634 was at station 2E-Cargo Jetty and where the population density was recorded highest. Simpson's Index value ranged between 0.273 to 0.776 indicated to lower to moderate diversity.

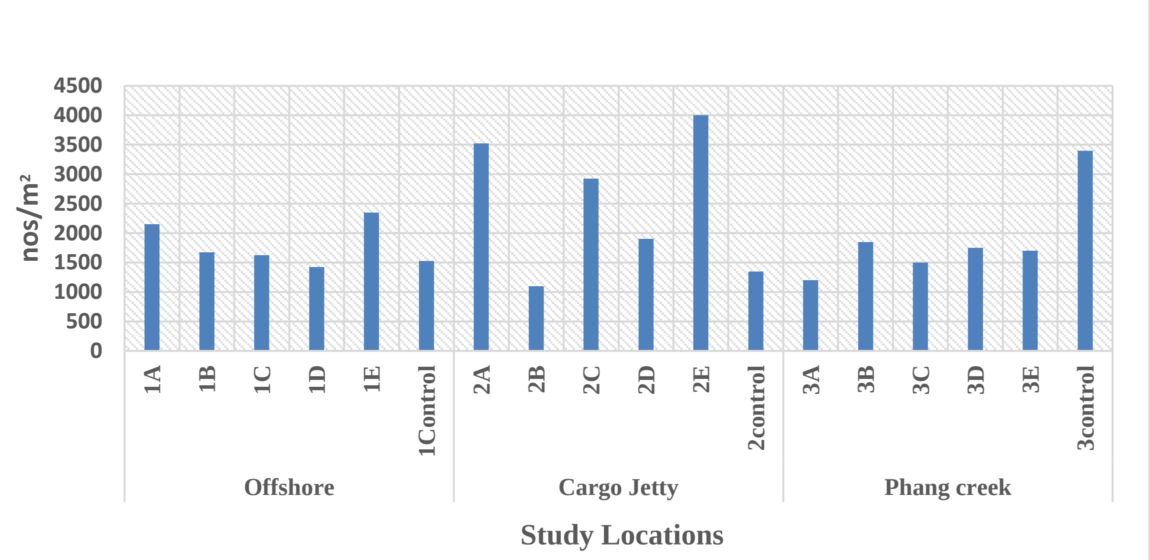

Figure 28. Population densities of Macro Benthos in various sites during Season 2

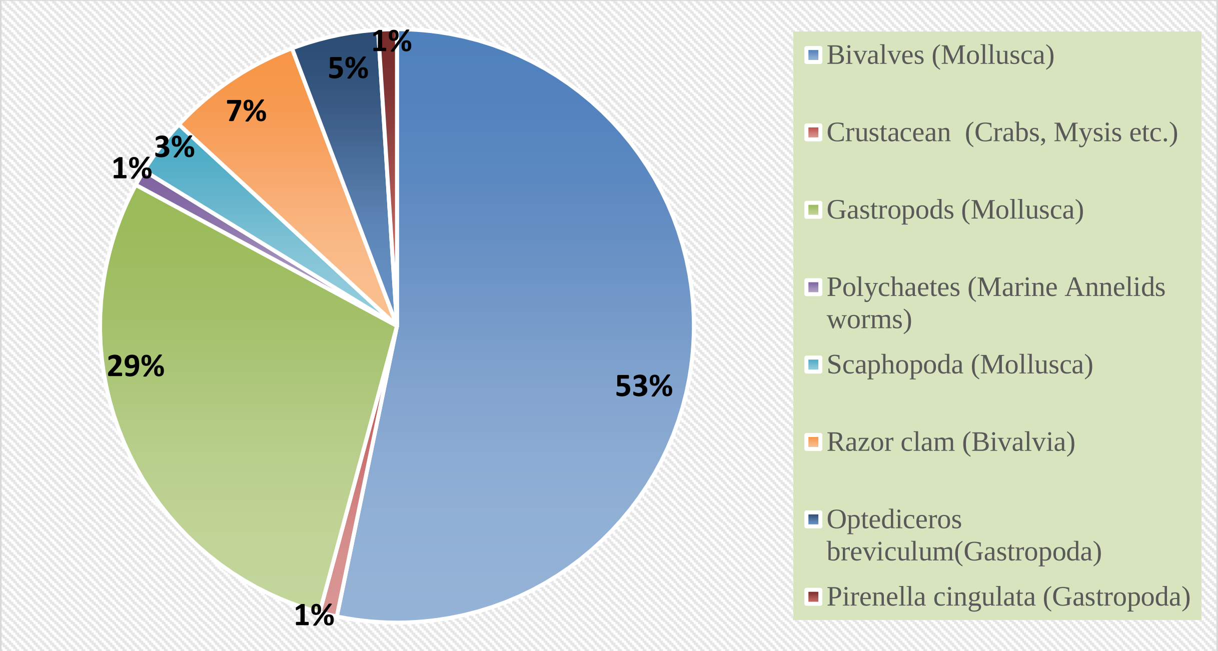

Figure 29. Percentage composition of Macrobenthos in various sites during Season 2

Table 6. Macrobenthos distribution in different sites of Deendayal Port during Season 2

Name of Station	**Offshore**						**Cargo Jetty**						**Phang creek**						**% of Occurrence**
	1A	**1B**	**1C**	**1D**	**1E**	**1-Control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Control**	
Name of Benthic Group																			
Bivalves (Mollusca)	1800	1100	725	1000	1550	1150	1925	625	1900	1100	2800	575	0	525	650	650	600	1000	94.44
Crustacean animals (Crabs, Mysis etc.)	0	0	350	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.55
Gastropoda (Mollusca)	350	425	550	425	800	375	1050	350	550	525	550	450	900	225	550	975	800	750	100
Polychaeta worms (Marine Annelids worms)	0	0	0	0	0	0	0	25	0	0	0	0	300	0	0	0	0	0	11.11
Scaphopoda (Mollusca)	0	150	0	0	0	0	225	100	225	50	350	50	0	0	0	0	0	0	38.88
Razor clam (Bivalvia)	0	0	0	0	0	0	325	0	250	225	300	275	0	225	300	125	300	400	55.55
Optediceros breviculum (Gastropoda)	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	1250	11.11
Pirenella cingulata (Gastropoda)	0	0	0	0	0	0	0	0	0	0	0	0	0	375	0	0	0	0	5.55
Total Population Density Nos/m^2	2150	1675	1625	1425	2350	1525	3525	1100	2925	1900	4000	1350	1200	1850	1500	1750	1700	3400	-
Biomass wet wt gm/m^2	**6.61**	**8.41**	**8.26**	**5.38**	**4.14**	**6.64**	**13.86**	**5.08**	**8.3**	**7.22**	**10.45**	**6.49**	**0.87**	**7.68**	**10.66**	**11.81**	**9.51**	**8.94**	**-**

Table 7: Diversity indices of benthic faunal groups at various station of Deendayal Port (Benthos) during Season 2

Variables	Offshore						Cargo Jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-Control	2A	2B	2C	2D	2E	2-Control	3A	3B	3C	3D	3E	3 - Control
Taxa_S	2	3	3	2	2	2	4	4	4	4	4	4	2	5	3	3	3	4
Individuals (Nos/m^2)	2150	1675	1625	1425	2350	1525	3525	1100	2925	1900	4000	1350	1200	1850	1500	1750	1700	3400
Dominance_D	0.727	0.504	0.360	0.581	0.551	0.629	0.400	0.433	0.471	0.426	0.522	0.335	0.625	0.224	0.362	0.454	0.377	0.284
Shannon Diversity	0.444	0.840	1.057	0.609	0.641	0.558	1.087	0.990	1.002	1.020	0.930	1.176	0.562	1.547	1.052	0.882	1.028	1.313
Simpson_1-D	0.273	0.496	0.640	0.419	0.449	0.371	0.601	0.567	0.530	0.574	0.478	0.665	0.375	0.776	0.638	0.547	0.623	0.716
Evenness	0.780	0.772	0.960	0.920	0.950	0.873	0.741	0.673	0.681	0.693	0.634	0.810	0.877	0.940	0.955	0.805	0.932	0.929
Menhinick	0.043	0.073	0.074	0.053	0.041	0.051	0.067	0.121	0.074	0.092	0.063	0.109	0.058	0.116	0.077	0.072	0.073	0.069
Margalef	0.130	0.269	0.271	0.138	0.129	0.136	0.367	0.428	0.376	0.397	0.362	0.416	0.141	0.532	0.274	0.268	0.269	0.369

3.3.3. Results on Species Composition, Population density and Biomass of Macrofauna during Season 3

Location 1 - Offshore site

Data collection was done at six sites (1A, 1B, 1C, 1D, 1E and 1- control). A Total of 5 groups(or types of benthos) of Benthic community were recorded in all stations at Offshore sites and they are Bivalves, Crustaceans, Gastropods (Mollusca), Polychaeta worms(annelida) and Razor clam (Mollusca). Data on Density and Biomass expressed in (Nos/m^2), (gm/m^2) respectively (Table 8).

Highest population density of benthic organisms were recorded in station 1B-Offshore (1075 nos/m^2), whereas no benthic diversity in station 1A-Offshore because of may be the not suitable substratum of biota. The density range of all stations varied from 0 to 1075 nos/m^2. Bivalves, Gastropoda and Polychaeta worms were more abundant among all the benthic organisms. The highest biomass value (expressed wet weight) of benthic fauna was observed in station 1B-Offshore (5.73 gm/m^2) and lowest value was 1A-Offshore (0) (Table 8).High Biomass values and also density values suggested suitable substratum for benthos and less predator pressure of higher animals.

Cargo Jetty

In Cargo Jetty, frequently observed Benthic groups were Bivalves-Gastropods than Crustacean animals and Razor clam (Bivalves). The population density range of 475 to 2425 nos/m^2 was recorded between all the stations (Cargo Jetty-2A, 2B, 2C, 2D, 2E &2-Control) during the study period. Highest and Lowest density were recorded in station 2D- Cargo Jetty(2425 nos/m^2) and 2E-Cargo Jetty (475 nos/m^2) respectively. The Biomass value indicated a highest value in station 2D- Cargo Jetty (140gm/m^2) and lowest in 2A- Cargo Jetty (4.16 gm/m^2) (Table 8). Average Biomass value of all station was 43.54 gm/m^2 which indicated the favourable environment of biota as well as suitable water quality and substratum. High density and biomass values of Bivalves and Gastropods also indicated symbiotic (or other) relation between them or with other invertebrates (Table 8 and Fig. 30 & 31).

Phang creek

Six Stations of Phang creek were selected for the study namely 3A, 3B, 3C, 3D, 3E and 3-control-Phang creek. In this Phang creek benthic organisms were represented by Bivalves, Polychaeta worms, Pirenella cingulata (Gastropoda, Mollusca) & *Optediceros breviculum* (Gastropoda, Mollusca). The population density was highest in station 3C-Phang creek (900 nos/m^2) and on the other side, lowest density was recorded in 3B-Phang creek (125 nos/m^2). Station 3E-Phang creek comprises highest wet wt (17.29 gm/m^2), whereas low at was recorded in3D-Phang creek (1 gm/m^2).

Overall result of macrofaunal community showed highest population density in 2D-Cargo Jetty (2425 nos/m^2) and same site high biomass observed (140 gm/m^2). Table 8 showed highest population values of Bivalves in 2D- Cargo Jetty (1700 nos/m^2) and lowest value comprised by other groups 25 nos/m^2 at various sites. *Optediceros breviculum* (Common name Mangrove snail-Small Gastropoda shell) and *Pirenella cingulata* were only recorded at Phang Creek because of the muddy habitat of Phang creek is preferred for many benthic organisms**.** This might be due to relatively stable and less polluted environment provided by muddy creek area of Phang creek further added that very low level of predation pressures on benthic community and also might be due to lesser anthropogenic activities in that area. Table 8 showed that average population density and biomass higher in Cargo Jetty area where mostly rocky or covered with coral base providing a unique habitat for gastropod, bivalves and other benthic organisms. In Offshore areas of sea have more water current and more numbers of higher predators might be also affected the diversity and distribution of marine biota especially benthic organisms and plankton.

In benthic communities, recorded species at all sites were Pirenella cingulata, Umbonium vestiarium, Optediceros breviculum, Tellina sp., *Clypeomorus bifasciata, Cly Pholas orientalis, Marcia sp, Dentalium sp Dosinia sp, Donax sp, Anadara sp, Turris sp, Pecten sp, Solen, Nereis sp etc. The percentage of occurrence (Table 8) revealed highest group present was Bivalves (94.44%) then followed by Gastropoda (55.55%), Polychaeta worms (38.88%) Razor clam, Optediceros breviculum and Pirenella cingulata (16.66%).* Lowest percentage of occurrence by Scaphopoda (5.55%). Compared to three sites, lowest density and biomass was observed at Offshore area and Phang creek (Table 8 and Figure 30) which indicated pollution level or stressful environment, monsoon effect and also might be some chemical and biological changes in water. Detail status of Population density, Group composition and biomass of the benthic community of all selected sites were depicted in (Table 8) and (Figure 30). In all the stations, highest percentage composition recorded by Bivalves(60%) followed by Gastropoda(21%), Crustacean animals (7%), Razor clam and Pirenella cingulata (4%), Polychaeta worms (3%), Optediceros breviculum (1%) and very less by Scaphopoda (Figure 31). Phytoplankton abundance and their size, zooplankton Body composition, patchy distribution of zooplankton, water currents, ebb and flow tides, and water churning process, changing in structure of muddy, rocky and sandy habitats are the main reasonsfor biomass and density fluctuation in Benthic cummunities. In Crustacean most commonly observed species are Crabs and attached Barnacles. Main Gastropods families recorded Trochidae, Cerithidea, Turritellidae, Mitridae and Bucciniae etc. *Nereis sp*, *Capitella sp*, *Nephtys sp*. like polychaete were observed in samples. More number of the broken bivalves, debris, plat items and broken gastropods are frequently observed in the Microscope.

Diversity indices of Benthic Community

Table 9 shows various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.00-1.22) indicated very low diversity. Highest diversity indices were recorded in Station 3E-Phang creek (1.22) where moderate value of density and biomass of benthos and other side in 1A-Offshore diversity indices value was 0 where no benthic organisms were present. The evenness values ranged between (0 to 0.98). The highest evenness value is 0.98 observed in station 3D-Phang creek and the lowest evenness index value 0 was at station 1A-Offshore and where the population density was recorded highest. Simpson's Index value ranged between 0 to 0.67 indicated to lower to very less moderate diversity (Table 9).

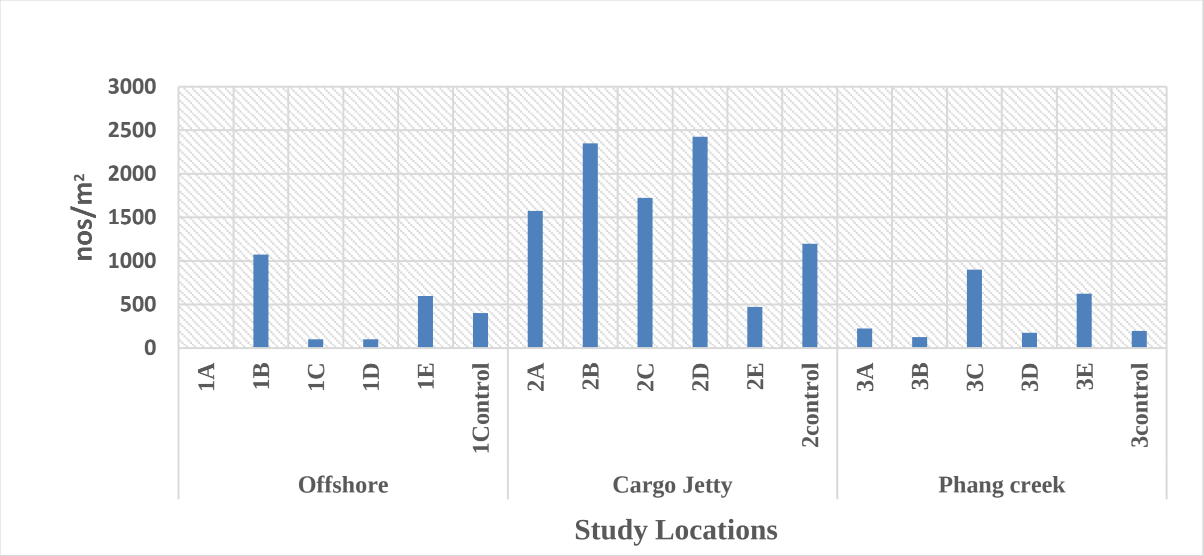

Figure 30. Population densities of Macro Benthos in various sites during Season 3

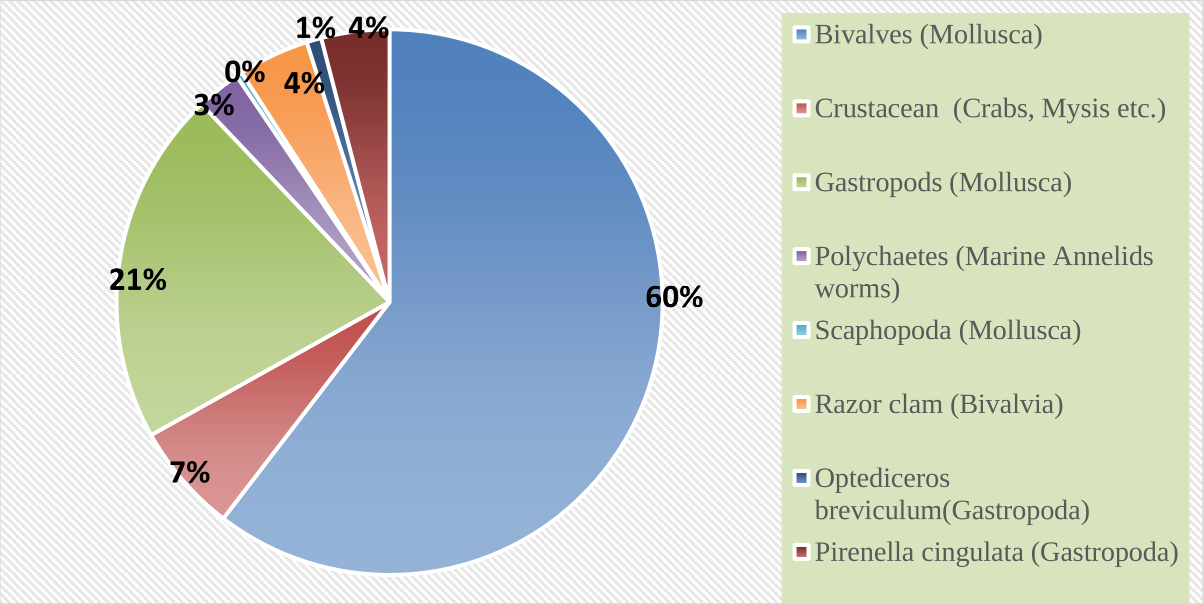

Figure 31. Percentage composition of Macrobenthos in various sites during Season 3

Table 8. Macrobenthos distribution in different sites of Deendayal Port during Season 3

Name of Station	**Offshore**						**Cargo Jetty**						**Phang creek**						**% Occurrence**
	1A	**1B**	**1C**	**1D**	**1E**	**1-Control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Control**	
Name of Benthic Group																			
Bivalves (Mollusca)	0	600	50	25	550	300	1050	1400	1300	1700	250	675	50	50	350	50	125	100	94.44
Crustacean animals (Crabs, Mysis etc.)	0	0	25	0	25	0	0	0	0	0	225	125	0	0	375	0	150	0	33.33
Gastropoda (Mollusca)	0	250	25	25	0	50	525	700	250	725	0	400	0	0	0	0	0	50	55.55
Polychaeta worms (Marine Annelids worms)	0	0	0	50	25	50	0	0	0	0	0	0	75	50	0	75	50	0	38.88
Scaphopoda (Mollusca)	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	5.55
Razor clam (Bivalvia)	0	225	0	0	0	0	0	250	125	0	0	0	0	0	0	0	0	0	16.66
Optediceros breviculum (Gastropoda)	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	50	0	50	16.66
Pirenella cingulata (Gastropoda)	0	0	0	0	0	0	0	0	0	0	0	0	100	0	175	0	300	0	16.66
Total Population Density Nos/m^2	0	1075	100	100	600	400	1575	2350	1725	2425	475	1200	225	125	900	175	625	200	94.44
Biomass wet wt gm/m^2	**0**	**5.73**	**1.64**	**1.62**	**5.12**	**4.18**	**4.16**	**98.27**	**7.13**	**140**	**5.88**	**5.81**	**3.34**	**1.78**	**5.72**	**1**	**17.29**	**1.32**	

Table 9: Diversity indices of benthic fauna at various station during Season 3

	Offshore						Cargo Jetty						Phang Creek					
Variables	**1A**	**1B**	**1C**	**1D**	**1E**	**1 control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3cont**
Taxa_S	0	3.0	3.0	3.0	3.0	3.0	2.0	3.0	4.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
Individuals (Nos/m^2)	0	1075	100	100	600	400	1575	2350	1725	2425	475	1200	225	125	900	175	625	200
Dominance_D	0	0.41	0.38	0.38	0.84	0.59	0.56	0.46	0.60	0.58	0.50	0.44	0.36	0.36	0.36	0.35	0.33	0.38
Shannon Diversity	0	0.99	1.04	1.04	0.34	0.74	0.64	0.91	0.79	0.61	0.69	0.93	1.06	1.06	1.05	1.08	1.22	1.04
Simpson_1-D	0	0.59	0.63	0.63	0.16	0.41	0.44	0.55	0.41	0.42	0.50	0.56	0.64	0.64	0.64	0.65	0.67	0.63
Evenness	0	0.90	0.94	0.94	0.47	0.70	0.94	0.83	0.55	0.92	1.00	0.84	0.96	0.96	0.95	0.98	0.85	0.94
Menhinick	0	0.09	0.30	0.30	0.12	0.15	0.05	0.06	0.10	0.04	0.09	0.09	0.20	0.27	0.10	0.23	0.16	0.21
Margalef	0	0.29	0.43	0.43	0.31	0.33	0.14	0.26	0.40	0.13	0.16	0.28	0.37	0.41	0.29	0.39	0.47	0.38

Chapter 4 Marine Water Quality (Physico-chemical)

4.1. Introduction

The coastal ecosystems harbor a rich diversity of marine flora and fauna because of their higher productivity (Saravanan et al., 2013). These ecosystems are the most precious and vulnerable environments (Jickells, 1998). Rapid urbanization and industrial growth showed a significant impact on coastal ecosystems, such as estuaries and the surrounding coastal areas. The presence of a dense human population in their watersheds contaminates the environment (Jha et al., 2015). Coastal environment reference characteristics are necessary to provide a better management solution for the coastal ecosystem (Barbier Edward et al., 2011). Hence assessing the water for various characteristics will indicate the intensity of pollutants present in such environments.

Considering the above scientific facets on the marine water quality, assessing the marine water for various characteristics will aid in understanding the magnitude of pollutants and also directly indicate the biological quality of the waters as well.

4.2. Materials and Methods

In the present study, the marine water and marine sediment samples were collected using standard protocol and analysis of the same was done following standard methods for marine water and sediment analysis as prescribed by APHA (2012), NIO manual (1982) and ICMAM Manual (2012). Surface water samples for general analysis were collected using a clean polyethylene bucket while an adequately weighted Niskin sampler was used to collect water samples from the bottom. A glass bottle sampler (1 L) was used for collecting water samples at 1 m below the surface. Parameters such as pH, Temperature, Salinity were recorded on spot using hand held meters and the same was also verified in the Laboratory. The water samples collected were stored in refrigerated conditions until further analysis of other parameters. As per the standard protocol, the fixatives and preservatives were added to the samples in case of parameters such as Dissolved Oxygen using Winkler A&B solution immediately, Chemical Oxygen Demand using concentrated H_2SO_4 to bring the <2 pH and preservation using nitric acid for heavy metals. In case of biological characteristics, the marine water samples for planktonic analysis were added with formalin. In general, all the collected water and sediment samples were stored in a sterile, polythene bottles and ziplock bags in an icebox to maintain suitable conditions till it is brought to the Laboratory. The list of parameters (Table 10) and the method adopted for the analysis of samples are detailed below.

Table 10: Physico-chemical and biological characteristics of marine water

S. No	Physico-chemical and Biological parameters
1	pH
2	Salinity (ppt)
3	Total Dissolved Solids (mg/L)
4	Total Suspended Solids (mg/L)
5	Turbidity (NTU)
6	Dissolved Oxygen (mg/L)
7	Bio-Chemical Oxygen Demand (mg/L)
8	Chemical Oxygen Demand (mg/L)
9	Phenolic compound (µg/L)
10	Petroleum Hydrocarbons (µg/L)
11	Oil and grease (mg/L)
12	Cadmium (mg/L)
13	Lead (mg/L)
14	Chromium (mg/L)
15	Copper (mg/L)
16	Cobalt (mg/L)
17	Nickel (mg/L)
18	Zinc (mg/L)
19	Magnesium (mg/L)
20	Chlorophyll (mg/m^3)
21	Phaeophytin (mg/m^3)
22	Phytoplankton Phytoplankton cell counts (no/L) Total Genera (no.) Major Genera
23	Zooplankton Biomass (ml/100m^3) Population (no/100m^3) Total Group (no.) Major Groups

4.2.1. 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.

4.2.2. Salinity

A suitable volume of the sample was titrated against silver nitrate (20 g/l) with potassium chromate as an indicator. The chlorinity is estimated and from that salinity values were derived using formula.

4.2.3. Total Dissolved Solids (TDS)

The 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). TDS values were calculated using the difference in the initial and final weight.

4.2.4. Total Suspended Solids (TSS)

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

4.2.5. Turbidity

The sample tube (Nephlometric 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 and the 40 NTU standard solution was 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 out by filling the sample tube with the sample, and the reading was noted.

4.2.6. Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

DO was determined by Winkler's method. For the determination of BOD, direct unseeded method was employed. The sample was filled in a BOD bottle in the field and incubated in the laboratory for 3 days after which DO was again determined and the difference was calculated.

4.2.7. Chemical Oxygen Demand (COD)

A known quantity of sea water was placed in a 50 ml Erlenmeyer flask and to which 3.0 g of silver sulphate was added and kept in a magnetic stirrer for proper mixing at room temperature to remove the chloride interference in the form of Silver chloride precipitate. The sample with white precipitate turned to a fade lilac mixed coloured precipitate is the indication. At this point, mixing of samples was stopped and the flasks were kept at 40˚ inclined position. Sedimentation of the coloured precipitate was very quick and 20 ml of the cleared sea water was taken carefully from the upper end of the flask bottom after a rest period of 5-10 min. To the 20ml of sea water sample diluted with 150 ml of distilled water, to which 10 ml of standard $K_2Cr_2O_7$ was added, to which 30 ml of Sulphuric acid was added. The tubes were connected to condensers and refluxed for 2 hours at 150±2^{0}C. After refluxion, the flasks were allowed to cool and titrated against Standard Ferrous Ammonium Sulphate with Ferroin as Indicator. Green blue to wine red is the indication of the end point of the experiment and a blank was run under simultaneous conditions.

4.2.8. Phenolic compounds

Phenols in water (500 ml) were converted to an orange coloured antipyrine complex by adding 4-aminoantipyrine. The complex was extracted in chloroform (25 ml) and the absorbance was measured at 460 nm using phenol as a standard.

4.2.9. Petroleum Hydrocarbons (PHc)

Water sample (1 l) was extracted with hexane and the organic layer was separated, dried over anhydrous sulphate and reduced to 10 ml at 30^{o}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^{o}C.

4.2.10. Oil and Grease

About 500 ml of sample was transferred to the separating funnel and sample bottle was carefully rinsed with 30ml of trichlorotrifluoroethane and add the solvent washings was added to the separating funnel. To this, 5ml of 1:1 HCL was added and shaken vigorously for about 2 minutes If soluble emulsion was formed, then the sample container was shaken for 5 to 10 minutes. Then the layers were allowed to separate and the lower layer (organic layer) was discarded from separating funnel. Then the solvent layer was drained through a funnel containing solvent moistened filter paper into a clean pre weight distillation flask. Then solvent was distilled from distillation flask over a water bath at 70 ^{0}C. Then the residue was transferred using minimum quantity of solvent into a clean pre weighed dried beaker and the beaker was placed on water bath for 15 minutes at 70 ^{0}C and evaporate off all the solvent and it was cooled in desiccators for 30 minutes and weight was taken.

4.2.11 Heavy metals

Heavy metals are of concern especially as it relates to the environment are Cadmium (Cd), Lead (Pb), Mercury (Hg), Chromium (Cr), Arsenic (As), Copper (Cu), Cobalt (Co), Nickel (Ni), Zinc (Zn), Magnesium (Mg) etc. For the release of mineral elements from soil and sediments, wet oxidation of samples are generally performed. Wet oxidation employs oxidizing acids (Tri / Di-acid mixtures).

Soil sample will be weighed to 0.5 gm and taken in 100ml beaker covered with a watch glass and 12 ml of Aqua regia in (1: 3 HNO3 : HCl) will be added and the beaker will be kept in digestion for 3 hours at 100^{0}c on a hot plate using sand bath and the samples will be evaporated to near dryness and the samples will be kept cool for 5 mins and then 20 ml of 2% nitric acid will be added and kept for 15 minutes in hot plate for digestion and remove from hot plate and cooled and filtered using Whatmann

No. 42 mm filter paper and then the final make up to 50 ml with 2 % nitric acid will be made. The extracted sample will be then aspirated to an AAS.

4.3. Results and Discussion

4.3.1. Physico-chemical characteristics of the marine water samples of Season 1

During the current year of study, three locations namely Offshore (Site 1), Cargo Jetty (Site 2) and Phang Creek (Site 3) were monitoring for various Physico-chemical characteristics in the marine water samples and the data is presented in Table 11-13. The description of the values recorded in each station is detailed as below.

Location 1 - Offshore location

In the 1st location Offshore, the pH values ranged between 8.11-8.15 with the average pH value of 8.13. The seawater salinity ranged with Mean±SD of 36.79±1.79. The maximum concentration of Phenolic compounds, Petroleum hydrocarbon and oil and grease concentrations were in the range of 11.06 µg/L, 77.22 µg/L and 3.60 mg/L respectively with the PHC concentration well within the prescribed limits of CPCB which is 100 mg/L. In case of major and minor elements are concerned, the concentration of Magnesium, Nickel, Lead, Cadmium, Zinc, Manganese, Cobalt was in the concentration of 1615.95 mg/L, 4.58 mg/L, 1.08 mg/L, 1.10 mg/L, 0.00, 0.52 mg/L, 0.00, 3.52 mg/L and 2.83 mg/L respectively. The metals Chromium and Copper were in the Below Detection Limits in the Offshore water samples. This was also confirmed by the Below Detection Limits observed in the same metals in the sediment samples of the same location. The data is presented in Table 11.

Location 2 - Cargo Jetty

The minimum, maximum, mean values of the pH values recorded during Season 1 in the Cargo jetty locations are 8.059, 8.164 and 8.101. The PHc concentrations recorded in the Site 2 were in the minimum of 26.77 µg/L and maximum of 35.13 µg/L with a mean PHc value of 30.508 µg/L. The Site 2 registered elevated levels of Oil and Grease concentrations to the maximum of 17.6 mg/L with the mean Oil and Grease values of 10.83 mg/L (Table 12). Similar to the first offshore location, the Phenolic compound concentrations recorded in the location 2 is also on a normal range between 2.03 - 12.52 µg/L. The mean values of the heavy metals Magnesium, Nickel, Cadmium, Zinc, Manganese and Cobalt were in the concentration of 1551.15 mg/L, 0.503 mg/L, 0.138 mg/L, 2.57 mg/L, 1.937 mg/L and 0.607 mg/L.

Location 3 - Phang Creek

The third location being Phang creek, the salinity values were in the range between 34.96 - 40.79 ppt with the mean salinity value of 37.911 ppt which is an indicative value of salinity for Gulf of Kachchh which is slightly higher than the other marine locations. Another significant characteristic of Gulf waters is that the higher turbidity which is also depicted in the water samples collected from the creek systems which showed the turbidity ranging from 56.3-91.3 NTU which is comparatively higher than the turbidity observed in the other marine waters which is the highlight of the Gulf and the Kandla being located in the tail end of Gulf of Kachchh. The petroleum hydrocarbon concentrations observed during this season was on an elevated concentration when compared to previous seasons and previous years though the concentration was within the CPCB prescribed limit of 100 µg/L. The reported PHc concentration was in the range of 54.77 - 92.9 µg/L with a mean PHc value of 78.259 µg/L. Similar to PHC, Oil and Grease concentration was also on a higher side with the maximum and mean concentration of 16.4 mg/L and 7.8 mg/L respectively (Table 13). On the basis of the maximum observed concentration of heavy metals in the Phang creek water samples, the order of occurrence of heavy metals are as follows. Magnesium > Manganese > Nickel > Cobalt > Cadmium > Zinc with their concentrations being 1794.06 > 2.565 > 0.615 > 0.33 > 2.87 > 1.885 respectively.

Table 11: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore) during Season 1

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	19.10	19.10	19.10	19.10	19.10	19.10	19.20	19.10	19.10	19.10	19.10	19.10
2	pH	8.14	8.14	8.13	8.12	8.14	8.13	8.11	8.13	8.13	8.12	8.12	8.15
3	Salinity (ppt)	34.82	35.62	35.22	34.42	39.22	35.62	38.82	38.42	35.22	37.62	37.62	38.82
4	Total Dissolved Solids (mg/L)	39291	38734	38597	38491	38961	38589	37869	38564	39397	39455	38190	39348
5	Total Suspended Solids (mg/L)	389.00	372.00	324.00	321.00	285.00	286.00	302.00	309.00	299.00	280.00	297.00	307.00
6	Turbidity (NTU)	91.10	67.10	68.30	48.90	42.30	33.00	43.90	46.20	59.30	42.60	39.10	45.90
7	Dissolved Oxygen(mg/L)	7.70	7.70	7.00	6.20	6.70	6.70	6.60	6.70	6.80	6.60	6.60	7.40
8	Bio-Chemical Oxygen Demand (mg/L)	3.90	3.50	3.50	3.30	3.90	3.30	3.20	2.70	3.10	3.00	2.80	2.90
9	Chemical Oxygen Demand (mg/L)	54	48	46	42	48	44	42	38	52	44	52	50
10	Phenolic Compounds (µg/L)	5.30	6.82	6.53	11.06	6.27	6.01	7.31	7.50	5.69	4.98	4.59	4.49
11	Petroleum Hydrocarbons (µg/L)	77.22	74.34	75.95	74.60	70.33	75.64	73.77	63.73	45.40	41.04	44.35	41.58
12	Oil and grease (mg/L)	1.20	0.80	2.40	2.40	0.40	0.80	3.60	2.40	0.80	0.40	1.20	0.40
13	Magnesium (mg/L)	1482.30	1397.25	1251.45	1397.25	1360.80	1470.15	1360.80	1129.95	1433.70	1324.35	1615.95	1579.50
14	Nickel (mg/L)	2.38	2.75	3.22	3.12	3.25	3.30	2.73	3.02	3.77	3.24	4.58	3.26
15	Lead (mg/L)	1.08	0.81	0.58	0.53	0.53	BDL	BDL	BDL	BDL	BDL	BDL	BDL
16	Cadmium (mg/L)	BDL	BDL	0.86	0.75	1.08	0.82	0.75	1.01	1.04	0.85	1.02	1.10
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	0.52	0.49	0.31	0.43	0.48	0.05	0.12	0.07	0.10	0.03	0.10	BDL
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	2.87	3.52	1.87	0.96	2.22	1.54	2.58	0.85	1.32	2.52	1.87	2.52
21	Cobalt (mg/L)	2.16	2.00	2.35	2.46	2.02	2.07	1.57	1.80	2.83	1.85	2.30	2.27

Note: BDL denotes Below Detection Limit.

Table 12: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty) during Season 1

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	19.3	19.1	19.3	19.2	19.3	19.2	19.3	19.4	19.3	19.4	19.5	19.4
2	pH	8.065	8.099	8.087	8.12	8.105	8.112	8.107	8.103	8.098	8.059	8.096	8.164
3	Salinity (ppt)	35.62	36.02	38.02	36.42	35.62	38.82	36.02	36.02	37.62	40.02	38.82	35.62
4	Total Dissolved Solids (mg/L)	39531	40163	39595	40153	39384	39909	40310	39856	39115	38859	39054	39260
5	Total Suspended Solids (mg/L)	268	253	270	260	239	238	345	354	358	272	271	344
6	Turbidity (NTU)	55.9	25	67.3	66.7	56.1	39.9	86.1	93.6	81.8	47.1	77.6	79.3
7	Dissolved Oxygen(mg/L)	6.4	6.4	6.5	6.5	6.4	6.4	6.5	6.5	6.6	6.4	6.1	6.1
8	Bio-Chemical Oxygen Demand (mg/L)	4.1	4.4	4.3	3.6	4	4.2	4.3	4.7	4.7	4.5	4.6	3.6
9	Chemical Oxygen Demand (mg/L)	44	42	56	48	42	40	38	36	34	32	48	44
10	Phenolic Compounds (µg/L)	6.11	4.5	2.9	3.59	5.76	10.67	9.67	2.03	12.52	6.14	3.2	10.93
11	Petroleum Hydrocarbons (µg/L)	31.18	35.13	30.38	32.46	29.7	29.41	32.2	30.96	31.95	27.72	28.24	26.77
12	Oil and grease (mg/L)	8.4	9.6	15.6	11.6	16	6.4	17.6	3.2	14.4	8	5.6	13.6
13	Magnesium (mg/L)	1701	1494.45	1603.8	1555.2	1518.75	1445.85	1640.25	1470.15	1482.3	1518.75	1567.35	1615.95
14	Nickel (mg/L)	BDL	BDL	BDL	BDL	0.04	0.475	0.5	BDL	BDL	BDL	BDL	0.995
15	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
16	Cadmium (mg/L)	0.03	0.035	BDL	BDL	0.21	0.355	BDL	0.09	0.045	0.2	0.105	0.17
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	2.57	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	2.35	1.87	2.11	0.89	1.58	2.24	1.75	1.56	1.48	1.25	3.58	2.58
21	Cobalt (mg/L)	BDL	0.265	0.26	BDL	0.67	0.565	0.295	BDL	BDL	0.45	1.08	1.27

Note: BDL denotes Below Detection Limit

Table 13: Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek) during Season 1

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.4	19.5	19.5	19.7	19.7
2	pH	8.101	8.121	8.147	8.142	8.147	8.125	8.132	8.114	8.092	8.059	8.048	8.037
3	Salinity (ppt)	39.54	37.46	37.46	40.79	37.88	39.12	37.04	36.63	39.12	34.96	38.72	36.21
4	Total Dissolved Solids (mg/L)	41486	41674	40893	42681	40870	41742	39829	39718	40191	40677	40311	40765
5	Total Suspended Solids (mg/L)	346	391	250	337	297	223	377	347	391	371	322	406
6	Turbidity (NTU)	91.3	90.8	91.3	89.4	65.3	56.3	87.3	85.4	71.1	67.4	87.9	85.6
7	Dissolved Oxygen(mg/L)	6.5	6.4	6.4	6.4	6.3	6.4	6.4	6.4	6.3	6.4	6.4	6.7
8	Bio-Chemical Oxygen Demand (mg/L)	3.4	3.2	3.5	3.4	3.2	3.1	3.1	3	3.3	3.1	4.1	3.8
9	Chemical Oxygen Demand (mg/L)	54	52	48	48	50	42	40	36	52	36	48	44
10	Phenolic Compounds (µg/L)	5.6	6.08	9.67	6.76	5.72	6.99	6.24	7.28	10.97	11.23	6.08	4.98
11	Petroleum Hydrocarbons (µg/L)	89.25	81.12	70.5	75.55	82.58	87.05	66.85	92.9	69.55	89.24	79.75	54.77
12	Oil and grease (mg/L)	1.2	0.8	1.6	2.8	3.6	3.6	16.4	12	16.4	8.4	13.2	13.6
13	Magnesium (mg/L)	1625.06	1572.05	1482.05	1638.06	1534.05	1456.05	1521.05	1560.06	1625.06	1794.06	1612.06	1534.05
14	Nickel (mg/L)	1.105	1.405	1.275	2.03	2.34	2.565	2.445	2.125	2.365	1.78	2.26	2.515
15	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
16	Cadmium (mg/L)	0.22	0.2	0.395	0.615	0.48	0.125	0.225	0.48	0.295	0.35	0.25	0.355
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	BDL	0.305	0.26	0.33	0.29	0.255	0.23	0.24	0.285	0.24	0.245	0.21
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	2.87	1.68	2.11	1.56	0.98	1.56	1.35	1.58	2.01	1.47	0.84	0.98
21	Cobalt (mg/L)	0.44	0.88	1.27	1.51	0.9	0.745	1.265	1.135	1.5	1.21	1.595	1.885

Note: BDL denotes Below Detection Limit

4.3.2. Physico-chemical characteristics of the marine water samples of Season 2

During the current year of study, three locations namely Offshore (Site 1), Cargo Jetty (Site 2) and Phang Creek (Site 3) were monitoring for various Physico-chemical characteristics in the marine water samples and the data is presented in Table 14-16. The description of the values recorded in each station is detailed as below.

Location 1 - Offshore location

The marine water samples in the Offshore locations revealed the pH values ranged between 7.83-8.06 with the average pH being 8.01 which was well within the prescribed limits for Coastal waters. In case of significant parameters like Phenolic compounds, Petroleum hydrocarbon and Oil & Grease, the maximum concentrations observed for the parameters are 19.55 µg/L, 21.61 µg/L and 4.0 mg/L. The data on different heavy metal concentrations observed in the sampling sites are given in Table 14.

Location 2 - Cargo Jetty

The mean pH value among the twelve samples collected in the Cargo Jetty samples are 8.037. Typical Kachchh water salinity concentrations were in the range of 39.33 - 42.79 ppt with the mean salinity of Kandla water was 40.917 ppt which is slightly higher than the salinity of any of the Indian coastal waters. Due to its tail end location, both the Turbidity and Total Suspended Solids concentrations are comparatively high in the waters with the maximum concentrations recorded as 73.59 NTU and 187.91 mg/L. The mean concentrations of Phenolic compounds, Petroleum hydrocarbon and Oil and Grease were recorded to be 13.564 µg/L, 29.290 µg/L and 1.033 mg/L. In addition to this, various toxic heavy metals were recorded which is presented in Table 15.

Location 3 - Phang Creek

In case of the creek system in DPA vicinity, Phang creek was monitored to understand the impact of disposed dredged materials as this is one the pre-designated sites. In this scenario, the pH value of the waters ranged between 8.01 - 8.1 and the mean pH value of this location is 8.055. Further, the possibility of higher load prevailing in the creek systems when compared to Offshore, the maximum concentration of Total Dissolved Solids, Total Suspended Solids and Turbidity concentrations were 43533 mg/L, 302 mg/L and 110.5 mg/L and these characteristics are indicator of a high turbidity nature of this area. Similarly, in case of major polluting parameters are concerned, the concentrations were 15.57 µg/L (Phenolic compounds), 42.38 µg/L (Petroleum hydrocarbon) and 7.2 mg/L in case of Oil and Grease. The highest concentration of Oil and Grease was found from this location. Similar to previous location metal data, the concentrations of metals recorded in the Phang creek is given in Table 16.

Table 14: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore) during Season 2

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	28.50	28.00	29.00	28.50	28.80	28.50	28.50	28.00	28.30	28.00	28.00	27.80
2	pH	8.01	8.00	8.01	8.01	7.96	7.83	8.05	8.03	8.03	8.03	8.06	8.04
3	Salinity (ppt)	40.20	36.74	34.15	38.04	36.31	37.17	34.58	36.31	37.60	35.87	38.04	35.44
4	Total Dissolved Solids (mg/L)	42368	42292	41527	42281	41219	41493	40084	40231	40759	41714	42215	42900
5	Total Suspended Solids (mg/L)	226.00	218.00	242.00	228.00	323.00	202.00	256.00	247.00	244.00	221.00	204.00	187.00
6	Turbidity (NTU)	120.10	60.10	153.90	132.90	141.30	139.20	108.20	100.80	146.70	133.60	158.10	104.50
7	Dissolved Oxygen(mg/L)	5.80	5.50	5.70	5.70	5.50	4.90	6.00	5.70	6.40	6.10	5.90	5.90
8	Bio-Chemical Oxygen Demand (mg/L)	1.30	1.20	1.60	1.00	2.30	1.80	1.10	1.10	1.70	1.40	0.90	0.90
9	Chemical Oxygen Demand (mg/L)	52	48	44	42	50	46	48	38	42	40	36	34
10	Phenolic Compounds (µg/L)	14.55	11.91	16.98	12.86	12.05	19.55	12.55	10.80	11.10	15.90	14.48	7.86
11	Petroleum Hydrocarbons (µg/L)	20.515	20.11	18.63	18.64	21.61	21.605	18.93	18.965	17.865	17.91	19.59	19.68
12	Oil and grease (mg/L)	3.20	4.00	2.80	2.80	2.00	2.00	0.80	1.20	2.80	1.60	4.00	2.80
13	Magnesium (mg/L)	1286.52	1187.56	1347.58	1287.98	1187.59	1045.89	1247.89	1148.98	1335.24	1258.47	1542.57	1422.24
14	Nickel (mg/L)	1.84	1.85	2.45	2.22	4.24	3.21	1.80	1.47	2.89	2.41	3.54	2.36
15	Lead (mg/L)	1.21	0.98	1.20	0.98	0.86	0.34	0.28	0.87	1.01	0.58	0.48	1.24
16	Cadmium (mg/L)	0.43	0.22	0.56	0.87	1.45	1.01	1.22	0.89	1.21	1.01	0.48	0.35
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	1.25	0.89	1.47	0.48	2.12	2.01	1.85	1.22	0.58	0.42	0.22	0.18
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	1.85	1.48	2.22	2.15	1.48	1.54	0.89	1.22	1.78	1.45	1.62	1.50
21	Cobalt (mg/L)	3.25	2.54	1.28	0.89	2.54	2.48	2.47	1.45	1.58	0.98	1.48	1.22

Note: BDL denotes Below Detection Limit.

Table 15: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty) during Season 2

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	29	28.5	29	28.5	28.9	28	28.7	28.5	29	28.8	29.5	29.2
2	pH	8.09	8.09	7.94	7.92	8.05	7.96	8.08	8.06	8.08	8.05	8.06	8.06
3	Salinity (ppt)	42.79	39.33	41.49	40.63	41.49	40.63	40.63	39.77	41.06	41.06	41.06	41.06
4	Total Dissolved Solids (mg/L)	41146	42035	42887	42285	41929	41658	43796	42232	41308	42098	42762	41774
5	Total Suspended Solids (mg/L)	189	172	190	174	201	189	187	174	212	192	195	180
6	Turbidity (NTU)	67	65.7	74.1	73.9	99.8	96.7	54.2	53.6	98.5	64.1	55.6	79.9
7	Dissolved Oxygen(mg/L)	6.42	5.61	5.81	5.94	5.72	5.14	5.52	5.34	5.35	5.51	5.81	5.34
8	Bio-Chemical Oxygen Demand (mg/L)	1.2	0.5	1.2	0.8	0.9	0.7	0.5	0.42	1.02	0.72	1	0.3
9	Chemical Oxygen Demand (mg/L)	42	38	44	40	52	38	34	32	44	42	38	32
10	Phenolic Compounds (µg/L)	12.77	9.7	6.74	7.82	11.98	24.19	20.6	6.24	20.74	12.99	8.11	20.89
11	Petroleum Hydrocarbons (µg/L)	30.865	30.975	29.425	29.335	27.875	27.49	32.925	33.235	26.18	26.08	29.205	27.895
12	Oil and grease (mg/L)	0.8	1.2	0.4	0.8	0.8	1.2	0.4	1.6	1.2	0.4	2.8	0.8
13	Magnesium (mg/L)	1548.25	1347.23	1258.59	11875.69	1358.47	1258.47	1547.38	1482.36	1542.82	1462	1358.68	1284.49
14	Nickel (mg/L)	0.32	0.28	0.58	0.45	1.25	0.89	1.14	0.98	1.25	0.87	0.98	0.87
15	Lead (mg/L)	0.35	BDL	BDL	0.25	0.18	BDL	0.21	0.15	BDL	0.98	BDL	BDL
16	Cadmium (mg/L)	0.02	0.03	0.07	0.05	0.18	0.09	0.54	0.24	0.05	BDL	BDL	BDL
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	0.89	0.75	1.25	1.01	1.54	1.21	0.98	0.75	1.1	0.58	1.48	1.3
19	Copper (mg/L)	0.25	BDL	0.18	0.16	BDL	0.25	0.2	BDL	0.21	BDL	0.08	BDL
20	Manganese (mg/L)	3.21	2.58	3.11	3.18	2.45	2.78	1.58	1.48	2.01	BDL	BDL	0.28
21	Cobalt (mg/L)	1.22	BDL	1.22	0.89	0.45	1.32	0.89	BDL	0.21	BDL	0.22	0.67

Note: BDL denotes Below Detection Limit

Table 16: Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek) during Season 2

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	29.2	29	28.8	28.7	28.5	28.3	29	28.8	30	29.5	28.9	28.7
2	pH	8.01	8.01	8.08	8.06	8.03	8.02	8.1	8.07	8.03	8.07	8.09	8.09
3	Salinity (ppt)	42..36	38.04	37.17	38.47	43.22	40.36	39.33	39.33	43.22	44.09	40.63	40.63
4	Total Dissolved Solids (mg/L)	40235	42246	43315	40769	42393	40806	41903	42599	41307	42128	43533	41175
5	Total Suspended Solids (mg/L)	245	221	287	262	302	274	287	268	301	289	301	278
6	Turbidity (NTU)	90	104.1	89.4	93.3	71.1	68.7	110.5	108.1	102.5	73.2	94.7	95.3
7	Dissolved Oxygen(mg/L)	5.54	5.31	5.72	5.51	5.32	5.1	5.37	5.24	5.38	5.11	5.47	5.26
8	Bio-Chemical Oxygen Demand (mg/L)	1.4	1.2	0.9	0.7	0.8	0.7	0.82	0.46	0.92	0.52	0.74	0.42
9	Chemical Oxygen Demand (mg/L)	38	32	40	34	42	36	48	40	34	32	40	36
10	Phenolic Compounds (µg/L)	12.27	13.35	15.57	14.71	11.98	15.14	13.35	15.49	5.38	10.26	12.77	10.19
11	Petroleum Hydrocarbons (µg/L)	24.93	25.07	35.14	35.325	42.285	42.38	25.38	25.44	21.875	21.85	26.005	27.325
12	Oil and grease (mg/L)	4	4.4	3.2	1.6	6.4	6	3.6	4	7.2	4.4	6.8	7.2
13	Magnesium (mg/L)	1536.65	1487.59	1325.25	1258.45	1456.25	1352.56	1478.59	1254.69	1458.87	1602.25	1458.56	1324.87
14	Nickel (mg/L)	BDL	BDL	0.85	0.48	1.22	0.25	1.02	0.89	1.21	0.22	0.45	1.12
15	Lead (mg/L)	0.03	BDL	0.52	0.42	BDL	BDL	BDL	BDL	0.24	0.32	BDL	BDL
16	Cadmium (mg/L)	0.18	0.11	0.25	0.45	0.36	0.34	0.48	0.35	0.48	0.35	BDL	0.25
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	0.35	0.28	0.48	0.32	1.28	0.65	1.04	0.75	0.46	0.57	0.32	0.25
19	Copper (mg/L)	0.32	0.18	BDL	0.24	0.62	0.21	BDL	0.58	0.4	0.08	0.2	0.34
20	Manganese (mg/L)	3.24	1.18	2.25	1.14	3.78	1.25	1.54	2.54	2.35	3.58	2.78	1.58
21	Cobalt (mg/L)	1.32	1.21	1.65	2.58	2.58	1.36	1.36	1.54	2.14	2.87	1.56	0.89

Note: BDL denotes Below Detection Limit

4.3.3. Physico-chemical characteristics of the marine water samples of Season 3

During the current year of study, three locations namely Offshore (Site 1), Cargo Jetty (Site 2) and Phang Creek (Site 3) were monitoring for various Physico-chemical characteristics in the marine water samples and the data is presented in Table 17-19. The description of the values recorded in each station is detailed as below.

Location 1 - Offshore location

The pH of the samples ranged between 7.80 - 7.96. In case of Phenolic compounds and Petroleum hydrocarbon the concentrations were in the range of 7.80 µg/L - 18.77 µg/L and 1.49-12.43 µg/L respectively. The concentrations of PHC was well within the limits as prescribed by CPCB which is 100 µg/L. The oil and grease concentration ranged between 0.80 - 6.40 mg/L which is also within the limits of 10 mg/L as per GPCB norms. The maximum concentration of heavy metals recorded were 312.65 mg/L, 0.43 mg/L, 2.86 mg/L, 0.43 mg/L, BDL, 0.33 mg/L, BDL, 3.89 mg/L, 0.41 mg/L for the metals such as Magnesium, Nickel, Lead, Cadmium, Chromium, Zinc, Copper, Manganese, Cobalt as shown in Table 17.

Location 2 - Cargo Jetty

In case of Cargo Jetty location, the mean pH value of 7.97±0.04 was observed. The maximum Dissolved Oxygen, Biochemical Oxygen Demand and Chemical oxygen demand was in the order of 7.50 mg/L, 2.60 mg/L and 52.0 mg/L during Season 3 (Table 18). The mean concentration of Phenolic compounds and Petroleum hydrocarbon was in the range of 10.68-1.75 µg/L and 1.50-0.13 µg/L which was again within the permissible limits of CPCB (100 µg/L). The mean value of metal concentrations of Magnesium, Lead, Cadmium, Zinc, and Manganese were in the order 244.47 mg/L, 3.69 mg/L, 0.36 mg/L, 0.51 mg/L and 2.53 mg/L. Metals such as Nickel, Chromium, Copper and Cobalt were not found in the samples at mg/L concentrations.

Location 3 - Phang Creek

In case of the creek systems of the port vicinity, the mean concentration of pH was recorded as 7.87±0.04, salinity values were of 33.11±3.08 ppt and the total dissolved concentrations which is a indicative of various anions and cations was in the average value of 36502.92±894.11 mg/L. In case of pollution indices such as Dissolved Oxygen, Biochemical

Oxygen Demand, Chemical Oxygen Demand, Phenolic compounds , Petroleum hydrocarbon, Oil and grease concentrations, the maximum concentration was observed to be 6.50 mg/L, 3.50 mg/L, 54.0 mg/L, 14.53 µg/L, 3.58 µg/L and 4.40 mg/L and except Biochemical Oxygen Demand, all the parameters are well within the limits prescribed by CPCB for marine waters. The minimum, maximum and mean concentrations of all the analysed heavy metals are given in Table 19.

Table 17: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore) during Season 3

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	32.00	31.50	32.00	31.50	32.30	32.00	33.20	33.00	33.50	33.00	33.00	32.80
2	pH	7.86	7.80	7.92	7.92	7.94	7.83	7.95	7.92	7.88	7.96	7.96	7.96
3	Salinity (ppt)	34.92	36.19	34.07	35.34	34.07	36.19	35.77	40.45	36.62	37.47	40.45	35.34
4	Total Dissolved Solids (mg/L)	36554	38624	38784	37382	37915	37742	38229	37022	37211	37889	38182	37880
5	Total Suspended Solids (mg/L)	212.00	245.00	202.00	242.00	189.00	176.00	224.00	198.00	187.00	198.00	188.00	172.00
6	Turbidity (NTU)	27.1	47.6	23.2	69.8	40.5	57.8	31.1	94.5	30.1	38	62.2	22.2
7	Dissolved Oxygen(mg/L)	6.70	8.60	6.60	6.30	6.80	6.50	7.00	6.80	6.60	6.80	6.80	7.00
8	Bio-Chemical Oxygen Demand (mg/L)	2.40	3.10	1.00	0.80	1.20	1.60	1.80	0.90	1.40	1.40	1.10	1.40
9	Chemical Oxygen Demand (mg/L)	52	48	44	42	44	44	50	46	48	42	38	38
10	Phenolic Compounds (µg/L)	18.770	15.770	7.800	11.610	11.610	13.730	9.050	11.020	10.440	11.020	16.940	9.490
11	Petroleum Hydrocarbons (µg/L)	12.430	2.814	2.671	2.726	2.043	1.879	1.762	1.677	1.963	1.488	1.731	1.533
12	Oil and grease (mg/L)	6.0	4.4	6.4	3.6	2.4	1.6	1.6	2.0	1.2	3.2	1.2	0.8
13	Magnesium (mg/L)	145.25	258.4	202.65	275.1	302.85	303.5	281.5	312.65	234.5	246.5	311.85	297.15
14	Nickel (mg/L)	BDL	0.01	0.43	BDL	0.16	0.42	BDL	BDL	BDL	BDL	BDL	BDL
15	Lead (mg/L)	0.41	0.78	1.05	0.71	1.76	1.95	1.69	2.37	2.08	2.26	2.55	2.86
16	Cadmium (mg/L)	0.22	0.30	0.29	0.09	0.43	0.27	0.24	0.40	0.33	0.24	0.21	0.16
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	0.19	0.15	0.24	0.06	0.29	0.24	0.15	0.33	0.23	0.21	0.20	0.16
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	2.28	2.56	3.12	2.98	2.54	1.58	3.12	3.89	2.56	2.89	1.87	1.56
21	Cobalt (mg/L)	0.14	0.31	0.24	BDL	0.41	BDL	BDL	0.24	BDL	0.32	0.00	0.15

Note: BDL denotes Below Detection Limit.

Table 18: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty) during Season 3

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	32	31.8	32	31.8	32	31.8	33.5	33	33.2	33	33.5	33.2
2	pH	7.91	7.91	7.92	7.92	7.98	7.98	8.01	7.99	8	7.99	8.01	7.98
3	Salinity (ppt)	37.05	37.47	34.49	38.32	34.92	36.62	34.49	34.07	34.07	36.19	34.49	36.19
4	Total Dissolved Solids (mg/L)	39225	38898	38101	38679	39194	37824	39268	38635	39347	30399	38163	38212
5	Total Suspended Solids (mg/L)	228	214	386	289	267	254	248	226	308	298	221	188
6	Turbidity (NTU)	32.2	28.1	44	15.8	61.7	14.7	17.8	28.8	35.7	30.8	45.1	42.3
7	Dissolved Oxygen(mg/L)	5.9	5.8	7.5	6.5	6.3	5.7	7.5	6	6.7	6.1	6.2	7
8	Bio-Chemical Oxygen Demand (mg/L)	1	1.1	2.6	1.2	1.5	0.4	2.2	1.7	1.5	1.4	1	2
9	Chemical Oxygen Demand (mg/L)	42.00	36.00	48.00	52.00	50.00	44.00	38.00	42.00	52.00	38.00	44.00	42.00
10	Phenolic Compounds (µg/L)	12.78	11.54	10.95	10.15	13.22	10.08	10.08	9.34	9.34	8.54	13.58	8.54
11	Petroleum Hydrocarbons (µg/L)	1.586	1.607	1.538	1.797	1.537	1.527	1.410	1.430	1.525	1.350	1.405	1.310
12	Oil and grease (mg/L)	1.2	1.2	2	2.4	5.6	5.2	5.6	6	2	1.6	2	1.2
13	Magnesium (mg/L)	290.6	262.9	265.45	175.45	217.2	326.35	160.65	328.25	240.25	198.95	188.8	278.75
14	Nickel (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Lead (mg/L)	2.75	3.14	2.935	3.265	3.09	3.205	3.635	4.125	4.165	4.44	4.835	4.72
16	Cadmium (mg/L)	0.39	0.345	0.22	0.06	0.4	0.2	0.375	0.445	0.56	0.53	0.51	0.325
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	4.37	0.175	0.17	0.36	0.11	0.065	0.065	0.205	0.245	0.07	0.15	0.16
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	1.28	1.89	2.58	2.87	3.54	3.89	2.87	2.54	1.87	2.02	2.22	2.75
21	Cobalt (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit

Table 19 Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek) during Season 3

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	31.5	31	31	30.9	31.5	31	32	31.8	32	31.8	32.5	32
2	pH	7.78	7.8	7.85	7.86	7.91	7.89	7.9	7.89	7.87	7.89	7.92	7.91
3	Salinity (ppt)	33.03	31.75	32.61	31.32	30.89	29.6	33.03	33.89	42.05	32.18	33.46	33.46
4	Total Dissolved Solids (mg/L)	36000	36355	35768	35120	36379	36886	36723	38106	36154	35707	38072	36765
5	Total Suspended Solids (mg/L)	287.00	256.00	225.00	218.00	306.00	287.00	248.00	223.00	308.00	298.00	312.00	298.00
6	Turbidity (NTU)	131.8	137.8	134.1	131.9	129.2	151.6	125.2	127.7	116.7	105.1	108.6	98.1
7	Dissolved Oxygen(mg/L)	6.5	6	5.8	5.6	5.6	5.7	5.5	5.8	6	6.3	5.7	5.8
8	Bio-Chemical Oxygen Demand (mg/L)	3.5	1.6	1.1	1.6	0.3	0.7	0.7	1.3	1.1	1.2	0.9	0.7
9	Chemical Oxygen Demand (mg/L)	54.00	52.00	48.00	40.00	42.00	40.00	38.00	36.00	50.00	36.00	48.00	42.00
10	Phenolic Compounds (µg/L)	11.97	14.17	11.32	12.19	14.17	14.53	12.19	11.1	11.32	12.78	11.32	9.27
11	Petroleum Hydrocarbons (µg/L)	3.583	1.609	1.275	1.702	1.489	1.370	1.543	1.605	1.235	1.235	1.430	1.497
12	Oil and grease (mg/L)	4.0	3.6	4.4	4.4	2.4	2.8	1.6	3.2	2.4	2.8	2.8	3.2
13	Magnesium (mg/L)	204.4	218.9	273.5	111.2	239.35	202.75	270.55	238.5	286.7	260.3	174.45	300.55
14	Nickel (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Lead (mg/L)	4.295	4.655	4.005	4.91	4.7	4.66	5.13	5.38	5.055	5.31	5.42	5.48
16	Cadmium (mg/L)	BDL	0.53	0.25	BDL	0.18	0.39	0.015	0.395	0.23	0.095	0.155	0.035
17	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Zinc (mg/L)	0.495	0.155	0.08	0.175	0.11	4.535	0.285	0.17	0.065	0.12	0.13	0.155
19	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20	Manganese (mg/L)	2.74	2.87	1.89	1.57	2.21	2.87	3.58	3.75	2.85	2.74	3.02	2.86
21	Cobalt (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit

Table 20: Comparison of the mean physico-chemical characteristics of the present study (2021-22) water data with the data of 2019-2020 and 2020-2021

Parameters	Period of study (in year)								
	2019-2020			2020-2021			2021-2022 (Present study)		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Temperature	23.76	23.29	19.50	25.18	24.20	25.47	19.31389	28.69167	32.21
pH	8.01	7.99	7.88	8.12	8.11	8.22	8.112056	8.032333	7.92
Salinity (ppt)	35.90	36.10	32.01	36.37	37.88	38.20	37.25028	39.34301	35.07
Total Dissolved Solids (mg/l)	41426.58	42141.50	42105.42	39443.36	40146.57	43872.58	39764.22	41872.28	37427.61
Total Suspended Solids (mg/l)	362.42	493.08	611.58	197.53	324.97	302.67	313.9167	232.4444	245.17
Turbidity (NTU)	304.33	376.67	398.33	33.37	78.86	58.86	65.92222	96.76111	67.75
Dissolved Oxygen (mg/l)	5.80	5.36	5.59	6.04	5.97	4.81	6.569444	5.581667	6.39
Bio-Chemical Oxygen Demand (mg/l)	1.15	0.65	0.56	1.32	1.05	0.55	3.619444	0.976111	1.40
Chemical Oxygen Demand (mg/l)	44.00	46.50	49.00	27.44	29.50	28.50	44.83333	40.22222	44.17
Phenolic Compounds (mg/l)	1.04	0.86	1.06	9.21	12.13	7.77	6.726944	13.16167	11.71
Petroleum Hydrocarbons (µg/L)	2.48	2.64	4.61	12.47	13.89	30.52	57.30972	26.07056	2.01
Oil and grease (mg/l)	4.77	5.33	6.37	5.94	3.98	2.76	6.677778	2.811111	3.00
Magnesium(mg/l)	1484.67	1513.57	1366.87	1997.45	1948.53	3153.30	1510.303	1656.042	246.85
Nickel (mg/l)	1.46	1.75	2.58	0.60	0.50	BDL	1.912222	1.372	0.08
Lead (mg/l)	1.01	BDL	BDL	2.11	3.22	7.26	0.701	0.498389	3.44
Cadmium (mg/l)	0.27	0.28	0.46	0.08	0.04	BDL	0.465593	0.425572	0.28
Chromium (mg/l)	BDL	BDL	BDL	0.29	0.68	BDL	0	0	0.00
Zinc (mg/l)	0.27	0.41	0.37	0.22	0.17	0.13	1.025606	0.896667	0.42
Copper (mg/l)	0.01	BDL	0.01	0.03	0.04	BDL	0	0.169	0.00
Cobalt (mg/l)	0.90	0.61	1.26	0.47	0.14	BDL	1.31	1.46	0.07

Note: BDL denotes Below Detection Limit.

During the present study is comparison of physico-chemical parameters in seawater during 2019-2020, 2020-2021 and the present study, i.e. 2021-2022 in three different stations (Offshore, Phang creek and Cargo jetties) from Kandla region as shown in Table 20.

Chapter 5 Marine Water Quality (Biological) -Phytoplankton

5.1. Introduction

“Planet Earth is dominated by the seas”. One of the most important natural resources that cover much of the earth’s surface is Ocean. First life on earth originated in the oceans. Ocean means continuous body of water and mixing of water. Mixing is the key dynamic character of the ocean. This dynamic character creates currents and exchanges between cold, deep waters and warmer surface waters. Intertidal, subtidal and basin are three main components of see zonation pattern (Davis, 1977).

The 3rd largest ocean of the world is the Indian Ocean. India forms a peninsula surrounded by the Arabian Sea in the west, the Bay of Bengal in the east and the main Indian Ocean in the south. Due to its seasonal weather fluctuations, Arabian Sea is well known for its biological adaptation to environment. Gujarat, western most state of India is part of Arabian Sea. Among all maritime states of India Gujarat has longest coastline of approximately 1600 km. Gujarat coasts having different coastal ecosystems like mangrove, sandy shores, muddy shores, rocky shores, mixed shores, wet sand shore, coral reefs and intertidal mudflats (Brink, 1993; Parasharya and Patel, 2014). Gujarat state is the only state in India bestowed with two gulfs, Gulf of Kachchh and Gulf of Khambhat. The Kachchh second largest district of the country with an area of 45,652 sq.km. Deendayal Port Authority (DPA) one among the 12 major ports of the country and it is located India’s western coastal area. It is also called Kandla Port very near to two famous cities of Gujarat state are Bhuj and Gandhidham. It is a largest Creek based Ports in the country.

Plankton denotes a group of organisms either animals (zooplankton) or plants (phytoplankton). Main phytoplankton in sea water are Diatoms (Tiwari and Nair, 1998; Thakur et al, 2015; Ceaumori et al. 2018), Cocolithophores, Sillicoflagellates, Blue green algae (Cynobacteria) and Dinoflagellates. Diatoms constitute the major part of the phytoplankton in sea water. Zooplankton comprises the second level in the food chain and includes Tintinnids, Foramonifers, Radiolarians, Amphipoda, Copepoda, Calanoida, Chaetognaths, larvae of benthic invertebrates and fish larvae etc. (Gajbhiye and Abidi, 1993; Thirunavukkarosu, 2013; Chakrabarty et al. 2017). The planktonic stages of invertebrates are economically important as a food for pelagic fishes. Zooplankton require a constant supply of oxygen (Dodson, 1992).

Diatoms occur both in the sea water and fresh water as well as in sediment. Marine diatoms are mostly Centric diatoms (Moura et al. 2007). Diatoms are most abundant around 50 meters below the sea surface and are more abundant in the cold waters of high latitudes. Diatoms are divided into two main types based on their shape- the Centric diatoms or Centrales, and the Pennate diatoms or Pennales (Tabassum, 2012). Dinoflagellates have plant like mechanisms such as photosynthetic activity, storage of energy (by synthesis of carbohydrates) etc. The Cyst-forming Dinoflagellates mostly occurred in all marine habitat. They are most primitive eukaryotes. Sometime some Dinoflagellates responsible for Harmful Algal Blooms in sea which causes death of fishes in large numbers. Algal bloom means rapid multiplication of dinoflagellates cells.

The zooplankton may be classified according to their habitat and depth, distribution, size and duration of planktonic life period (Omori and lkeda, 1984). There are the two main classification on base of habitat Marine plankton or Haliplankton and Freshwater plankton or Limnoplankton. Marine plankton further divided in to 3 types' ocean plankton, neritic plankton and brackish water plankton. Oceanic plankton or Off-shore plankton generally found in surface water & continental shelf region water whereas neritic zooplankton means occurring to continental zone to neritic or deep sea (Besiktepe et al, 2015). Brackish water plankton generally inhabiting brackish water like mangrove, estuaries and sea vegetation area.

The factor of size is very important to understanding the classification of both zooplankton and phytoplankton. Based on size various categories of plankton are nanoplankton (2-20 μm), microplankton (20-200 μm), mesoplankton (200 μm-2 mm), macroplankton (2-20 cm), megaplankton (> 20 mm), nanoplankton (2-20 μm) and smallest one is picoplankton (0.2-2 μm).

Understanding of diversity and distribution of marine organisms would not be complete without consideration of abiotic and biotic factors of marine environment. Amongst the various abiotic factors affecting the survival of marine invertebrates in coastal and estuarine regions, salinity and temperature are of primary importance (Rao and Balasubramanian, 1996; Sreenivasulu et al, 2017). Planktons are affected by changes in biotic & abiotic factors of environment and can rapidly respond to climatic changes. Phytoplankton are primary producers of sea whereas as a primary consumers zooplankton play precious role to control the primary producers in sea. Benthic organisms and Higher vertebrate animals use plankton as a food material in Ocean life. Zooplankton and Phytoplankton are main prey food source for different Fishes. The main food items of Mesopelagic fishes are zooplankton larvae, juvenile fish and many small invertebrate animals.

Population always either stable or fluctuating, depends on environment and economical condition surrounding it (Taylor, 1988; Garzke et al. 2017). Population of plankton and other marine living organisms on which the whole aquatic life depends directly or indirectly is largely governed by the interaction of a number of biological, chemical and physical processes and tolerance to one or more of these conditions (Reid and Wood 1976). The population of plankton diversity largely related Seasonal and Monthly variability in Physical, Chemical and Biological parameters; Interspecific competition among the Zooplankton; Inter-relationship for prey and predator between zooplankton and their mostly predator animals; Grazing ratio of Zooplankton; Suspension of sediment; Fluctuation in Phytoplankton abundance; Waves, Currents and Tidal turbulence effect; Fluctuation in Chlorophyll a and Nutrients; Input of Organic and other Pollution creating sources; Fish potential ratio; Monsoon effect; Suddenly changes in atmosphere; Peak time of every seasons and it's effect; Vertical migration of Zooplankton; Food selection pattern of predator; Collection time and number of collected samples, mixing of water column, high surf action, Seasonal upwelling and downwelling in water column. Sometimes it is observed that effect of one variable is not similar to another factor or variable. Above all factors are affected population of Plankton either by directly or indirectly.

5.2. Estimation of Chlorophyll and Phaeophytin

Phytoplankton (Chlorophyll a) pigment which is responsible for synthesizing the energy for metabolic activities of phytoplankton through the process of photosynthesis in CO_2 is used and O_2 is released is an essential part to understand the consequence of pollutants due to release in the system. To estimate this, 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 phaeophytin the fluorescence of the acetone extract was measured using Fluorometer (Turner Design) before and after treatment with dilute acid (0.1N HCL).

5.3. Results

5.3.1. Chlorophyll and Phaeophytin concentration during Season 1

The concentration of phytopigments are directly proportional to the turbidity of the waters and in general, Kandla waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.11 to 0.53 mg/m3 with a mean ± SD being 0.36±0.16 mg/m^3 in the Offshore (Table 21), 0.119 to 0.399 mg/m3 with mean ± SD of 0.259±0.072 mg/m3 in the Cargo Jetty (Table 22) and 0.221 to 0.517 mg/m3 with mean ± SD being 0.351±0.111mg/m3 in the Phang creek location (Table 23). Phaeophytin is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.10 – 0.41 mg/m3 with a Mean±SD of 0.25±0.1 mg/m^3 in the Offshore location. In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.11 – 0.342 mg/m^3 with a Mean±SD of 0.196±0.075 mg/m^3 and in case of the creek location, the concentration of phaeophytin was still low compared to the Offshore location with values ranging between 0.121 – 0.278 mg/m^3 with a Mean±SD of 0.209±0.051mg/m^3 (Table 21). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 21: Chlorophyll and Phaeophytin concentration observed in the Offshore site during Season 1

Parameters	1A		1B		1C		1D		1E		1 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.45	0.44	0.51	0.51	0.45	0.28	0.11	0.12	0.53	0.19	0.34	BDL
Phaeophytin	0.21	0.28	0.17	0.35	0.41	0.20	BDL	BDL	0.28	BDL	0.10	BDL

Table 22: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site during Season 1

Parameters	2A		2B		2C		2D		2E		2 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.280	0.245	0.311	0.119	0.229	0.221	0.290	0.190	0.288	0.399	0.280	BDL
Phaeophytin	0.116	0.170	0.285	0.164	0.280	0.185	0.204	0.110	0.160	0.142	0.342	BDL

Table 23: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site during Season 1

Parameters	3A		3B		3C		3D		3E		3 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.483	0.466	0.517	0.411	0.442	0.279	0.221	0.352	0.221	0.354	0.229	0.242
Phaeophytin	0.278	0.211	0.178	0.257	0.254	0.244	BDL	0.121	BDL	0.212	0.186	0.148

5.3.2. Chlorophyll and Phaeophytin concentration during Season 2

The concentration of phytopigments are directly proportional to the turbidity of the waters and in general, Kandla waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.31-1.31 mg/m^3 with a mean ± SD being 0.60±0.28 mg/m^3 in the Offshore (Table 24), 0.17 to 0.52 mg/m^3 with mean ± SD of 0.356±0.098 mg/m^3 in the Cargo Jetty (Table 25) and 0.21 to 0.75 mg/m^3 with mean ± SD being 0.391±0.149 mg/m^3 in the Phang creek location (Table 26).

The another phytopigment estimated was Phaeophytin, which is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.19 – 0.73 mg/m3 with a Mean±SD of 0.35±0.16 mg/m^3 in the Offshore location. In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.11 – 0.41 mg/m^3 with a Mean±SD of 0.256±0.082 mg/m^3 and in case of the creek location, the concentration of phaeophytin was almost similar when compared to the other two locations and was ranging between 0.18 – 0.51 mg/m^3 with a Mean±SD of 0.306±0.111 mg/m^3 (Table 26). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 24: Chlorophyll and Phaeophytin concentration observed in the Offshore site during Season 2

Parameters	1A		1B		1C		1D		1E		1 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	1.31	0.67	0.81	0.61	0.66	0.36	0.66	0.4	0.31	0.35	0.35	0.67
Phaeophytin	0.41	0.28	0.73	0.56	0.21	0.31	0.19	0.21	0.28	0.27	0.29	0.47

Table 25: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site during Season 2

Parameters	2A		2B		2C		2D		2E		2 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.45	0.17	0.33	0.35	0.35	0.27	0.52	0.35	0.32	0.51	0.35	0.3
Phaeophytin	0.34	0.11	0.27	0.27	0.27	0.18	0.41	0.22	0.19	0.32	0.3	0.19

Table 26: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site during Season 2

Parameters	3A		3B		3C		3D		3E		3 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.36	0.22	0.37	0.42	0.58	0.36	0.3	0.21	0.31	0.39	0.75	0.42
Phaeophytin	0.21	0.2	0.21	0.34	0.5	0.32	0.27	0.18	0.28	0.27	0.51	0.38

5.3.3. Chlorophyll and Phaeophytin concentration during Season 3

The concentration of phytopigments are directly proportional to the turbidity of the waters and in general, Kandla waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.48-1.01 mg/m^3 with a mean ± SD being 0.72±0.15 mg/m^3 in the Offshore (Table 27), 0.22 to 0.82 mg/m^3 with mean ± SD of 0.53±0.19 mg/m^3 in the Cargo Jetty (Table 28) and 0.32 to 0.84 mg/m^3 with mean ± SD being 0.61±0.17 mg/m^3 in the Phang creek location (Table 29).

Another phytopigment estimated was Phaeophytin, which is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.13 – 0.52 mg/m^3 with a Mean±SD of 0.30±0.12 mg/m^3 in the Offshore location (Table 27). In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.11 – 0.31 mg/m^3 with a Mean±SD of 0.21±0.07 mg/m^3 (Table 28) and in case of the creek location, the concentration of phaeophytin was almost similar when compared to the other two locations and was ranging between 0.12 – 0.60 mg/m^3 with a Mean±SD of 0.36±0.17 mg/m^3 (Table 29). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 27: Chlorophyll and Phaeophytin concentration observed in the Offshore site during Season 3

Parameters	1A		1B		1C		1D		1E		1 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.830	0.720	1.010	0.640	0.720	0.480	0.680	0.650	0.590	0.660	0.710	0.950
Phaeophytin	0.460	0.520	0.330	0.130	0.220	0.310	0.280	0.130	0.360	0.320	BDL	0.210

Table 28: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site during Season 3

Parameters	2A		2B		2C		2D		2E		2 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.460	0.420	0.630	0.730	0.480	0.670	0.780	0.220	0.360	0.319	0.821	0.494
Phaeophytin	0.280	0.170	BDL	0.180	0.110	0.310	0.210	BDL	0.130	0.120	0.270	0.280

Table 29: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site during Season 3

Parameters	3A		3B		3C		3D		3E		3 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.460	0.520	0.620	0.400	0.540	0.820	0.320	0.630	0.630	0.740	0.830	0.840
Phaeophytin	0.120	0.160	0.520	0.490	0.410	0.590	0.220	0.430	0.300	0.230	0.600	0.230

Table 30: Comparison of the mean chlorophyll and phaeophytin concentrations in the present study (2021-22) and the previous year data (2019-2020 and 2020-21)

Parameters	Period of study (in year)								
	2019-2020			2020-2021			2021-2022 (Present study)		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Chlorophyll mg/m^3	0.48	0.55	0.28	0.68	0.61	0.75	0.32	0.45	0.62
Phaeophytin mg/m^3	5.99	BDL	0.12	2.07	1.88	11.53	0.22	0.30	0.29

Comparison of the mean value of biological parameters such as chlorophyll and phaeophytin level varied from 0.28-0.55mg/m^3 and BDL-5.99 mg/m^3 during (2019-2020) and 0.61-0.75 mg/m^3 and 1.88-11.53 mg/m^3 during (2020-2021) and 0.32 – 0.62 mg/m^3 in case of Chlorophyll and 0.22-0.30 mg/m^3 in case of Phaeophytin. In the present study, there was a slight decrease in Chlorophyll concentration in Station 1 and Station 2, whereas the Station 3 had a higher mean average of Chlorophyll when compared to the previous years. In case of Pheophytin, the concentration was ranging from BDL – 5.99 in case of 2019-2020, in case of 2020-2021, the concentration was between 1.88 – 11.53 mg/m3, whereas 0.22-0.30 mg/m3 was observed in the present study which showed a decrease in the phaeophytin concentration when compared with the previous years at all the stations as shown in (Table 30).

5.4. Phytoplankton sampling and analysis

Phytoplankton samples were collected in the ten prefixed sampling sites using standard plankton net with a mesh size of 51 µm. Plankton nets are with a square mouth covering an area of 0.900 cm^2 (30cm square mouth) fitted with a flow meter (Hydrobios). Nets were towed from a moving boat for 10 minutes and the plankton adhering to the net was concentrated in the net bucket. Plankton soup from the net bucket was transferred to a pre-cleaned and rinsed container and preserved with 5% neutralized formaldehyde. The containers were appropriately labelled. The initial and final flow meter reading was noted down for calculating the amount of water filtered to estimate plankton density. As per flow meter reading, a total amount of 165 m^3 of water was filtered by the net. One liter of water was separately collected for density estimation to counter check density estimation obtained by the flow meter reading. Quantitative analysis of phytoplankton (cell count) was carried out using a sedge wick-Rafter counting chamber. One ml of soup added to a Sedgwick counting chamber was observed under an inverted compound microscope. The number of cells present in individual cells of the counting chambers (1/1000) was noted and identified up to a generic level. Several observations were fixed to represent the entire quantity of the soup (generally more than30 times) and the recorded data were used to calculate the density(No/l) using the formula,N = n×v/V (where N is the total no/l; n is an average number of cells in 1 ml; v is the volume of concentrate; V is the total volume of water filtered). The phytoplankton diversity richness and evenness were past software.

5.4.1. Phytoplankton community structure recorded during Season 1

The study was conducted at 3 sites (or regions) of Kandla Port and near area where dredging activities is going on. Namely three selected study stations are Offshore, Cargo Jetty and Phang Greek.

Location 1 - Offshore

In this sites, frequently observed species were *Entomoneis sp*., *Pleurosigma sp*, *Scenedesmus sp*, *Surirella sp*, *Synedra ulna*, and *Thalassiosira sp*. Whereas rarely seen species were *Climacosphaenia elongata*, *Navicula sp*, *Oscillatoria sp*, *Rhizosolenia imbricata* & *Thalassiothrix sp*. Dictyocha sp, Actinocyclus sp. and Oscillatoria sp. only recorded at site 1A, 1C and 1E respectively. High population density recorded at site 1A (22240 no/l) and low density recorded at site 1control (4640 no/l). The maximum number of species observed in site 1C (17 nos.) followed by 1A (16 nos.), 1D & 1E (15 nos.), 1B (11 nos.) and 1control (6). The population density greatly varied (4640 - 22240 No/l) being highest at site 1A (22240 no/l) and lowest value at site 1control (4640 No/L). The highest number of species noticed at site 1A (16 nos.) where density also higher and low species number was 6 at site 1control. Both Dinoflagellate phytoplankton *Ceratium furca* and *Dinoflagellated cyst* recorded at this site.

Location 2 - Cargo jetty

The population density greatly varied between 20800 nos/l to 9120 nos/l. Highest density value recorded at 2control (20800 nos/l) and lowest value at 2A (9120). The highest number of species noticed in the site 2control where density was also higher and lowest number of species noticed at 2C (5nos.). In this Cargo Jetty station commonly or frequently observed species were *Coscinodiscus granii, Coscinodiscus concinnus*, *Coscinodiscus radiatus*, *Guinardia sp, Synedra sp*. The rarely found species were *Biddulphia, Campylodiscus sp, Chaetoceros peruvianus*, *Gyrosigma sp, Nitzschia sp, Pleurosigma sp* etc.

Location 3 - Phang Creek

The population density of phytoplankton ranged from 3360 nos/l to 15680 nos/l same way species availability ranged from 5 to 10 nos. Maximum and minimum value of population density were recorded in site 3C (15680 nos/l) to 3E (3360 nos/l). Highest number of species recorded in site 3D (10nos) and lowest in site 3control (5 nos). *Coscinodiscus granii, Coscinodiscus concinnus*, *Coscinodiscus radiatus*, Guinardia were frequently noticed in samples whereas less observed species were *Biddulphia sp, Navicula sp, Oscillatoria sp, Pseudo-nitzschia sp, Thalassiosira leptopus* in this site.

Overall view of Phytoplankton showed that total 41species of Marine phytoplankton were identified during winter season of current year (2022). Among them 19 centric diatom, 16 Pennate diatom, 2 Dinoflagellate, 3 blue green algae and 1 heteroknot algae were observed. Plankton identification, both zooplankton and phytoplankton, was done by using relevant identification, taxonomic keys and with standard literatures, monographs & research articles. Majority dominated species are *Coscinodiscus concinus*, *C.granii*, *C.radiatus*, *Synedra ulna*, *Synedra sp.*, whereas some species like *Triceratium broeckii*, *Thalassiosira leptopus, Surrirella fastuosa*, *Surirella ovalis, Actinocyclus sp, Chaetoceros peruvianus*, *Dictyocha sp, Microcystis colony*, *Pseudo-nitzschia* colony, *Rhizosolenia imbricate* etc. rarely recorded during sample analysis. Highest phytoplankton density was observed at the site 1A-Offshore (22240 no/l) and lowest was observed at site 3E-Phang Creek (3360 no/l) (Table 31). Total number of highest species observed at site 1C-Offshore (17 nos) and lowest in site 2C-Cargo Jetty and also 3control-Phang Creek (5 nos). Dinoflagellated Cyst were only recorded in Offshore area of Port. During laboratory analysis some Dinoflagellate species also recorded like *Dinoflagellate cysts* and *Ceratium furca.* Some Blue green algae represented by

Oscillatoria sp, Microcystis colony and Scenedesmus sp. The high population density composed by species like *Coscinodiscus granii, Coscinodiscus concinnus*, *Synedra sp, Synedra ulna, Thalassiosira sp, Coscinodiscus radiates* (Table 31). This result indicated that genus Coscinodiscus very common with good numbers in all sites. In some sites least number of species and low density of phytoplankton might be responsible by the high pre-predation ratio, some level of pollution, high turbidity, total suspended solids, current of water and suddenly change in favourable environment condition. Data on List of Zooplankton species recorded and its density is shown in Table 31.

5.4.4. Diversity Indices of Phytoplankton

Table 32 shows the diversity indices calculation for phytoplankton showed that Shannon Index ranged from (1.27 to 2.72) indicated moderate to slightly higher level of diversity status Phytoplankton species composition. Lowest evenness recorded at site 2D-Cargo Jetty (0.503), whereas highest in at 1E (0.937). Simpson dominance index (1-D) showed the range from 0.579 to 0.926 where higher value in 1C-Offshore (0.926) and lower in 2B-Cargo Jetty (0.579).

Table 31. Density of Phytoplankton at different sites of Deendayal Port during Season 1

Name of Sites	Offshore						Cargo Jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-Control	2A	2B	2C	2D	2E	2-Control	3A	3B	3C	3D	3E	3-Control
Actinocyclus sp.	0	0	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacillaria paxillifera colony	0	0	640	1280	0	0	0	0	0	320	480	640	0	0	0	0	0	0
Biddulphia sp	800	0	0	960	1440	0	960	0	0	0	0	0	0	480	0	0	0	0
Campylodiscus sp.	0	0	0	320	960	0	0	0	0	0	0	320	0	0	0	0	0	0
Ceratium furca	0	0	0	320	800	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetoceros peruvianus	0	0	0	0	0	0	0	0	0	0	0	320	0	0	0	0	0	0
Climacosphaenia elongata	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coscindiscus concinnus	0	2080	800	0	1280	0	2560	0	4480	2880	3520	4800	1440	2240	4320	0	800	1920
Coscinodiscus granii	0	1920	480	0	1920	0	3200	8160	3840	5120	3200	6720	1920	1920	7200	0	480	5120
Coscinodiscus radiatus	5600	0	0	0	0	0	320	960	2080	1600	960	0	800	480	1920	1120	960	640
Coscinodiscus sp.	0	0	0	0	0	0	0	0	0	0	0	2720	0	0	0	0	0	0
Dictyocha sp.	160	0	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dinoflagellated Cysts	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ditylum sp.	0	160	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entomoneis sp.	0	640	640	320	640	480	0	0	0	0	0	0	0	0	0	0	0	0
Guinardia sp.	0	0	0	0	0	0	160	320	0	480	320	480	0	160	0	320	0	480
Gyrosigma sp.	0	0	320	320	640	0	0	320	0	0	0	0	640	320	0	320	0	0
Microcystis colony	0	0	0	0	0	0	0	0	0	160	0	0	0	0	0	0	0	0
Navicula sp.	480	0	0	0	0	0	640	0	0	0	0	0	0	480	0	0	0	0
Nitzschia sp.	0	640	800	480	0	0	0	0	480	0	0	0	0	0	0	960	320	0
Odontella mobiliensis	0	0	0	0	0	320	0	0	0	0	0	0	0	0	0	0	0	0
Oscillatoria sp.	0	0	0	0	640	0	0	0	0	0	0	480	0	0	0	320	0	0
Pinnularia sp.	160	0	480	0	0	0	0	0	0	0	0	0	0	0	0	0	160	0
Planktoniella blanda	2240	0	1120	0	0	640	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma sp	800	960	0	320	800	0	960	0	0	0	0	0	0	0	0	0	0	0
Pseudo-nitzschia colony	0	0	0	0	0	0	0	0	0	0	0	0	320	0	0	0	0	0
Rhizosolenia imbricata	1120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhizosolenia sp.	0	0	0	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Rhobdonema adriaticum	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus sp.	320	320	480	480	1120	800	320	640	0	320	0	0	0	0	960	320	0	0
Surirella ovalis	640	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella sp.	0	0	480	1120	960	320	0	0	0	0	0	0	0	0	0	0	0	0
Surirella fastuosa	0	0	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synedra sp.	0	0	0	800	1280	0	0	1920	0	160	1280	1600	0	0	640	960	0	0
Synedra ulna	0	320	320	1600	640	0	0	800	960	0	0	0	480	960	640	800	320	1440
Thalassionema nitzschioides colonies	1600	0	1440	800	0	0	0	0	0	0	1600	0	0	0	0	0	0	0
Thalassiosira leptopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0
Thalassiosira sp.	4960	320	0	2560	1440	2080	0	0	0	480	1440	1120	0	800	0	960	0	0
Thalassiothrix sp.	1600	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	0
Triceratium sp.	320	480	480	0	0	0	0	0	0	160	0	0	0	0	0	0	0	0
Triceratium broeckii	0	0	0	0	640	0	0	0	0	0	0	0	0	0	0	480	0	0
Total No. of Genus/Species= **41**																		
Density of Phytoplankton (No/L)	**22240**	**8480**	**9920**	**11840**	**15200**	**4640**	**9120**	**13120**	**11840**	**11680**	**12800**	**20000**	**5600**	**7840**	**15680**	**6560**	**3360**	**9600**
Total=199250 (No/lit)																		

Table 32. Diversity Indices of Phytoplankton at different selected sites of Kandla Port during Season 1

	Offshore						**Cargo Jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1-Control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Control**
Taxa_S	16	11	17	15	15	6	8	7	5	10	8	11	6	9	6	10	7	5
Individuals (Nos/m^2)	22240	8480	9920	11840	15200	4640	9120	13120	11840	11680	12800	20000	5600	7840	15680	6560	3360	9600
Dominance_D	0.143	0.149	0.074	0.109	0.076	0.270	0.232	0.421	0.287	0.277	0.184	0.203	0.228	0.180	0.309	0.123	0.188	0.354
Shannon Diversity	2.28	2.12	2.72	2.44	2.64	1.54	1.69	1.27	1.37	1.62	1.85	1.89	1.62	1.92	1.40	2.18	1.79	1.27
Simpson_1-D	0.857	0.851	0.926	0.892	0.924	0.730	0.768	0.579	0.713	0.723	0.816	0.797	0.772	0.820	0.691	0.877	0.812	0.646
Evenness	0.611	0.758	0.892	0.764	0.937	0.777	0.678	0.507	0.789	0.503	0.793	0.604	0.839	0.755	0.677	0.887	0.859	0.714
Menhinick	0.107	0.120	0.171	0.138	0.122	0.088	0.084	0.061	0.046	0.093	0.071	0.078	0.080	0.102	0.048	0.124	0.121	0.051
Margalef	1.499	1.106	1.739	1.493	1.454	0.5922	0.7677	0.6328	0.4265	0.961	0.7402	1.01	0.5793	0.8922	0.5176	1.024	0.7389	0.4362

5.4.2. Phytoplankton community structure recorded during Season 2

The study was conducted at 3 sites (or regions) at Deendayal Port and near area where dredging activities is going on Creek and the stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

In this site, frequently observed species were *Coscinodiscus oculus-iridis, Coscinodiscus radiatus*, *Coscinodiscus granii*, *Gyrosigma sp*, *Synedra ulna*, & *Thalassiosira fraunfeldii colony, Thalassiosira nitzschioides colony*, *Triceratium broeckii*. whereas less observed species were *Ceratium furca, Ceratium tripos, Entomoneis sp, Pinnularia sp, Protoperidinium sp*, *Pyrophacus sp*, *Triceratium favus.* Highest population density was recorded at site 1C-Offshore (896000 NoS/l) and low density recorded at site 1control-Offshore (33120 no/l). The maximum number of species observed in site 1a-Offshore (21 nos.) followed by 1B-Offshore (19 nos.), 1C-Offshore (11 nos), 1E-Offshore (10 nos) and 1D-1Control-Offshore (8 nos). The population density greatly varied (33120 nos/l to 89600nos/l). Among all recorded Phytoplankton Centric diatoms were 18, Pennate diatom- 9, Dinoflagellated -4 and Unidentified -1. Dinoflagellats like Ceratium furca, Ceratium tripos, Protoperidinium sp and Pyrophacus sp were recorded which are sometimes responsible for Algal Blooms in water.

Cargo jetty

The population density greatly varied between 34240 Nos/l to 62080 Nos/l. Highest density value recorded at 2B-Cargo Jetty (62080 No/l) and lowest value was at 2D-Cargo Jetty (34240). The highest number of species noticed in the site 2B- Cargojetty (17 nos.) where as density was also higher and lowest number of species noticed at 2C and 2E-Cargo Jetty (12 nos.). In this Cargo Jetty station commonly or frequently observed species were *Coscinodiscus granii*, *Coscinodiscus oculus-iridis*, *Coscinodiscus radiatus*, *Navicula sp*, *Pleurosigma sp*, *Thalassionema frauenfeldii colony*, *Thalassionema nitzschioides colony*, *Thalassiosira sp*. The rarely found species were *Biddulphia*, *Cyclotella sp*, *Odontella sp*,, *Surirella sp, Tripos azoricus, Coccolithoohores etc.* Among all Phytoplankton 18 Centric Diatoms, 2 Dinoflagellated cysts, 1 Coccolithophore, 1 Green algae, 9 Pennate Diatoms and 1 unidentified phytoplankton recorded.

Phang Creek

The population density of phytoplankton ranged from 26240 No/l to 71040 No/l same way species availability ranged from 12 to 25 nos. Maximum and minimum value of population density were recorded in site 3A-Phang Creek (71040 No/l) to 3E-Phang Creek (26240 No/l). Highest number of species recorded in site 3D-Phang Creek (25 nos) and lowest in site 3A-Phang Creek (12 nos).

Coscinodiscus centralis, Coscinodiscus oculus-iridis, Coscinodiscus radiatus, Coscinodiscus granii Coscinodiscus wailesii, Euglena sp, Planktoniella blanda, Synedra sp, Synedra ulna Thalassiosira leptopus were frequently noticed in samples whereas less observed species were *Planktoniella sol, Thalassiosira ecenntrica, Triceratium favus, Oscillatoria sp, Ditylum brightwelii* in this site.

Overall view of Phytoplankton showed that a total 54 species of Marine phytoplankton were identified during winter season of the year 2022. Among them, 25 were Centric diatoms, 14 were Pennate diatoms, 6 were Dinoflagellates, 1 was a Blue Green Algae, 1 was a Coccolithophores, 1 belong to Silicoflagellata, 2 were Green algae, 1 species was Unidentified. Plankton identification, both zooplankton and phytoplankton, was done by using relevant identification and taxonomic keys and with standard literatures, monographs and research articles. Some species like *Biddulphia sp*, *Thalassiosira leptopus, Climacosphaenica sp, Tripos azoricus, Pediastrum sp, Ditylum brightwelli, Protoperidinium sp, Scendesmus sp.* were rarely recorded during sample analysis. Input of the fresh water indicated by the presence of some common fresh water species like *Euglena sp*, *Green algae, Oscillatoria sp, Pediastrum sp, Scenedesmus sp*. Highest phytoplankton density was observed at the site 1C-Offshore (89600 No/l) and lowest was observed at site 3E-Phang creek (26240 No/l) (Table 33). Total number of highest species observed at site 1A-Offshore (21 nos) and lowest in site 1D-Offshore and also 1-control-Offshore (8 nos). **During** laboratory analysis some Dinoflagellate species were also recorded like *Ceratium tripos, Protoperidinium sp, Pyrophacus sp, Tripos azoricus*. **Some** Blue green algae represented by *Oscillatoria sp and Scenedesmus sp*. The high population density composed by species like *Coscinodiscus granii, Coscinodiscus radiatus, Coscinodiscus granii, Planktoniella blanda, Thalassiosira sp, Thalassionema frauenfeldii colony, Thalassionema nitzschioides colony and Synedra ulna.* (Table 33). This result indicated that genus *Coscinodiscus sp*. was very common with good numbers in all sites. In some sites, least number of species and low density of phytoplankton might be responsible due to by the high Pre-Predation ratio, Pollution, High turbidity, Total suspended solids, Water current of water and suddenly changes in favourable environment conditions. The individual density of species of sites viz. has been depicted in Table 33. All values of zooplankton density, list of zooplankton and others shown in Table 33.

Diversity Indices of Phytoplankton

The Table 34 shows diversity indices calculation for phytoplankton showed that the Shannon Index ranged from (1.784 to 3.004) indicated moderate to slightly higher level of diversity status. High Shannon Index was recorded at 3D-Phang Creek (3.004) and low at 1control-Offshore (1.784). Lowest evenness recorded at site 1A-Offshore (0.486) where highest phytoplankton numbers (21 Nos) were noticed, whereas highest was in at 3E-Phang Creek (0.925) where density was low recorded (26240 nos/l). Simpson dominance index 1-D-Offshore was showed the range from 0.782 to 0.940 whereas higher value in 3D-Phang Creek (0.940) and lowest was at in 1-Control-Offshore (0.782) (Table 34)

Table 33. Density of Phytoplankton at different sites of Deendayal Port during Season 2

Name of Sites	**Offshore**						**Cargo Jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1 control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2 control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3 control**
Genus of Phytoplankton																		
Actinocyclus sp	0	960	8320	0	3040	3520	2720	0	0	1920	0	0	0	2240	0	4480	0	0
Biddulphia sp.	1760	0	0	0	0	0	0	0	0	640	0	0	0	0	0	0	0	0
Campylodiscus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratium furca	640	1440	0	0	0	0	0	0	0	0	0	0	0	0	0	1280	0	0
Ceratium sp.	0	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	0
Ceratium tripos	0	960	0	0	0	0	0	0	0	0	0	0	0	0	0	2080	0	0
Climacosphaenia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	960	0	0	0	0
Coccolithophores	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	1760	0	0
Coscindiscus centralis	0	0	0	0	0	0	0	0	0	1440	0	2560	0	960	1600	1280	1440	2080
Coscindiscus oculus-iridis	3040	4320	10560	9920	4640	3360	4160	4160	2560	1440	960	0	11840	2400	3200	0	800	0
Coscindiscus radiatus	1600	4480	4160	0	2560	3040	2560	4480	1920	0	3200	3360	800	960	1920	5760	2080	4160
Coscinodiscus granii	16480	5440	29920	10080	11360	13120	12000	13280	13760	0	13920	9920	11680	9600	3360	2720	2080	3200
Coscinodiscus sp	0	2720	0	0	0	0	3200	0	0	0	0	4320	0	0	0	1760	0	0
Coscinodiscus wailesii	0	0	0	0	0	0	0	0	0	0	0	0	0	8480	1600	3200	2560	1920
Cyclotella sp.	0	0	0	0	0	0	0	0	0	1440	0	2560	0	0	1760	4320	0	1600
Dictyocha sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	0	0
Ditylum brightwelli	0	0	0	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0
Entomoneis sp	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euglena sp.	0	0	0	0	0	0	0	0	0	0	0	0	2560	3040	0	1760	2400	0
Green algae	0	0	0	0	0	0	0	0	0	0	0	800	0	800	0	1120	0	0
Guinardia sp	0	480	0	0	0	0	0	0	0	0	0	640	0	0	640	0	0	0
Gyrosigma sp.	1120	0	0	2080	0	0	1440	2880	0	0	0	0	0	0	0	0	0	0
Navicula lyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	800	960	0	0
Navicula sp.	640	1440	0	0	0	0	800	1440	1280	1440	0	0	0	0	2240	0	0	0
Nitzschia sp.	320	0	0	0	0	0	0	0	0	0	0	800	0	0	960	0	0	0
Odontella sinensis	0	0	0	0	0	0	0	0	0	0	0	1440	0	0	0	0	320	0
Odontella mobiliensis	0	0	0	0	0	0	1920	0	0	0	2560	0	0	0	0	0	1120	1600
Odontella sp.	0	0	0	0	0	0	0	0	0	0	960	0	0	0	0	0	0	0
Oscillatoria sp.	0	0	0	0	0	0	0	0	0	960	1280	0	0	1120	0	0	0	0
Pediastrum sp.	0	0	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0
Pinnularia sp.	800	0	0	0	0	640	640	0	0	0	0	0	0	0	0	0	0	0
Planktoniella blanda	1440	0	8160	2560	4320	3840	0	3360	0	4480	0	0	6400	3840	3360	4320	1760	5920
Planktoniella schutt	1920	0	3360	0	0	0	0	0	0	0	0	2080	3520	0	0	0	0	0

Planktoniella sol	0	0	0	0	1920	0	0	1920	0	1760	0	0	0	800	0	0	0	0
Pleurosigma sp.	0	3040	0	0	320	0	1600	2080	1440	2240	0	0	3040	0	0	1920	1280	0
Protoperidinium sp.	0	960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrophacus sp.	640	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus sp.	0	0	0	0	0	0	0	3840	0	0	0	0	0	0	0	0	0	0
Stellate trichome microplant parts	0	0	0	0	0	0	1280	0	0	0	0	0	0	0	0	0	0	0
Surirella sp.	0	1920	0	0	1120	0	0	1280	0	1440	0	0	0	0	0	0	1920	0
Synedra sp.	1440	0	0	1120	0	0	0	0	960	0	2720	0	0	3040	800	1280	1600	1120
Synedra ulna	0	2880	1120	0	2880	1600	3840	0	1600	0	2720	2240	0	0	480	1440	0	960
Thalassionema frauenfeldii colony	0	8480	4960	4160	0	0	1120	6720	1760	3360	7520	0	5920	5920	3040	4320	2240	3200
Thalassionema nitzschioides colony	5120	12000	6560	5920	0	0	960	2560	4160	2720	3360	5120	0	5280	0	7520	2560	4160
Thalassiosira ecentrica	1760	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1760	0	0
Thalassiosira ferelineata	0	4960	0	0	0	0	0	0	0	0	0	0	8960	0	0	0	0	0
Thalassiosira leptopus	1440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalassiosira sp	160	14400	11040	6560	6720	4000	3840	8800	4160	6560	3840	1920	13120	8480	5120	2240	2080	5440
Triceratium broeckii	800	2080	1440	0	0	0	0	960	1600	1600	0	0	2720	1600	0	1600	0	1280
Triceratium favus	480	0	0	0	0	0	0	1600	480	0	0	0	0	320	0	480	0	0
Triceratium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tripos azoricus	0	0	0	0	0	0	0	1920	0	0	0	0	0	0	0	0	0	0
Unidentified sp.	320	8000	0	0	0	0	0	0	0	0	3200	0	0	640	640	640	0	4480
Density of Phytoplankton (diff. sites wise.) (no/lit)	**42560**	**80960**	**89600**	**42400**	**38880**	**33120**	**42080**	**62080**	**35680**	**34240**	**46240**	**38560**	**71040**	**60480**	**31520**	**61120**	**26240**	**41120**
																		Total=877920 No/l
Total No Of Genus/Species= **53**																		

Table 34. Diversity Indices of Phytoplankton at different selected sites of Deendayal Port during Season 2

	Offshore						**Cargo jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	21	19	11	8	10	8	15	17	12	16	12	14	12	19	16	25	15	14
Individuals (Nos/m^2)	42560	80960	89600	42400	38880	33120	42080	62080	35680	34240	46240	38560	71040	60480	31520	61120	26240	41120
Dominance_D	0.182	0.095	0.170	0.171	0.161	0.218	0.129	0.103	0.194	0.093	0.150	0.125	0.127	0.096	0.089	0.060	0.075	0.093
Shannon Diversity	2.324	2.594	2.054	1.886	2.022	1.784	2.375	2.533	2.046	2.576	2.177	2.34	2.205	2.567	2.567	3.004	2.63	2.49
Simpson_1-D	0.818	0.905	0.830	0.829	0.839	0.782	0.871	0.897	0.806	0.908	0.850	0.876	0.873	0.904	0.911	0.940	0.925	0.907
Evenness	0.486	0.705	0.709	0.824	0.756	0.744	0.717	0.741	0.645	0.822	0.735	0.741	0.756	0.686	0.814	0.807	0.925	0.861
Menhinick	0.102	0.067	0.037	0.039	0.051	0.044	0.073	0.068	0.064	0.086	0.056	0.071	0.045	0.077	0.090	0.101	0.093	0.069
Margalef	1.88	1.59	0.88	0.66	0.85	0.67	1.32	1.45	1.05	1.44	1.02	1.23	0.98	1.64	1.45	2.18	1.38	1.22

5.4.3 Phytoplankton community structure recorded during Season 3

The study was conducted at 3 sites (or regions) at Kandla Port and near area where dredging activities is going on Creek and the stations are Offshore, Cargo Jetty and Phang Creek.

Offshore

In this site, frequently observed species were *Coscinodiscus wailesii, Coscinodiscus radiatus, Coscinodiscus granii, Odontella mobiliensis, Planktoniella blanda, Thalassiosira fraunfeldii colony, Thalassiosira nitzschioides colony, Thalassiosira sp.*. whereas less observed species were *Ceratium fusus, Ceratium tripos, Entomoneis sp, Corethron sp, Coscinodiscus astermophalus sp, Navicula sp, Triceratium broeckii.* Total 38 Phytoplankton were recorded in this Offshore area. Highest population density was recorded at site 1A-Offshore (99200 Nos/l) and low density recorded at site 1control-Offshore (29440 nos/l). The maximum number of species observed in site 1A-Offshore (24 nos.) followed by 1B-Offshore (22 nos.), 1C & 1E -Offshore(17 nos), 1D-Offshore (14 nos) and 1Control-Offshore (11 nos). The population density greatly varied (29440 nos/l to 99200 nos/l). Dinoflagellats like *Ceratium furca*, *Ceratium tripos*, *Ceratium fusus*, *Pyrophacus sp* were recorded which are sometimes responsible for Algal Blooms in water. *Euglena sp* and *Synuara sp (alga colony)* were frequently found in this area which indication of some level of water mixing or other words monsoon effects.

Cargo jetty

Total 53 Phytoplankton were recorded in this Cargo Jetty area. The population density greatly varied between 19360 Nos/l to 80960 Nos/l. Highest density value recorded at 2C-Cargo Jetty (80960 No/l) and lowest value was at 2Control-Cargo Jetty (19360). The highest number of species noticed in the site 2C- Cargojetty (27 nos.) where as lowest in 2Control-Cargojetty (15 nos.) The density and species number, both highest in 2C-Cargo Jetty and same lowest in 2Control-Cargo Jetty. In this Cargo Jetty station commonly or frequently observed species were *Coscinodiscus wailesii*, *Ditylum brightwellii Thalassionema frauenfeldii colony*, *Thalassionema nitzschioides colony*, *Thalassiosira sp*. *Odontella sinensis*, *Odontella mobiliensis*, *Rhizosolenia sp*. etc. The rarely found species were *Chaetoceros peruvianus, Coscinodiscus asteromphalus, Dinoflagellated cysts, Euglena* *sp,Rhizosolenia shrubsolei, Thalassiosira rotula and Triceratium favus etc.* More number of species were recorded here result indicated may be because of water circulation pattern.

Phang Creek

The population density of phytoplankton ranged from 25760 No/l to 39040 No/l same way species availability ranged from 15 to 21 nos. Maximum and minimum value of population density were recorded in site 3E/3Control-Phang Creek (39040 nos/l) and 3B-Phang Creek (25760 No/l) respectively. Highest number of species recorded in site 3C-Phang Creek (21nos) and lowest in site 3B-Phang Creek (15 nos). Total recorded phytoplankton was 34 in this creek area.

Coscinodiscus radiatus, Coscinodiscus granii Coscinodiscus wailesii, Odontella sinensis Odontella mobiliensis, Synedra sp, Synedra ulna Thalassionema frauenfeldii colony, Thalassionema nitzschioides etc. were frequently noticed in samples whereas less observed species were *Planktoniella sol, Thalassiosira ecenntrica, Triceratium favus, Oscillatoria sp, Ditylum brightwelii*in this site.

Overall view of Phytoplankton showed that a total 63 species of Marine phytoplankton were identified during monsoon season of the year 2022. Among them, 35 Centric diatoms, 14 Pennate diatoms, 5 Dinoflagellates, 1 Blue green algae, 7 Green algae, 1 Silioflagellates, 1 Unidentified were observed. Plankton identification, both zooplankton and phytoplankton, were done by using relevant identification and taxonomic keys and with standard literatures, monographs and research articles. Some species like *Biddulphia sp, Amphipleura sp, Chaetoceros peruvianus, Dictyocha sp, Dinoflagellated cysts, Rhizosolenia alata* were rarely recorded during sample analysis. Input of the fresh water indicated by the presence of some common fresh water species like *Euglena sp, Green algae, Oscillatoria sp, Pediastrum sp*. Presence of Dinoflagellates also sighting of bottom water circulation up to surface water layer. Highest phytoplankton density was observed at the site 1B-Offshore (96800 No/l)and lowest was observed at site 2Control-Cargo Jetty (19360 No/l) (Table 35). Total number of highest species observed at site 2C-Cargo Jetty (27 nos) and lowest in site 1Control-Offshore (11 nos). During laboratory analysis some Dinoflagellate species were also recorded like *Ceratium tripos, Ceratium fusus, Ceratium furca, Dinoflagellated cysts and Pyrophacus sp*. Some Blue green algae represented by *Oscillatoria sp, Euglena sp and Scenedesmus sp*. The high population density composed by species like *Coscinodiscus granii, Coscinodiscus* *radiatus, Coscinodiscus wailesii Ditylum brightwellii, Odontella sinensis, Odontella mobiliensis, Synura sp (alga colony), Thalassionema frauenfeldii colony, Thalassionema nitzschioides colony* (Table 35). This result indicated that genus *Coscinodiscus sp*. *Thalassionema sp and Odontella sp.* were very common with good numbers in all sites. *Sunura sp* of heterokont algae which are mostly found in freshwater, also recorded in frequently. In some sites, least number of species and low density of phytoplankton might be responsible due to by the high Pre-Predation ratio, Pollution, High turbidity, Total suspended solids, Water current and suddenly changes in environment conditions. The individual density of species of sites, zooplankton density, list of zooplankton has been given in table 35.

Diversity Indices of Phytoplankton

Diversity indices calculation for phytoplankton showed that the Shannon Index ranged from (2.18 to 2.93) indicated lowest to slightly moderate level of diversity status (Table 36). High Shannon Index was recorded at 3C-Phang Creek (2.93) and low at 1control-Offshore (2.18). Lowest evenness recorded at site 1A-Offshore (0.65) where number of species was 24 and highest density (99200 Nos/l), whereas highest was in at 1D-Offshore (0.91) where species number was 14. Simpson dominance index ranged from 0.86 to 0.94 whereas higher value in 3C/3E-Phang Creek (0.94) and lowest was at in 1-Control-Offshore (0.86) (Table 36)

Table 35. Density of Phytoplankton at different sites of Deendayal Port during Season 3

Name of Sites	**Offshore**						**Cargo Jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1 control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2 control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3 control**
Genus of Phytoplankton																		
Actinocyclus octonarius	0	0	0	0	0	0	0	3360	0	0	0	0	0	0	0	0	0	0
Actinocyclus sp.	3040	6080	2560	0	1440	1920	6560	0	0	320	0	960	1760	320	0	1120	0	0
Amphipleura sp	0	0	0	0	0	0	3360	0	0	0	0	0	0	0	0	0	0	0
Bacillaria paxillifera colony	0	0	0	0	0	0	0	1280	0	0	0	0	0	0	0	0	0	0
Biddulphia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	960	0
Ceratium furca	1280	1440	0	1120	1120	0	800	1920	1120	0	1120	0	800	0	0	0	0	0
Ceratium fusus	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratium tripos	1440	0	0	0	0	0	0	0	0	0	640	0	480	0	0	320	0	0
Chaetoceros sp	0	0	0	0	0	0	0	0	1120	0	0	0	0	0	0	0	0	0
Chaetoceros decipiens	0	0	0	0	0	0	0	0	2400	640	800	0	0	0	0	0	0	0
Chaetoceros peruvianus	0	0	0	0	0	0	0	0	0	640	0	0	0	0	0	0	0	0
Corethron sp.	1120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coscindiscus granii	0	0	5440	3520	2560	2560	4960	4960	3680	0	1120	2080	2400	0	1920	1600	2560	2240
Coscinodiscus asteromphalus	0	2240	0	0	0	0	1440	0	0	0	0	0	960	1600	960	0	0	0
Coscinodiscus centralis	0	0	2080	0	0	1760	1120	0	0	0	0	0	0	960	1760	2240	2400	1920
Coscinodiscus radiatus	1920	0	2080	3200	2520	3520	1760	0	2400	2880	0	480	800	2560	1920	2560	2880	2880
Coscinodiscus sp.	0	2080	0	0	0	1920	0	0	1120	0	0	1120	0	0	0	0	0	0
Coscinodiscus wailesii	9920	17440	16160	6560	6880	7680	15360	16480	10880	2560	800	4320	3840	4000	3200	5920	4160	5440
Cyclotella sp.	0	0	0	0	0	0	0	0	1920	1760	0	0	0	0	0	0	0	0
Dictyocha sp	0	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0
Dinoflagellated Cysts	0	0	0	0	0	0	0	0	0	1120	0	0	0	0	0	0	0	0
Ditylum brightwelli	6880	5280	2560	2240	2080	0	4000	2560	13280	3200	1920	2080	0	1440	0	1440	0	0
Entomoneis sp	0	1440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euglena sp.	20320	17600	15520	0	3520	0	0	1920	0	0	0	0	0	0	0	0	0	0
Green algae	0	0	0	0	1120	0	0	0	3520	7680	0	0	1600	0	1120	1120	1760	2080
Guinardia sp	0	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrosigma sp.	0	0	0	0	0	0	0	1440	0	640	0	480	0	1120	0	0	960	0
Navicula sp.	320	0	0	0	0	1600	0	0	0	960	3360	0	0	0	480	640	0	0
Nitzschia sp.	1600	0	0	0	1120	0	0	2560	0	0	800	0	0	0	1280	0	0	0
Nitzschia longissima	0	0	0	0	0	0	0	1280	0	0	0	0	0	0	0	0	0	0
Odontella sinensis	3200	3520	4800	0	0	0	2240	2280	1600	1120	0	0	0	800	2240	2560	1440	1920
Odontella mobiliensis	9440	3360	4960	1920	2720	0	4640	2880	5440	1120	0	0	1440	1280	2720	1920	1760	1600
Odontella sp.	0	0	0	0	0	0	1440	0	0	0	2400	800	0	0	2080	0	640	1120
Oscillatoria sp.	0	0	0	0	0	0	0	0	3200	0	0	0	2080	0	0	0	0	2080
Pediastrum sp	0	0	0	0	0	0	0	0	0	0	0	0	1280	0	0	0	0	0
Planktoniella blanda	3040	1440	2880	0	2240	0	0	800	0	0	1120	0	0	0	800	0	800	480
Planktoniella sp.	0	0	0	1440	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma sp.	800	0	0	0	640	0	0	0	1120	640	0	0	0	0	0	800	480	0
Pyrophacus sp.	0	1280	0	1440	0	0	0	1440	1600	0	0	0	0	0	0	0	0	0

Rhizosolenia sp	0	0	0	0	0	0	0	1920	2080	1280	0	640	0	0	0	0	0	0
Rhizosolenia alata	0	0	0	0	0	0	0	0	0	800	960	0	0	0	0	0	0	0
Rhizosolenia imbricata	0	0	0	0	0	0	0	0	0	0	960	800	0	0	0	0	0	0
Rhizosolenia shrubsolei	0	0	0	0	0	0	0	2400	0	0	0	0	0	0	0	0	0	0
Scenedesmus sp.	0	0	0	0	0	0	0	0	1760	0	640	640	1120	1600	1280	0	1440	0
Surirella sp.	0	1120	0	0	0	0	0	1440	1760	0	0	0	0	0	0	0	0	0
Synedra ulna	0	0	2720	0	800	0	0	0	320	0	0	0	1280	1760	1440	2560	3680	2240
Synedra sp	0	0	5280	0	0	640	0	0	800	0	480	640	640	1600	1600	1760	1600	1120
Synura sp (alga colony)	2240	3360	2080	3520	2080	1440	1280	2560	0	1760	640	0	1760	2720	0	0	0	0
Synura spinosa	0	0	0	0	0	0	1280	0	0	0	0	0	0	0	0	0	0	0
Thalassionema frauenfeldii colony	7520	9920	4160	4320	6560	0	5280	3840	3680	2400	1760	1120	1440	0	2880	480	2240	1760
Thalassionema nitzschioides colony	8640	3840	4960	2880	4000	4960	7680	6560	6880	4320	3840	1440	2560	2080	3360	3200	3840	3520
Thalassiosira rotula	0	0	0	0	0	0	0	0	0	1280	0	0	0	0	0	0	0	0
Thalassiosira ecentrica	3840	2720	0	0	0	0	0	0	0	0	0	0	0	0	0	1120	800	0
Thalassiosira ferelineata	0	2400	0	0	0	0	3360	0	1760	0	960	0	0	0	1440	0	0	0
Thalassiosira leptopus	1440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	800
Thalassiosira punctigera	3360	2400	0	3040	0	0	0	1440	0	800	0	0	0	0	960	0	0	1440
Thalassiosira sp.	3360	5440	11040	3040	6080	1440	6240	5120	4160	3040	1120	1760	2880	1920	800	3840	2240	2400
Thalassiothrix sp	0	0	0	0	0	0	0	1440	0	0	0	0	0	0	0	0	0	0
Triceratium broeckii	0	0	640	0	0	0	0	640	480	480	0	0	0	0	0	0	0	0
Triceratium favus	640	0	0	0	0	0	0	0	160	0	0	0	0	0	0	0	0	0
Trieres mobiliensis	3360	1920	0	2720	0	0	1920	0	2720	1440	800	0	0	0	3200	2080	2400	3360
Trieres sp.	0	0	0	0	0	0	0	640	0	0	960	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640
Density of Phytoplankton (diff. sites wise.)(no/lit)	99200	96800	89920	40960	47480	29440	74720	73160	80960	42880	27680	19360	29120	25760	37440	38880	39040	39040
Total=931840 No/l																		
Total No Of Genus/Species= **63**																		

Table 36. Diversity Indices of Phytoplankton at different selected sites of Deendayal Port during Season 3

	Offshore						**Cargo jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	24	22	17	14	17	11	19	25	27	24	22	15	18	15	21	20	20	19
Individuals (Nos/m^2)	99200	96800	89920	40960	47480	29440	74720	73160	80960	42880	27680	19360	29120	25760	37440	38880	39040	39040
Dominance_D	0.09	0.10	0.10	0.09	0.09	0.14	0.09	0.09	0.07	0.07	0.07	0.10	0.07	0.08	0.06	0.07	0.06	0.07
Shannon Diversity	2.74	2.68	2.54	2.54	2.61	2.18	2.65	2.86	2.91	2.87	2.90	2.49	2.76	2.59	2.93	2.80	2.85	2.80
Simpson_1-D	0.91	0.90	0.90	0.91	0.91	0.86	0.91	0.91	0.93	0.93	0.93	0.90	0.93	0.92	0.94	0.93	0.94	0.93
Evenness	0.65	0.66	0.75	0.91	0.80	0.80	0.74	0.70	0.68	0.74	0.83	0.80	0.88	0.88	0.89	0.82	0.86	0.87
Menhinick	0.08	0.07	0.06	0.07	0.08	0.06	0.07	0.09	0.09	0.12	0.13	0.11	0.11	0.09	0.11	0.10	0.10	0.10
Margalef	2.00	1.83	1.40	1.22	1.49	0.97	1.60	2.14	2.30	2.16	2.05	1.42	1.65	1.38	1.90	1.80	1.80	1.70

Chapter 6 Marine Water Quality-Biological (Zooplankton)

6.1. Introduction

Zooplankton are the attractive, various and plentiful group of faunal species living inside the water bodies throughout the world. Most of the zooplankton are microscopic which can drift with the currents. Although most of them can swim, they have no ability to progress against water currents (Alcaraz and Calbet, 2003). They are representatives of all key invertebrate phyla and eventually support to the most marine life. They directly serve as a food resource for various young fish (larvae) and invertebrates such as larvae of squid and lobster, many small planktivorous fish such as sardine and anchovy, and even a few large marine animals such as baleen whales and manta rays etc. They also play important role in food web by indirectly supporting a few large ocean predators such as tuna, sharks etc, which feed upon the small planktivorous fish. In this way they are the major link in the marine life in between phytoplankton and fish including commercially important species, their study is the important part for getting knowledge of the functioning of marine ecosystems (Alcaraz and Calbet, 2003). They are subdivided into holoplankton and meroplankton. Holoplankton are nothing but the permanent members of the plankton which spend their entire lives in the water column while meroplankton are the temporary members. Zooplankton are powerfully approachable to environmental variables such as sunlight, temperature, salinity, pH, dissolved oxygen, food availability etc.

The study was conducted at 3 sites in Deendayal Port area and nearby areas where dredging activities are going on. The three selected study stations are Offshore, Cargo Jetty and Phang Creek.

6.2. Methodology

The present investigation was carried out in the three sampling locations such as offshore dredging, cargo jetty and Phang creek dumping site during January 2022 and September 2022 for three sampling seasons. In each location five replicate samples and one control samples were collected. Zooplankton samples were collected using a standard zooplankton net with a mouth area of 0.25 m^2 fitted with a flow meter. The net was towed from a boat for 5 min with a constant boat speed of 2 nautical miles per hour. The initial and final reading in the flow meter was noted down and the soup collected in the plankton bucket was transferred to appropriately labeled container and preserved with 5% neutralized formaldehyde. To counter-check the zooplankton density values obtained, water samples of 100 Lwere collected and preserved, which was later analysed for zooplankton density. One ml of the zooplankton soup was added to a Sedgwick counting chamber and was observed under a compound microscope. The group/taxa were identified using standard identification keys and their number was counted. Random cells in the counting chamber were taken for consideration and the number of zooplankton was noted down along with their binomial name. This was repeated for five 1 ml samples 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 [Shannon-Wiener diversity index (H'), Margalef's species richness (d), and Pielou's evenness (J'), Simpson dominance (D)] were determined using past software.

6.3. Results

6.3.1. Distribution and density of Zooplankton during Season 1

The study was conducted at 3 sites (or regions) of Kandla Port and near area where dredging activities is going on. Namely three selected study stations are Offshore, Cargo Jetty and Phang Greek.

Location 1 - Offshore site

The Veliger larva of Bivalve, Zoea larva of Crustacean, Foraminifera, Ostracoda, Sponge spicules were the mostly common zooplankton throughout the all sites of Offshore region Highest population density recorded at site 1B (13120 No./100m^3) and lowest in 1conntrol (7360 No/100m^3). Site 1C and 1A have maximum number of species (15 Nos) whereas minimum found in the site 1control (9nos). High biomass observed in the site 1D (48.33 ml/100m^3) and low biomass in site 1E (3.32 ml/100m^3). The range of the population density, biomass and number of species were (7360 to 13120 no/100m^3), (3.32 to 48.33 ml/100m^3) and (9 to 15 Nos) respectively in all sites. The frequently observed species were Veliger larva of Bivalve, Zoea larva of Crustacean (Decapoda), Foraminifera, Osracoda and Spicules of

Sponge (Sponge spicules). *Sagitta* sp, *Dentilium*, Polychaeta larva and *Euterpina* sp (Harpacticoida) rarely recorded in this station as shown in Table 37.

Location 2 - Cargo Jetty site

The population density of zooplankton varied from 8480 no/100m^3 to 13280 no/100m^3 as shown in Table 38. Maximum density noticed in site 2B (13280 no/100m^3) and minimum in site 2C (8480 no/100m^3). The site 2D composed highest number of species (15nos) other way minimum number of species observed in site 2A (7nos). Biomass in ranged between (2.33 to 8.93 ml/100m^3) where highest biomass noted in site. Frequently observed species were Sponge spicules, Zoea larva of Crustacean, Foraminifera and Nauplius larva of Copepoda, Egg capsules of Littorinids whereas little time observed species were Mysis larvae, *Oithona* sp (Cyclopoida), *Arcella* sp (Protozoa).

Location 3 - Phang Creek site

This Creek area was represented by the majority zooplankton fauna of Egg capsule of Littorinids, Nauplius larva of Copepoda, Sponge spicules, Zoea larva of Crustacea, Foraminifera (mainly *Globigerina* sp.), *Parvocalanus* sp (Calanoida). Very less time or rarely recorded species were Gnathiid isopoda larva, *Tintinnopsis* Cylindrica, Mysis larva. Range of zooplankton Biomass between 1.85 to 7.97 ml/100m$^{3.}$ Highest biomass recorded in site 3control (7.97 ml/100m^3) and lowest in site 3B (1.85 ml/100m^3). Maximum and Minimum species counted in site 3E (14nos) and 3A (3 Nos) respectively. Population density maximum recorded in site 3E (15840 no/100m^3) and minimum in site 3C (5920 No/100m^3) as presented in Table 39.

Overall assessment of zooplankton showed that the total number of 38 Zooplankton recorded during winter season. Out of these (38 Nos) zooplankton, 29 zooplankton recorded in Offshore region 28 zooplankton at Cargo Jetty and 24 zooplankton in Phang Creek region recorded. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea), Mollusca (Bivalvia & Gastropoda), Protozoa, Echinodermata, Porifera, Chaetognatha, Annelida, Tunicata (Chordata). Generally, study of zooplankton population dynamics and in discussion level, more emphasize is given up to group level ratio rather than to species level because of microscopic size of zooplankton so owing to the difficulty in identifying the zooplankton, some species consider as a group or genus level. The mostly dominant or frequently observed species were Nauplius larva, Veliger larva of Bivalve, Zoea larva of Crustacea, Sponge spicules, *Globigerina* sp *(Foraminifera)* and other Foraminifera. The range of Population density, Biomass and Number of Species were (5920 to 13600 no/100 m^3), (1.85 to 48.33 ml/100m^3) and (3 to 15 nos) respectively. Average high biomass noted at Offshore region compare to Cargo Jetty & Phang Creek (Table 37,38,39). High population density recorded in site 3control-Phang Creek (13600 no/100m3) and lowest recorded in site 3C-Phang Creek (5920 no/100m^3). Among all recorded zooplankton majority dominancy occurred by the Copepoda and Crustacean larvae. Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda in overall zooplankton community. Porifera, Chaetognatha and Tunicata only represented by the one species namely Sponge spicules, *Sagitta sp* and *Oikopleura sp* respectively. In Offshore maximum Percentage of Occurrence (%) by the Ostracoda (20.87%) and minimum by the *Acrocalanus sp (calanoida)* and Nauplius larva of Harpacticoida (0.25%). In Cargo Jetty maximum Percentage of Occurrence (%) by the Zoea larva of Crustacea (26.67%) and minimum (0.25%) by the Gnathiid isopoda larva, Nauplius larva of Harpacticoida. and Tintinnida. In Phang Creek station maximum Percentage of Occurrence (%) by the Zoea larva of Crustacea (30.70%) and minimum (0.29%) by the Animal egg sac, Annelida, Euterpina sp and *Tintinnopsis orientalis*.

During analysis time Species of Foraminifera and Spicules of sponge frequently observed. These both are very important for paleontological study aspects and also for evolutionarily, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Data on zooplankton density and list of zooplankton species recorded is presented in Tables 37-39.

Diversity Indices of Zooplankton

Table 40 shows the *diversity indices showed different diversity index calculation for zooplankton. The Shannon-wiener diversity index* (H') fluctuated between 0.69 to 2.46 indicated very poor to moderate range of diversity with a maximum value in site 1C-Offshore (2.46) and minimum value in site 3A-Phang Creek (0.69). Range of the evenness was 0.554 to 0.901 where highest and lowest recorded in site 1D-Offshore (0.901) and 3E (0.554) respectively. Highest Simpson index 0.90 noted at two site 1C-Offshore and 1D-Offshore whereas lowest in site 3A (0.37). Range of Simpson Index was 0.37 to 0.90 between the stations (Table 40).

Table 37. Density of Zooplankton at Offshore site of Deendayal Port during Season 1

Sr No.	Name of Genera/Group	1A	1B	1C	1D	1E	1 Control	Total density (no/100m^3)	% of Occurrence
1	Acrocalanus sp.(Calanoida)	160	0	0	0	0	0	160	0.25
2	Animal Egg masses	640	1120	320	0	0	0	2080	3.31
3	Cyphonautes larva bryozoans	320	0	480	0	320	320	1440	2.29
4	Dentilium sp.	0	0	0	320	0	0	320	0.51
5	Echinopluteus larva of Echinodermata	320	0	320	0	0	0	640	1.02
6	Euterpina sp (Harpacticoida)	0	0	0	0	320	0	320	0.51
7	Gastropoda Veliger larva	0	0	800	0	0	0	800	1.27
8	Globigerina sp. (Foraminifera)	0	800	0	1600	0	0	2400	3.82
9	Other Harpacticoida	0	0	320	0	480	0	800	1.27
10	Nauplius larvae of Calanoida	320	0	320	0	640	0	1280	2.04
11	Nauplius larvae of Cyclopoida	320	0	160	0	0	0	480	0.76
12	Nauplius larvae of Harpacticoida	0	0	0	0	160	0	160	0.25
13	Nauplius larva of other Crustacea	0	0	0	640	0	480	1120	1.78
14	Neogloboquadrina sp.(Foraminifera)	0	0	0	320	0	0	320	0.51
15	Oithona sp (Cyclopoida)	320	0	320	800	0	0	1440	2.29
16	Ostracoda	3840	3360	160	1440	1920	2400	13120	20.87

17	Other Foraminifera	0	3040	1120	0	160	1600	5920	9.41
18	Other Calanoida	320	0	1120	800	960	800	4000	6.36
19	Other Cyclopoida	320	640	1600	960	1280	160	4960	7.89
20	Parvocalanus sp (Calanoida)	480	320	960	0	0	0	1760	2.80
21	Prawn larvae	0	480	0	0	0	0	480	0.76
22	Polychaeta larva	0	0	0	0	0	320	320	0.51
23	Quinqueloculina sp.(Foraminifera)	0	0	0	800	0	0	800	1.27
24	Sagitta sp. (Arrow worm)	0	0	0	640	0	0	640	1.02
25	Sponge Spicules	960	0	1120	800	320	0	3200	5.09
26	Tintinnopsis beroidea(Tintinnida)	1920	0	0	0	1120	0	3040	4.83
27	Tintinnopsis orientalis(Tintinnida)	960	800	0	0	480	0	2240	3.56
28	Veliger larva of Bivalve	320	960	0	0	160	480	1920	3.05
29	Zoea larva of Crustaceans	0	1600	1920	1440	960	800	6720	10.69
Total Density(no/100m^3)		**11520**	**13120**	**11040**	**10560**	**9280**	**7360**	**62880**	**100%**
Total No of Genera/Groups=29									
Biomass (ml/100m^3)		**36.76**	**25.42**	**18.12**	**48.33**	**3.32**	**13.51**		

Table 38. Density of Zooplankton at Cargo Jetty site of Deendayal Port during Season 1

Sr No.	Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Total density (no/100m3)	% of Occurrence
1	Acrocalanus sp.(Calanoida)	0	0	0	0	480	480	960	1.48
2	Arcella sp. (Protozoa)	320	0	0	0	0	0	320	0.49
3	Bolivina sp. (Foraminifera)	0	0	0	0	0	480	480	0.74
4	Cyphonautes larva bryozoans	0	0	480	0	0	320	800	1.23
5	Euterpina sp (Harpacticoida)	0	0	0	960	0	0	960	1.48
6	Egg capsule of Littorinids	800	800	0	1600	0	1920	5120	7.90
7	Globigerina sp. (Foraminifera)	1920	0	0	320	0	0	2240	3.46
8	Gnathiid isopoda larva	0	0	160	0	0	0	160	0.25
9	Other Harpacticoida	0	640	0	0	320	320	1280	1.98
10	Mysis larvae	0	0	0	0	160	0	160	0.25
11	Nauplius larvae of Calanoida	0	480	0	320	960	0	1760	2.72
12	Nauplius larvae of Cyclopoida	0	0	0	320	320	0	640	0.99
13	Nauplius larvae of Harpacticoida	0	320	0	0	160	0	480	0.74
14	Nauplius larva of other crustacea	0	0	0	160	0	0	160	0.25
15	Oithona sp (Cyclopoida)	0	0	0	160	0	320	480	0.74

16	Ostracoda	2880	1920	640	0	0	0	5440	8.40
17	Other Foraminifera	480	2720	0	960	0	0	4160	6.42
18	Other Calanoida	0	0	160	0	1920	800	2880	4.44
19	Other Cyclopoida	0	0	160	800	1280	2400	4640	7.16
20	Parvocalanus sp (Calanoida)	0	960	0	640	320	640	2560	3.95
21	Polychaeta larva	0	320	160	0	320	0	800	1.23
22	Quinqueloculina sp.(Foraminifera)	0	0	0	160	0	1120	1280	1.98
23	Sponge Spicules	1440	0	2560	800	1280	0	6080	9.38
24	Tintinnopsis beroidea(Tintinnida)	0	0	0	320	0	0	320	0.49
25	Tintinnopsis orientalis(Tintinnida)	0	0	0	0	800	0	800	1.23
26	Tintinnida sp.	0	0	0	160	0	0	160	0.25
27	Veliger larva of Bivalve	0	800	960	0	640	0	2400	3.70
28	Zoea larva of Crustaceans	2880	4320	3200	2560	2240	2080	17280	26.67
Total Density(no/100m^3)		10720	13280	8480	10240	11200	10880	64800	100%
Total No of Genera/Groups=28									
Biomass (ml/100m^3)		8.93	4.81	6.25	2.33	2.40	7.58		

Table 39. Density of Zooplankton at Phang Creek site of Deendayal Port during Season 1

S. No.	Name of Genera/Group	3A	3B	3C	3D	3E	3 Control	Total density (no/100m^3)	% of Occurrence
1	Acrocalanus sp.(Calanoida)	640	0	0	480	0	0	1120	2.05
2	Animal Egg masses	0	0	0	0	0	160	160	0.29
3	Annelida	0	0	0	0	0	160	160	0.29
4	Euterpina sp (Harpacticoida)	0	0	0	0	160	0	160	0.29
5	Egg Capsule of Littorinids	0	2080	1600	1760	0	4640	10080	18.42
6	Globigerina sp. (Foraminifera)	0	480	0	0	1600	1440	3520	6.43
7	Gnathiid isopoda larva	0	0	0	0	320	0	320	0.58
8	Other Harpacticoida	0	320	0	0	0	160	480	0.88
9	Mysis larvae	0	0	0	0	160	0	160	0.29
10	Nauplius larvae of Calanoida	0	0	0	0	480	0	480	0.88
11	Nauplius larva of other crustacea	0	0	0	480	0	0	480	0.88
12	Oithona sp (Cyclopoida)	0	160	0	0	160	0	320	0.58
13	Ostracoda	0	0	0	320	3200	2560	6080	11.11
14	Oikopleura sp (Tunicata)	0	0	0	0	320	0	320	0.58
15	Other Foraminifera	0	800	0	0	640	1600	3040	5.56
16	Other Calanoida	0	1440	0	320	0	160	1920	3.51
17	Other Cyclopoida	0	0	0	0	800	0	800	1.46

18	Parvocalanus sp (Calanoida)	0	0	480	160	480	0	1120	2.05
19	Prawn larvae	0	0	0	0	0	160	160	0.29
20	Sponge Spicules	800	640	1120	320	1440	800	5120	9.36
21	Tintinnopsis orientalis(Tintinnida)	0	0	0	0	0	160	160	0.29
22	Tintinnopsis cylindrica (Tintinnida)	0	0	640	0	0	0	640	1.17
23	Veliger larva of Bivalve	0	0	0	0	640	480	1120	2.05
24	Zoea larva of Crustaceans	4960	640	2080	2560	5440	1120	16800	30.70
Total Density(no/100m^3		**6400**	**6560**	**5920**	**6400**	**15840**	**13600**	**54720**	**100%**
Total No of Genera/Groups=24									
Biomass		**3.81**	**1.85**	**3.94**	**4.08**	**3.33**	**9.97**		

Table 40. Diversity indices of Zooplankton at different sites of Deendayal Port during Season 1

	Offshore						**Cargo jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1-Control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Control**
Taxa_S	15	10	15	12	14	9	7	10	9	15	14	11	3	8	5	8	14	13
Individuals (Nos/m^2)	11520	13120	11040	10560	9280	7360	10720	13280	8480	10240	11200	10880	6400	6560	5920	6400	15840	13600
Dominance_D	0.16	0.16	0.10	0.10	0.11	0.19	0.20	0.19	0.26	0.13	0.12	0.14	0.63	0.19	0.25	0.26	0.19	0.19
Shannon Diversity	2.23	2.05	2.46	2.38	2.37	1.89	1.72	1.94	1.63	2.35	2.35	2.14	0.69	1.84	1.48	1.65	2.06	1.98
Simpson_1-D	0.84	0.84	0.90	0.90	0.89	0.81	0.80	0.81	0.74	0.87	0.88	0.86	0.37	0.81	0.75	0.75	0.81	0.81
Evenness	0.618	0.773	0.776	0.901	0.766	0.736	0.799	0.698	0.568	0.695	0.745	0.768	0.663	0.784	0.878	0.65	0.559	0.5542
Menhinick	0.140	0.087	0.143	0.117	0.145	0.105	0.068	0.087	0.098	0.148	0.132	0.106	0.038	0.099	0.065	0.100	0.111	0.112
Margalef	1.497	0.949	1.504	1.187	1.423	0.899	0.647	0.948	0.884	1.516	1.394	1.076	0.228	0.797	0.461	0.799	1.344	1.261

6.3.2. Distribution and density of Zooplankton during Season 2

The study was conducted at 3 sites in Deendayal Port area and nearby areas where dredging activities are going on. The three selected study stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

The *Ostracoda, Sponge spicules, Eggs capsules of Littorinids, Euterpina sp (Harpacticoida), Globigerina sp (Foraminifera), Nauplius larva of Copepoda, Nauplius larva of Barnacles, Tintinnopsis radix (Tintinnida), Copepoda egg sacs(pouch)* were the mostly common zooplankton throughout observed in all sites of Offshore points. Highest population density was recorded at site 1D-Offshore (128800 No/100m^3) and lowest in 1-control-Offshore (44000 No/100m^3). **Site** 1B-Offshore has maximum number of species (28 nos) whereas minimum was found in the site 1-control-Offshore (15 nos). High biomass was observed in the site 1Control-Offshore (55.97 ml/100m^3) and low biomass was in site 1E-Offshore (10.17 ml/100m^3). The range of the population density, biomass and number of species were (44000 to 128800 no/100m^3), (10.17 to 55.97 ml/100m^3) and (12 to 33 nos) respectively in all sites. Less observed species are *Ammonia sp* (Foraminifera), *Arcella sp* (Protozoa) *Sagitta sp, Dentilium, Calcarina sp* (Foraminifera), *Spirilina sp* (Foraminifera), Centropages sp (Calanoida) etc. rarely recorded in this station. Total 52 zooplankton was recorded in Offshore station adding that more composition of zooplankton by phylum Crustacea and Foraminifera as shown in Table 41.

Cargo Jetty

The population density of zooplankton varied from 47320 No/100m^3 to 96140 No/100m^3. Maximum density was noticed in site 2C-Cargo Jetty (96140 no/100m^3) and minimum was at site 2Control-Cargo Jetty (47320 no/100m^3) as given in Table 42. The site 2C-Cargo Jetty comprises highest number of species (33 nos) and minimum number of species was observed in site 2B-Cargo Jetty (15 nos). Biomass ranged between 15 to 57.14 ml/100m^3 where highest biomass noted in site 2B-Cargo Jetty and lowest in 2A-Cargo Jetty. Frequently observed species were *Centropages sp* (Calanoida), *Clausocalanus sp* (Calanoida) Zoea larva of Crustacean, *Oithona sp* (Cyclopoida), *Subeucalanus sp* (Calanoida), *Tintinnopsis beroidea* (Tintinnida), Tintinnopsis radix (Tintinnida), and *Egg capsules of Littorinids* whereas less observed species were *Nodosaria sp* (Foraminifera), Copepoda egg sacs(pouch), *Euchaeta sp* (Calanoida), *Diacyclops sp* (Cyclopoida), *Leprotintinnus nordqvistii* (Tintinnida), *Leprotintinnus simplex* (Tintinnida). Total recorded zooplankton was 60 nos. in Cargo Jetty.

Phang Creek

This Creek area was represented by the zooplankton fauna majority of Egg capsule of Littorinids, Nauplius larva of Copepoda, Sponge spicules, Clausocalanus sp (Calanoida), Oithona sp (Cyclopoida), Tintinnopsis beroidea (Tintinnida). **Very** less time or rarely recorded species were Amphipoda, Cibicides sp (Foraminifera), Coccolithophores, Eponidis sp (Foraminifera) The range of zooplankton Biomass was between 0.50 to 30.49 ml/100m^3 . Highest Biomass was recorded in site 3D-Phang creek (30.49 ml/100m^3) and lowest in site 3B-Phang creek (0.50 ml/100m^3). Maximun and Minumum species count was at in site 3A,3C and 3D-Phang creek (25 nos) and 3E-Phang creek (12 nos) respectively. Population density was maximum recorded in site 3C-Phang creek (101600 No/100m^3) and minimum in site 3E-Phang creek (36360 No/100m^3).

Overall assessment of zooplankton showed that the total number of 38 Zooplankton recorded during monsoon season. Out of these (86 nos) zooplankton, 52 zooplankton recorded in Offshore region, 60 zooplankton at Cargo Jetty and 55 zooplankton in Phang Crek region. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea) as presented in Table 43. Protozoa (mainly foraminifera and tintinnids), Porifera (Sponge spicules) Generally zooplankton population dynamics and studies emphasize is given up to group level rather than to species level because of microscopic size of zooplankton so owing to the difficulty in identifying the zooplankton as some species are considered as a group or genus level. The most dominant or frequently observed species were *Clausocalanus sp* (Calanoida), *Egg capsules of Littorinids, Ostracoda, Tintinnopsis radix, Oithona sp* (Cyclopoida), *Zoea larva of Crustacea, Sponge spicules, Globigerina sp (Foraminifera)* and other Foraminifera. The range of Population density, Biomass and Number of Species were (36360 to 128800 no/100 m^3), (0.50 to 57.14 ml/100m^3) and (12 to 33 nos) respectively. **Averag**e high biomass noted at Cargo Jetty followed by Offshore and Phang creek (Table 41,42,43). Highest population density was recorded in site 1D-Offshore(128800 no/100m^3) and lowest was recorded in site 3E-Phang Creek (36360 ,No/100m3). Among all recorded zooplankton, majority dominance occurrence was by the Copepoda, Crustacean larvae, Spong Spicules, Foraminifera (Protozoa), Tintinnids

(Protozoa), Egg capsules of Littorinids (Mollusca). Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda, Mollusca, Protozoa and Poriffera. The Chaetognatha and tunicata groups were only represented by the one species namely Sponge spicules, *Sagitta sp* and *Oikopleura sp* respectively. In Offshore**,** maximum Occurrence (%) was by the Egg Capsules of Littorinids (18.33%) and minimum by the Radiolarian (0.10%). In Cargo Jetty, maximum Percentage of Occurrence (%) by the Eggs of Littorinids (14.31%) and minimum by the Nodosaria sp (0.07%) (Foraminifera).. In Phang Creek maximum Occurrence (%) was by the Egg capsules of Littorinids (12.42%) and minimum (0.08%) by the *Cibicides sp* (Foraminifera).

During analysis, some Species of Foraminifera and Spicules of sponge were frequently observed. These both are very important for paleontological study aspects and also for evolutionary, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Some deep sea species also recorded that is indication of water circulation pattern. Data on zooplankton density, list of zooplankton is shown in Table (41,42,43).

Diversity Indices of Zooplankton

Table 44 shows diversity of zooplankton. The Shannon-wiener diversity index (H') fluctuated between 2.42 to 3.22 indicated moderate to quite high range of diversity with a maximum value in site 2C-Cargo Jetty (3.22) and minimum value in site 3E-Phang creek (2.42). Range of the evenness was 0.514 to 0.938 where highest and lowest recorded in site 3E-Phang Creek (0.938) where lowest density was recorded and 1D-Offshore (0.514) respectively. Highest Simpson index 0.95 noted at site 2C-Cargo Jetty whereas lowest in site 1A (0.88).

Table 41. Density of Zooplankton at Offshore site of Deendayal Port during Season 2

Name of Genera/Group	**1A**	**1B**	**1C**	**1D**	**1E**	**1 Control**	**Individual total density (no/100m^3)**	**% of Occurrence**
Acartia sp (Calanoida)	0	0	5120	0	0	0	5120	1.06
Ammonia sp. (Foraminifera)	0	0	0	0	3360	0	3360	0.70
Arcella sp (Amoebozoa)	0	0	1280	0	0	0	1280	0.27
Bolivina sp.(Foraminifera)	0	0	7040	3360	1440	0	11840	2.46
Calcarina sp. (Foraminifera)	0	0	0	0	800	0	800	0.17
Centropages sp. (Calanoida)	0	1440	0	0	0	0	1440	0.30
Clausocalanus sp (Calanoida)	2560	5120	0	3520	0	0	11200	2.32
Copepoda egg sacs (egg pouch)	0	4320	3840	0	0	6880	15040	3.12
Cyclops sp (Cyclopoida)	0	0	0	6560	0	0	6560	1.36
Cyphonautes larva of bryozoans	640	0	0	0	1920	0	2560	0.53
Dentalium	0	0	0	0	0	640	640	0.13
Diacyclops sp. (Cyclopoida)	5440	1920	0	0	0	0	7360	1.53
Egg Capsules of Littorinids	12480	13120	13920	43040	0	5760	88320	18.33
Eucalanus sp. (Calanoida)	0	0	0	3200	0	0	3200	0.66
Euchaeta sp (Calanoida)	0	0	0	1600	0	0	1600	0.33
Euterpina sp (Harpacticoida)	960	3520	0	0	480	2560	7520	1.56
Eutintinnus apertus (Tintinnida)	0	0	0	2240	1920	0	4160	0.86

Globigerina sp. (Foraminifera)	2720	3520	12320	4640	4160	0	27360	5.68
Labidocera sp. (Calanoida)	0	1120	0	0	0	0	1120	0.23
Larva of Hydrozoa (Phylum: Cnidaria)	0	2880	0	0	3040	1440	7360	1.53
Leprotintinnus nordqvistii (Tintinnida)	0	2080	0	0	2720	0	4800	1.00
Leprotintinnus simplex (Tintinnida)	0	0	0	0	1760	0	1760	0.37
Nauplius larva of Copepoda	1920	3360	1600	0	7360	2720	16960	3.52
Nauplius larva of Harpacticoida	0	0	0	0	0	1600	1600	0.33
Nauplius larvae of Barnacles	2720	2720	0	0	1920	1120	8480	1.76
Nauplius larvae of Crustacea	0	0	0	0	0	4960	4960	1.03
Nonion sp. (Foraminifera)	0	0	0	2240	960	0	3200	0.66
Oithona sp. (Cyclopoida)	0	5120	9120	3520	0	0	17760	3.69
Ophiopluteus larva of (Echinodermata)	1440	0	0	0	1440	0	2880	0.60
Ostracoda	1120	320	2720	0	4640	4640	13440	2.79
Other Calanoida	0	0	0	16960	0	1280	18240	3.78
Other Cyclopoida	0	1440	0	7040	0	0	8480	1.76
Parvocalanus sp (Calanoida)	1760	1920	0	0	0	0	3680	0.76
Quinqueloculina sp.(Foraminifera)	0	10240	0	2720	0	0	12960	2.69
Radiolaria skeleton	320	800	0	320	160	0	1600	0.33
Radiolaria sp (Protozoa)	0	320	0	160	0	0	480	0.10

Rosalina sp. (Foraminifera)	800	1440	3200	4640	4960	0	15040	3.12
Sagitta sp (arrow worm)	1120	0	0	0	0	0	1120	0.23
Small Gastropoda	0	0	0	1280	0	0	1280	0.27
Spirillina sp. (Foraminifera)	0	0	0	0	3360	0	3360	0.70
Spiroloculina sp (Foraminifera)	1440	1920	1760	0	0	0	5120	1.06
Sponge spicules	10880	8480	10240	9920	5760	5920	51200	10.62
Temora sp (Calanoida)	0	0	3040	0	5280	2720	11040	2.29
Thermocyclops sp. (Cyclopoida)	0	0	0	0	3360	0	3360	0.70
Tintinnopsis beroidea (Tintinnida)	3680	0	0	960	0	0	4640	0.96
Tintinnopsis cylindrica (Tintinnida)	1280	4480	4000	2720	0	0	12480	2.59
Tintinnopsis lobiancoi (Tintinnida)	0	2240	0	3680	0	0	5920	1.23
Tintinnopsis orientalis (Tintinnida)	0	2720	5760	0	1280	0	9760	2.03
Tintinnopsis radix (Tintinnida)	1920	1120	5600	2720	1920	0	13280	2.76
Veliger larvae of Bivalve	0	640	3520	1760	0	1760	7680	1.59
Zoea larva of Crustaceans	0	4000	0	0	2880	0	6880	1.43
Unidentified sp.	0	0	640	0	0	0	640	0.13
Total No. Of Genera/Groups =52								
Site-wise Total Density (no/100m^3)	55200	92320	94720	128800	66880	44000	**Total Density =481920**	**100%**
Biomass (ml/100m^3)	**11.24**	**13.38**	**15.67**	**16.91**	**10.17**	**55.97**		

Table 42. Density of Zooplankton at Cargo Jetty site of Deendayal Port during Season 2

Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Individual total density (no/100m^3))	% of Occurrence
Acartia sp (Calanoida)	0	1600	960	800	2080	0	5440	1.27
Acrocalanus sp. (Calanoida)	1920	0	0	1280	0	0	3200	0.75
Bolivina sp.(Foraminifera)	0	0	1920	2240	0	0	4160	0.97
Calcarina sp. (Foraminifera)	0	0	960	960	0	0	1920	0.45
Centropages sp. (Calanoida)	640	2240	1760	960	1760	0	7360	1.72
Clausocalanus sp (Calanoida)	1920	1760	2560	1920	2880	0	11040	2.58
Copepoda egg sacs (egg pouch)	1280	0	0	0	0	0	1280	0.30
Corycaeus sp (Calanoida)	0	0	0	1440	0	0	1440	0.34
Cyphonautes larva of bryozoans	2720	0	0	0	1440	1600	5760	1.35
Diacyclops sp. (Cyclopoida)	0	0	0	1760	0	0	1760	0.41
Egg Capsules of Littorinids	11680	8640	9920	14880	5600	10400	61120	14.31
Euchaeta sp (Calanoida)	0	0	0	0	1440	0	1440	0.34
Euterpina sp (Harpacticoida)	7040	3520	0	2080	2880	0	15520	3.63
Eutintinnus sp. (Tintinnida)	0	0	0	0	1920	0	1920	0.45
Fish larva	0	0	0	0	1120	0	1120	0.26
Globigerina sp. (Foraminifera)	0	0	6400	12480	3360	2400	24640	5.77
Heterolaophonte (Harpacticoida)	0	0	0	0	1760	0	1760	0.41

Larva of Crustacea	0	0	0	0	640	0	640	0.15
Larva of Hydrozoa (Phylum: Cnidaria)	1920	0	300	1440	0	0	3660	0.86
Leprotintinnus nordqvistii (Tintinnida)	0	0	0	1760	0	0	1760	0.41
Leprotintinnus pellucidus (Tintinnida)	0	0	0	1920	1120	0	3040	0.71
Leprotintinnus simplex (Tintinnida)	0	0	0	0	3360	0	3360	0.79
Microsetella sp (Harpacticoida)	0	2520	0	0	0	1760	4280	1.0
Nauplius larva of Calanoida	0	0	3040	0	0	0	3040	0.71
Nauplius larva of Copepoda	0	0	4320	2720	0	0	7040	1.65
Nauplius larvae of Barnacles	4160	0	1760	2240	1760	0	9920	2.32
Nauplius larvae of Cyclopoida	0	0	4000	0	0	0	4000	0.94
Nodosaria sp (Foraminifera)	0	0	320	0	0	0	320	0.07
Oithona brevicornis	0	0	1440	0	0	0	1440	0.34
Oithona sp. (Cyclopoida)	3360	3520	4320	2400	2240	2400	18240	4.27
Ophiopluteus larva of (Echinodermata)	0	0	1440	960	0	0	2400	0.56
Ostracoda	3840	3840	1440	0	0	1720	10840	2.54
Other Calanoida	3040	2720	0	0	0	0	5760	1.35
Other Cyclopoida	1760	0	1280	0	0	0	3040	0.71
Paracalanus sp. (Calanoida)	2240	0	3200	0	0	0	5440	1.27
Parvocalanus sp (Calanoida)	1920	1280	0	1760	0	1920	6880	1.61
Polychaeta larvae (Annelida)	0	2560	0	0	0	0	2560	0.60

Pseudodiaptomus sp (Calanoida)	0	0	0	0	2080	0	2080	0.49
Quinqueloculina sp.(Foraminifera)	0	0	1760	3680	3840	0	9280	2.17
Radiolaria skeleton	0	0	0	0	320	480	800	0.19
Radiolaria sp (Protozoa)	0	0	320	0	160	0	480	0.11
Rosalina sp. (Foraminifera)	0	0	1920	3520	0	800	6240	1.46
Sagitta sp (arrow worm)	0	1600	0	0	0	0	1600	0.37
Small Gastropoda	0	0	1600	0	0	0	1600	0.37
Spirillina sp. (Foraminifera)	0	0	0	320	0	640	960	0.22
Spiroloculina sp (Foraminifera)	0	0	1920	640	2720	1920	7200	1.69
Sponge spicules	16320	8320	7040	0	0	8320	40000	9.36
Subeucalanus (Calanoida)	3360	0	0	1920	1280	1920	8480	1.98
Temora sp (Calanoida)	4640	0	0	0	0	1760	6400	1.75
Tintinnopsis beroidea (Tintinnida)	1920	2560	5280	6240	2720	1600	20320	4.76
Tintinnopsis cylindrica (Tintinnida)	0	0	0	0	0	1440	1440	0.34
Tintinnopsis lobiancoi (Tintinnida)	0	0	0	0	1440	0	1440	0.34
Tintinnopsis mortenseni (Tintinnida)	0	0	800	0	0	0	800	0.19
Tintinnopsis radix (Tintinnida)	2560	0	6400	1760	1920	2240	14880	3.48
Tintinnopsis sp (Tintinnida)	0	0	4960	0	0	1600	6560	1.54
Tintinnopsis tubulosa (Tintinnida)	0	0	2400	3200	0	1920	7520	1.56

Triloculina sp (Foraminifera)	0	0	1280	0	0	0	1280	0.30
Veliger larvae of Bivalve	0	0	2560	1760	3040	0	7360	1.72
Zoea larva of Crustaceans	2080	8480	6560	5120	8960	0	31200	7.30
Unidentified sp.	0	0	0	320	0	480	800	0.19
Total No. Of Genera/Groups =60								
Site-wise Total Density (no/100m^3)	**80320**	**55160**	**96140**	**84480**	**63840**	**47320**	**Total Density =427260**	**100%**
Biomass (ml/100m^3)	**15**	**57.14**	**20**	**27.27**	**20.55**	**41.03**		

Table 43. Density of Zooplankton at Phang Creek site of Deendayal Port during Season 2

Name of Genera/Group	**3A**	**3B**	**3C**	**3D**	**3E**	**3 Control**	**Total density (no/100m3)**	**% of Occurrence**
Acartia sp (Calanoida)	0	0	1440	1440	0	0	2880	0.74
Acrocalanus sp. (Calanoida)	1280	0	2880	0	0	2080	6240	1.60
Amphipoda	0	0	0	800	0	0	800	0.21
Arcella sp (Amoebozoa)	1120	0	0	0	0	0	1120	0.29
Centropages sp. (Calanoida)	2560	0	0	0	0	0	2560	0.66
Cibicides sp (Foraminifera)	0	320	0	0	0	0	320	0.08
Clausocalanus sp (Calanoida)	7360	7200	9920	0	0	4960	29440	7.57
Clytemnestra sp (Harpacticoida)	0	0	0	1120	0	1280	2400	0.62
Cyclops sp (Cyclopoida)	0	960	2240	0	0	0	3200	0.82
Cyphonautes larva of bryozoans	800	0	0	1600	0	0	2400	0.62
Diacyclops sp. (Cyclopoida)	0	0	1440	0	0	1280	2720	0.70
Egg Capsules of Littorinids	9920	7520	12160	3040	4960	10720	48320	12.42
Eponides sp (Foramonifera)	0	800	0	0	0	0	800	0.21
Eucalanus sp. (Calanoida)	1280	2560	0	2080	0	0	5920	1.52
Euterpina sp (Harpacticoida)	0	0	2560	0	3520	3360	9440	2.43
Eutintinnus apertus (Tintinnida)	2400	0	0	800	0	0	3200	0.82
Eutintinnus lususundae (Tintinnida)	0	0	0	0	0	2080	2080	0.53
Eutintinnus sp. (Tintinnida)	1600	0	0	0	0	0	1600	0.41
Gastrula embryo of Seastar	0	0	0	800	0	0	800	0.21

Globigerina sp. (Foraminifera)	0	2560	0	7040	2080	0	11680	3.00
Labidocera sp. (Calanoida)	0	0	800	960	0	800	2560	0.66
Larva of Hydrozoa (Phylum: Cnidaria)	0	800	0	0	0	0	800	0.21
Leprotintinnus nordqvistii (Tintinnida)	1280	1440	0	0	0	0	2720	0.70
Microsetella sp (Harpacticoida)	2080	5440	0	2880	0	0	10400	2.67
Mysis larva	0	1120	0	960	0	0	2080	0.53
Nauplius larva of Copepoda	4800	5120	2080	10080	3360	5760	31200	8.02
Nauplius larvae of Barnacles	2400	3360	5120	3520	0	1760	16160	4.15
Nauplius larvae of Cyclopoida	0	0	0	1760	0	0	1760	0.45
Nonion sp. (Foraminifera)	0	0	0	640	0	0	640	0.16
Oithona sp. (Cyclopoida)	1920	3040	9440	1600	0	4000	20000	5.74
Ophiopluteus larva of (Echinodermata)	0	0	2080	2720	0	1920	6720	1.73
Ostracoda	1440	1280	2880	0	3840	0	9440	2.43
Other Calanoida	0	0	0	1280	0	3200	4480	1.15
Other Cyclopoida	1280	0	2240	0	0	4160	7680	1.97
Paracalanus sp. (Calanoida)	0	0	3680	0	0	0	3680	0.95
Parvocalanus sp (Calanoida)	0	2400	0	0	0	1440	3840	0.99
Planispirinella sp (Foraminifera)	0	0	480	0	0	0	480	0.12
Polychaeta larvae (Annelida)	0	0	2240	0	0	0	2240	0.58

Pontellopsis sp. (Calanoida)	480	0	0	0	0	0	480	0.12
Quinqueloculina sp.(Foraminifera)	5920	1280	0	0	0	2080	9280	2.39
Sagitta sp (arrow worm)	0	0	0	0	1600	0	1600	0.41
Sponge spicules	10880	5280	0	3040	3200	2080	24480	6.29
Subeucalanus (Calanoida)	0	0	0	0	0	2720	2720	0.70
Temora sp (Calanoida)	2720	1280	7520	1120	3520	0	16160	4.15
Textularia sp. (Foraminifera)	0	0	0	1760	0	0	1760	0.45
Tintinnopsis beroidea (Tintinnida)	1440	1440	0	1760	3200	0	7840	2.02
Tintinnopsis cylindrica (Tintinnida)	0	0	6880	0	0	1440	8320	2.14
Tintinnopsis karajacensis (Tintinnida)	0	0	0	0	0	800	800	0.21
Tintinnopsis lobiancoi (Tintinnida)	0	0	2720	0	0	0	2720	0.70
Tintinnopsis orientalis (Tintinnida)	3840	0	8480	0	0	0	12320	3.17
Tintinnopsis radix (Tintinnida)	0	0	0	0	2560	0	2560	0.66
Tintinnopsis tubulosa (Tintinnida)	1920	2400	2080	3360	960	0	10720	2.76
Veliger larvae of Bivalve	0	0	7520	0	0	0	7520	1.93
Zoea larva of Crustaceans	1760	2560	2560	2400	3560	0	12840	3.30
Unidentified sp.	320	0	160	0	0	0	480	0.12
Total No of Genera/ Groups =55								
Site-wise Total Density (no/100m^3)	72800	60160	101600	58560	36360	57920	Total density =387400	100%
Biomass (ml/100m^3)	2.50	0.50	13.57	30.49	19.09	11.59		

Table 44. Diversity indices of Zooplankton at different sites of Deendayal Port during Season 2

Variables	**Offshore**						**Cargo jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	19	28	18	23	24	15	21	15	33	30	27	20	25	22	25	25	12	20
Individuals (Nos/m^2)	55200	92320	94720	128800	66880	44640	80320	55160	96140	84480	63840	47320	72800	60160	101600	58560	36360	59520
Dominance_D	0.12	0.06	0.08	0.15	0.06	0.10	0.09	0.10	0.05	0.08	0.06	0.10	0.08	0.07	0.07	0.07	0.09	0.08
Shannon Diversity	2.50	3.01	2.65	2.47	2.97	2.48	2.72	2.51	3.22	2.98	3.08	2.64	2.87	2.83	2.92	2.94	2.42	2.81
Simpson_1-D	0.88	0.94	0.92	0.85	0.94	0.90	0.91	0.90	0.95	0.92	0.94	0.90	0.92	0.93	0.93	0.93	0.91	0.92
Evenness	0.639	0.722	0.786	0.514	0.813	0.795	0.726	0.818	0.755	0.655	0.802	0.701	0.705	0.773	0.740	0.754	0.938	0.792
Menhinick	0.081	0.092	0.058	0.064	0.093	0.071	0.074	0.064	0.106	0.103	0.107	0.092	0.093	0.090	0.078	0.103	0.063	0.086
Margalef	1.649	2.362	1.484	1.87	2.07	1.308	1.771	1.282	2.789	2.556	2.35	1.765	2.144	1.908	2.082	2.186	1.047	1.819

6.3.3. Distribution and density of Zooplankton during Season 3

Offshore

The *Ostracod, Euterpina sp (Harpacticoida), Globigerina sp (Foraminifera), Nauplius larva of Copepoda, Tintinnopsis orientalis (Tintinnida), Copepoda egg sacs(pouch), Veliger larva of Bivalve, Sagitta sp (arrow worm), Zoea larva of Decapoda, Polychaeta worms*, Cyphonautes larva of bryozoans, *Cyclops sp* (Cyclopoida), Clausocalanus sp (Calanoida) were the mostly common zooplankton throughout observed in all sites of Offshore points. Highest population density was recorded at site 1A-Offshore (251520 No/100m^3) where also number of species highest recorded (37) and lowest density in 1D-Offshore (50400 No/100m^3) where number of species recorded lowest numbers (24). High biomass was observed in the site 1C-Offshore (22.11 ml/100m^3) and low biomass was in site 1E-Offshore (8.63 ml/100m^3). The range of the population density, biomass and number of species were (50400 to 251520no/100m^3), (8.63 to 22.11 ml/100m^3) and (24 to 37 nos) respectively in all sites. Less observed species are *Elphidium sp* (Foraminifera), Fish larva, *Centropages sp (Calanoida), Tortanus sp (Calanoida), Calocalanus sp (Calanoida), Acrocalanus sp (Calanoida), Diacyclops sp (Cyclopoida), Eutintinnus sp (Tintinnida*) etc. rarely recorded in this station. Total 68 zooplankton was recorded in Offshore station adding that more composition of zooplankton by phylum Crustacea and Tintinnids and Echinodermata.

Cargo Jetty

The population density of zooplankton varied from 11680 No/100m^3 to 85440 No/100m^3. Maximum density was noticed in site 2A-Cargo Jetty (85440no/100m^3) and minimum was at site 2D-Cargo Jetty (11680no/100m^3). The site 2A-Cargo Jetty comprises highest number of species (36nos) and minimum number of species was observed in site 2D-Cargo Jetty (12nos). Biomass ranged between 1.06 to 17.88 ml/100m^3 where highest biomass noted in site2A-Cargo Jetty and lowest in 2D-Cargo Jetty. Frequently observed species were *Copepoda egg sacs, Euterpina sp (Harpacticoida), Globigerina sp (Foraminifera), Nauplius larva of Barnacles, Ophiopluteus larva of Echinodermata, Other Cyclopoida, Zoea larva of Decapoda* etc. whereas less observed species were *Acartia sp (Calanoida), Ammonia sp (Foraminifera), Attheyella sp (Harpacticoida*), *Calocalanus sp (Calanoida), Daphnia sp, Trilloculina sp (Foraminifera), Spirillina sp (Foraminifera), Parvocalanus sp (Calanoida), Stentor sp (Protozoa)* . Total recorded zooplankton was 63 in Cargo Jetty.

Phang Creek

This Creek area was represented by the zooplankton fauna majority of *Nauplius larva of Crustacea, Sponge spicules, Clausocalanus sp (Calanoida), Copepoda egg sacs, Tintinnopsis beroidea (Tintinnida), Globigerina sp (Foraminifera), Leprotintinnus pellucidus (Tintinnida), Ostracoda, Polychaeta worms, Temora sp (Calanoida), Tintinnopsis orientalis (Tintinnida), Tintinnopsis tubulosa) (Tintinnida).* Very less time or rarely recorded species were *Amphipoda, Nonion sp (Foraminifera), Bolivina sp(Foraminifera), Amphistegina sp (Foraminifera) Eponidis sp (Foraminifera), Egg capsules of Littorinids, Diacyclops (Cyclopoida), Paracalanus sp (Calanoida), Tintinnopsis karajacensis (Tintinnida).* The range of zooplankton Biomass was between 0.50 to 30.49 ml/100m^3. Highest Biomass was recorded in site 3D-Phang creek (34 ml/100m^3) and lowest in site 3B-Phang creek (7.59 ml/100m^3). Maximun and Minumum species count was at in site 3D-Phang creek (31nos) and 3A-Phang creek (20nos) respectively. Population density was maximum recorded in site 3Control-Phang creek (63840 No/100m^3) and minimum in site 3B-Phang creek (44960 No/100m^3).

Overall assessment of zooplankton showed that the total number of 94 Zooplankton recorded during monsoon season. Out of these (94 nos) zooplankton, 68 zooplankton recorded in Offshore region, 63 zooplankton at Cargo Jetty and 58 zooplankton in Phang Crek region. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea), , Protozoa (mainly foraminifera and tintinnids), Porifera (Sponge spicules) and Larva of Echinodermata. Generally zooplankton population dynamics and studies emphasize is given up to group level rather than to species level because of microscopic size of zooplankton so owing to the difficulty in identifying the zooplankton as some species are considered as a group or genus level. The most dominant or frequently observed species were *Clausocalanus sp* (Calanoida), *Cyclops sp (Cyclopoida), Ostracoda, different species of Tintinnopsis, Nauplius larva of Barnacles,, Zoea larva of Decapoda, Globigerina sp (Foraminifera), different species of Foraminifera, Sagitta sp (arrow worms), Veliger larva of Bivalves, Copepoda egg sacs*. The range of Population density, Biomass and Number of Species were (11680 to 251520 no/100 m^3), (1.06 to 34 ml/100m^3) and (12 to 37nos) respectively. Average high biomass noted at Offshore followed by Phang creek and Cargo Jetty (Table 45, 46, 47). Highest population density was recorded in site 1A-Offshore (251520 no/100m^3) and lowest was recorded in site 2D-Cargo Jetty (11680 No/100m3).

Among all recorded zooplankton, majority dominance occurrence was by the Copepoda, Crustacean larvae, Spong Spicules, Foraminifera (Protozoa), Tintinnids (Protozoa), Egg capsules of Littorinids (Mollusca). Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda, Mollusca, Protozoa, Poriffera and Echinodermata. The Chaetognatha and Tunicata groups were only represented by the one species namely *Sagitta sp* and *Oikopleura sp* respectively. In Offshore**,** maximum Occurrence (%) was by the Leprotintinnus nordqvistii (Tintinnida) (14.29%) and minimum by the Egg Capsules of Littorinids and Dentalium (0.05%). In Cargo Jetty, maximum Percentage of Occurrence (%) by the Foraminifera (8.40%) and minimum by the Unidentified sp (0.12%). In Phang Creek maximum Occurrence (%) was by the Leprotintinnus pellucidus (Tintinnida) (13.20%) and minimum (0.10%) by the Unidentified sp, Unidentified crustacean, Labidecera sp, Eucalanus sp, Eponides sp (Foraminifera).

During analysis, some Species of Foraminifera and Spicules of sponge were frequently observed. These both are very important for paleontological study aspects and also for evolutionary, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Some deep sea species also recorded that is indication of water circulation pattern. Data on zooplankton density, list of zooplankton is shown in Tables 45-47.

Diversity Indices of Zooplankton

Table 48 shows diversity indices of zooplankton species observed in the samples. The Shannon-wiener diversity index (H’) fluctuated between 2.29 to 3.34 indicated moderate to quite high range of diversity with a maximum value in site 1E-Offshore (3.34) and minimum value in site 2D-Cargo Jetty (2.29). Range of the evenness was 0.60 to 0.88 where highest and lowest recorded in site 1E-Offshore and 2E-Cargo Jetty (0.88) and 3A-Phang Creek (0.60) respectively. Range of Simpson index was 0.87 to 0.95 (Table 48).

Table 45. Density of Zooplankton at Offshore site of Deendayal Port during Season 3

Name of Genera/Group	1A	1B	1C	1D	1E	1 Control	Individual total density (no/100m^3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	2560	1120	0	0	0	0	3680	0.56
Acrocalanus sp (Calanoida)	0	0	0	0	0	2080	2080	0.32
Ammonia beccarii (Foraminifera)	0	0	0	1440	0	0	1440	0.22
Calcarina sp (Foraminifera)	0	7520	0	1600	0	0	9120	1.38
Calocalanus sp (Calanoida)	0	0	0	0	0	1440	1440	0.22
Centropages sp. (Calanoida)	2720	0	0	0	0	0	2720	0.41
Cibicides sp (Foramonifera)	0	0	0	1440	1920	0	3360	0.51
Clausocalanus sp (Calanoida)	25760	11520	11840	5440	6720	5920	67200	10.20
Clytemnestra sp (Harpacticoida)	1440	0	1440	0	0	0	2880	0.44
Copepoda eggs sacs (pouch)	1920	4480	3360	0	3360	1440	14560	2.21
Corycaeus sp (Calanoida)	1280	0	0	0	0	0	1280	0.19
Cyclops sp (Cyclopoida)	15520	4640	5120	3520	3360	2560	34720	5.27
Cyphonautes larvaof bryozoan	4640	2720	3840	0	1760	0	12960	1.97
Dentalium	0	0	0	0	0	320	320	0.05
Diacyclops sp (Cyclopoida)	12960	0	0	0	0	0	12960	1.97
Discorbis sp (Foraminifera)	0	4160	0	0	0	0	4160	0.63
Egg capsules of	0	320	0	0	0	0	320	0.05

Littorinids								
Elphidium sp (Foraminifera)	0	0	2240	0	0	0	2240	0.34
Eponides sp (Foraminifera)	0	0	0	0	1760	0	1760	0.27
Eucalanus sp (Calanoida)	0	0	3200	0	1120	0	4320	0.66
Euterpina sp. (Harpacticoida)	8640	480	5440	1280	640	0	16480	2.50
Eutintinnus sp (Tintinnida)	0	0	0	0	480	0	480	0.07
Fish larva	0	0	1440	0	0	0	1440	0.22
Globigerina sp (Foraminifera)	960	3520	1120	0	3520	0	9120	1.38
Labidocera sp. (Calanoida)	2080	0	1280	0	0	0	3360	0.51
Larva of Hydrozoa (Phylum: Cnidaria)	1600	640	0	0	2400	0	4640	0.70
Leprotintinnus nordqvistii (Tintinnida)	0	640	0	0	0	0	640	14.29
Leprotintinnus pellucidus (Tintinnida)	0	0	0	0	3520	0	3520	0.53
Microsetella sp (Harpacticoida)	0	0	3520	0	0	0	3520	0.53
Nauplius larvae of Barnacles	6240	1920	0	2560	800	2880	14400	2.19
Nauplius larvae of Copepoda	13120	6880	4960	2560	3360	3200	34080	5.17
Nauplius larvae of Crustacea	8160	0	0	0	3200	3200	14560	2.21
Nauplius larvae of Cyclopoida	3680	0	0	0	1440	0	5120	0.78
Nonion sp (Foraminifera)	0	0	0	0	1120	0	1120	0.17
Oithona attenuata (Cyclopoida)	0	0	4640	0	2880	1280	8800	1.34
Oithona similis	6880	0	0	0	0	0	6880	1.04

Oithona sp (Cyclopoida)	10720	1600	3040	2880	0	3680	21920	3.33
Ophiopluteus Larva (Echinodermata)	4320	3040	2080	1440	3040	1440	15360	2.33
Ostracoda	1760	6400	2080	1600	2400	2400	16640	2.53
Other Calanoida	0	0	0	1120	0	800	1920	0.29
Other Foraminifera	0	0	4960	5760	3680	4640	19040	2.89
Paracalanus sp (Calanoida)	14560	0	2560	2080	0	2080	21280	3.23
Parvocalanus sp (Calanoida)	9920	0	0	0	3360	0	13280	2.02
Polychaete larva (Annelida)	11520	3840	5920	1760	2080	0	25120	3.81
Protozoean larva (Decapoda)	6080	0	1920	0	3360	0	11360	1.72
Pseudodiaptomus sp. (Calanoida)	5920	0	1280	960	0	1120	9280	1.41
Quinqueloculina sp. (Foraminifera)	11680	0	0	0	2080	800	14560	2.21
Radiolaria skeleton	0	480	0	0	0	0	480	0.07
Rosalina sp (Foraminifera)	0	2560	0	0	0	1440	4000	0.61
Sagitta sp (arrow worm)	1280	0	2560	2080	1440	1600	8960	1.36
Small Gastropoda	0	0	3360	0	0	0	3360	0.51
Spiroloculina sp (Foraminifera)	0	7840	0	0	3040	1760	12640	1.92
Sponge Spicules	1920	1600	1920	0	0	1600	7040	1.07
Subeucalanus sp (Calanoida)	10080	0	0	0	0	0	10080	1.53
Temora sp (Calanoida)	10080	1440	1920	0	0	0	13440	2.04
Tintinnopsis beroidea (Tintinnida)	1280	1280	0	0	0	0	2560	0.39
Tintinnopsis cylindrica (Tintinnida)	0	7200	0	0	1440	0	8640	1.31
Tintinnopsis karajacensis (Tintinnida)	0	0	0	1120	0	0	1120	0.17

Tintinnopsis orientalis (Tintinnida)	10560	5920	4160	2240	2080	1440	26400	4.01
Tintinnopsis sp (Tintinnida)	2720	2400	0	0	0	0	5120	0.78
Tintinnopsis tubulosa (Tintinnida)	0	2720	0	1440	0	0	4160	0.63
Tortanus sp. (Calanoida)	0	0	0	0	0	800	800	0.12
Triloculina sp. (Foraminifera)	0	0	0	1920	0	0	1920	0.29
Veliger larvae of Bivalve	2240	7040	9440	1760	1760	1600	23840	3.62
Zoea larva of Decapoda	14240	1760	14880	1440	960	2720	36000	5.47
Unidentified Calanoida	480	0	0	0	0	0	480	0.07
Unidentified Copepoda	0	0	1280	960	1920	640	4800	0.73
Unidentified larva	0	0	1280	0	0	0	1280	0.19
Total No. Of Genera/Groups =68								
Site-wise Total Density (no/100m^3)	**251520**	**107680**	**118080**	**50400**	**76000**	**54880**	**Total Density =658560**	**100%**
Biomass (ml/100m^3)	**18.23**	**13.64**	**22.11**	**9.62**	**8.63**	**19.09**		

Table 46. Density of Zooplankton at Cargo Jetty site of Deendayal Port during Season 3

Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Individual total density (no/100m^3))	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	1280	0	0	0	0	0	1280	0.49
Ammonia sp (Foraminifera)	0	0	0	0	0	4480	4480	1.71
Attheyella sp (Harpacticoida)	960	0	0	0	0	0	960	0.37
Calcarina sp (Foraminifera)	960	0	0	0	0	0	960	0.37
Calocalanus sp (Calanoida)	0	0	0	0	0	960	960	0.37
Centropages sp. (Calanoida)	0	0	0	0	0	640	640	0.24
Clausocalanus sp (Calanoida)	1440	10880	7040	0	960	1280	21600	8.22
Copepoda eggs sacs (pouch)	3360	1440	960	0	0	0	5760	2.19
Corycaeus sp (Calanoida)	0	1120	0	0	0	0	1120	0.43
Cyclops sp (Cyclopoida)	0	2880	2400	0	0	0	5280	2.01
Cyphonautes larvaof bryozoan	0	0	2080	0	0	0	2080	0.79
Daphnia sp	0	800	0	0	0	0	800	0.30
Diacyclops sp (Cyclopoida)	0	1440	0	0	0	0	1440	0.55
Discorbis sp (Foraminifera)	1120	0	0	0	0	0	1120	0.43
Elphidium sp (Foraminifera)	0	0	0	0	0	640	640	0.24
Euterpina sp. (Harpacticoida)	1120	640	1600	2720	320	1600	8000	3.05
Fish larva	0	0	960	0	0	800	1760	0.67
Globigerina sp (Foraminifera)	6560	0	1600	320	1920	800	11200	4.26
Leprotintinnus nordqvistii (Tintinnida)	1760	0	0	800	0	0	2560	0.97
Leprotintinnus sp (Tintinnida)	0	0	1440	0	0	0	1440	0.55
Mesochra sp (Harpacticoida)	0	800	1120	0	0	0	1920	0.73

Microsetella sp (Harpacticoida)	0	800	1920	0	0	0	2720	1.04
Nauplius larvae of Barnacles	1600	2240	1920	0	0	1760	7520	2.86
Nauplius larvae of Copepoda	5120	7040	2720	0	1280	0	16160	6.15
Nauplius larvae of Crustacea	0	5440	2560	800	0	3360	12160	4.63
Nauplius larvae of Cyclopoida	0	1600	0	0	0	0	1600	0.61
Oikopleura sp (Tunicata)	1120	0	0	0	0	0	1120	0.43
Oithona nana (Cyclopoida)	0	0	0	0	0	960	960	0.37
Oithona sp (Cyclopoida)	0	4960	2880	0	640	2080	10560	4.02
Ophiopluteus Larva (Echinodermata)	1440	1120	1440	0	1440	1440	6880	2.62
Ostracoda	6240	0	1440	0	0	1760	9440	3.59
Other Calanoida	1440	0	0	0	2080	1920	5440	2.07
Other Cyclopoida	1440	2080	1600	1440	0	960	7520	2.86
Other Foraminifera	13280	0	4320	0	1760	2720	22080	8.40
Other Harpacticoida	0	0	0	1440	0	0	1440	0.55
Paracalanus sp (Calanoida)	1440	0	0	0	0	960	2400	0.91
Parvocalanus sp (Calanoida)	960	0	0	0	0	0	960	0.37
Polychaete larva (Annelida)	800	1760	0	0	0	0	2560	0.97
Protozoean larva (Decapoda)	3520	0	0	0	0	0	3520	1.34
Quinqueloculina sp. (Foraminifera)	0	2240	2080	1120	800	0	6240	2.38
Radiolaria skeleton	0	0	0	0	800	960	1760	0.67
Rosalina sp (Foraminifera)	0	0	480	640	0	1440	2560	0.97
Rotifera	3520	1760	1280	800	0	0	7360	2.80
Sagitta sp (arrow worm)	1280	1920	1280	0	0	0	4480	1.71

Small Gastropoda	1120	0	320	0	0	0	1440	0.55
Spirillina sp. (Foraminifera)	0	0	0	0	640	480	1120	0.43
Spiroloculina sp (Foraminifera)	1440	0	0	160	0	0	1600	0.61
Sponge Spicules	960	1600	1280	0	0	0	3840	1.46
Subeucalanus sp (Calanoida)	2080	0	0	0	0	0	2080	0.79
Stentor sp (Ciliates)	0	0	800	0	0	0	800	0.30
Temora sp (Calanoida)	800	1600	0	0	0	0	2400	0.91
Thalassiosira punctigera	2240	0	0	0	0	0	2240	0.85
Tintinnopsis cylindrica (Tintinnida)	1440	0	2080	0	0	0	3520	1.34
Tintinnopsis orientalis (Tintinnida)	6080	0	2080	0	800	0	8960	3.41
Tintinnopsis sp (Tintinnida)	0	2560	480	0	0	0	3040	1.16
Tintinnopsis tubulosa (Tintinnida)	1440	2560	0	640	0	320	4960	1.89
Triloculina sp. (Foraminifera)	0	0	0	0	0	960	960	0.37
Veliger larvae of Bivalve	1920	0	640	0	0	0	2560	0.97
Zoea larva of Decapoda	2080	800	320	800	320	0	4320	1.64
Unidentified		0	320	0	0	0	320	0.12
Unidentified Calanoida	640	0	0	0	0	0	640	0.24
Unidentified Copepoda	1440	640	640	0	0	480	3200	1.22
Unidentified Crustacea	0	320	0	0	960	0	1280	0.49
Total No. Of Genera/Groups =63								
Site-wise Total Density (no/100m^3)	**85440**	**63040**	**54080**	**11680**	**14720**	**33760**	**Total Density =262720**	**100%**
Biomass (ml/100m^3)	**17.78**	**7.14**	**4.44**	**1.06**	**1.11**	**5.56**		

Table 47. Density of Zooplankton at Phang Creek site of Deendayal Port during Season 3

Name of Genera/Group	3A	3B	3C	3D	3E	3 Control	Total density (no/100m3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	1760	1280	0	1120	0	1280	5440	1.64
Amphistegina sp (Foraminifera)	0	0	0	480	0	0	480	0.14
Bolivina sp (Foraminifera)	0	1600	0	0	0	0	1600	0.48
Centropages sp. (Calanoida)	0	640	0	0	0	1120	1760	0.53
Clausocalanus sp (Calanoida)	0	0	1760	2560	4960	5760	15040	4.53
Copepoda eggs sacs (pouch)	1760	2080	0	2560	2240	3520	12160	3.66
Cyclops sp (Cyclopoida)	0	0	1440	1440	0	1600	4480	1.35
Cyphonautes larvaof bryozoan	0	1440	0	0	0	0	1440	0.43
Diacyclops sp (Cyclopoida)	0	800	0	0	0	0	800	0.24
Egg capsules of Littorinids	0	0	0	0	0	1280	1280	0.39
Eponides sp (Foraminifera)	0	320	0	0	0	0	320	0.10
Eucalanus sp (Calanoida)	0	0	0	320	0	0	320	0.10
Euterpina sp. (Harpacticoida)	0	0	2240	0	160	0	2400	0.72
Eutintinnus apertus (Tintinnida)	0	0	0	640	0	0	640	0.19
Eutintinnus sp (Tintinnida)	320	0	0	0	0	320	640	0.19
Globigerina sp (Foraminifera)	2400	2560	3200	3840	2720	1600	16320	4.91
Labidocera sp. (Calanoida)	0	0	0	0	320	0	320	0.10
Lagena sp (Foraminifera)	0	800	0	0	0	0	800	0.24
Leprotintinnus nordqvistii (Tintinnida)	2560	800	0	0	0	0	3360	1.01
Leprotintinnus pellucidus (Tintinnida)	13280	3520	7360	6560	5600	7520	43840	13.20

Loxostomum sp (Foraminifera)	0	1440	1760	0	0	0	3200	0.96
Microsetella sp (Harpacticoida)	0	0	0	480	0	0	480	0.14
Nauplius larvae of Barnacles	0	2720	1760	2560	3200	3200	13440	4.05
Nauplius larvae of Crustacea	960	960	1600	3200	3200	2080	12000	3.61
Nonion sp (Foraminifera)	0	0	0	320	0	0	320	0.10
Oithona sp (Cyclopoida)	0	0	0	2240	2880	2080	7200	2.17
Ophiopluteus Larva (Echinodermata)	0	0	0	960	0	0	960	0.29
Oscillatoria sp	0	0	1280	0	0	0	1280	0.39
Ostracoda	1440	1920	1600	3200	3200	0	11360	3.42
Other Calanoida	0	1280	960	0	2240	1920	6400	1.93
Other Cyclopoida	0	0	0	0	1440	1760	3200	0.96
Other Foraminifera	2080	4000	2080	1920	3360	0	13440	4.05
Paracalanus sp (Calanoida)	0	0	0	0	1600	0	1600	0.48
Parvocalanus sp (Calanoida)	0	0	0	0	0	640	640	0.19
Planispirinella sp (Foraminifera)	0	0	800	0	0	0	800	0.24
Polychaete larva (Annelida)	3200	1280	800	1600	2240	3360	12480	3.76
Pseudodiaptomus sp. (Calanoida)	0	960	480	0	0	0	1440	0.43
Quinqueloculina sp. (Foraminifera)	960	1760	0	2240	0	960	5920	1.78
Radiolaria skeleton	0	0	0	960	0	0	960	0.29
Rosalina sp (Foraminifera)	2560	0	0	1760	1920	0	6240	1.88
Sagitta sp (arrow worm)	2400	1440	0	1280	2080	2080	9280	2.79
Sponge Spicules	14880	1920	4000	1080	6080	5760	33720	10.15
Temora sp (Calanoida)	1600	1280	0	960	2560	2080	8480	2.55

Textularia sp (Foraminifera)	0	0	0	160	0	0	160	0.05
Tintinnids	0	0	0	1920	0	2080	4000	1.20
Tintinnopsis beroidea (Tintinnida)	0	2400	0	0	1280	0	3680	1.11
Tintinnopsis cylindrica (Tintinnida)	2080	0	1760	0	0	0	3840	1.16
Tintinnopsis karajacensis (Tintinnida)	0	0	0	0	0	1280	1280	0.39
Tintinnopsis orientalis (Tintinnida)	2080	1280	1440	3200	4320	2240	14560	4.38
Tintinnopsis radix (Tintinnida)	0	0	0	0	0	2560	2560	0.77
Tintinnopsis rotundata (Tintinnida)	0	3360	1440	0	0	0	4800	1.45
Tintinnopsis sp (Tintinnida)	2400	0	4800	3040	2400	3520	16160	4.87
Tintinnopsis tubulosa (Tintinnida)	1120	1120	1280	640	480	2240	6880	2.07
Triloculina sp. (Foraminifera)	0	0	1920	0	1280	0	3200	0.96
Veliger larvae of Bivalve	0	0	0	0	960	0	960	0.29
Zoea larva of Decapoda	320	0	800	0	0	0	1120	0.34
Unidentified	0	0	0	320	0	0	320	0.10
Unidentified Crustacea	0	0	0	320	0	0	320	0.10
Total No. Of Genera/Groups =58								
Site-wise Total Density (no/100m^3)	**60160**	**44960**	**46560**	**53880**	**62720**	**63840**	**Total density =332120**	**100%**
Biomass (ml/100m^3)	**15.71**	**7.59**	**8.57**	**34**	**18.25**	**13.01**		

Table 48. Diversity indices of Zooplankton at different sites of Deendayal Port during Season 3

	Offshore						**Cargo jetty**						**Phang Creek**					
	1A	**1B**	**1C**	**1D**	**1E**	**1-Cont**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-Cont**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-Cont**
Taxa_S	37	30	31	24	32	27	36	27	32	12	14	24	20	27	23	31	25	26
Individuals (Nos/m^2)	251520	107680	118080	50400	76000	54880	85440	63040	54080	11680	14720	33760	60160	44960	46560	53880	62720	63840
Dominance_D	0.05	0.05	0.05	0.06	0.04	0.05	0.06	0.07	0.05	0.12	0.09	0.06	0.13	0.05	0.07	0.05	0.05	0.06
Shannon Diversity	3.29	3.11	3.18	3.04	3.34	3.12	3.24	2.95	3.23	2.29	2.51	2.98	2.49	3.16	2.92	3.15	3.03	3.06
Simpson_1-D	0.95	0.95	0.95	0.94	0.96	0.95	0.94	0.93	0.95	0.88	0.91	0.94	0.87	0.95	0.93	0.95	0.95	0.94
Evenness	0.72	0.75	0.77	0.87	0.88	0.84	0.71	0.71	0.79	0.82	0.88	0.82	0.60	0.87	0.81	0.75	0.83	0.82
Menhinick	0.07	0.09	0.09	0.11	0.12	0.12	0.12	0.11	0.14	0.11	0.12	0.13	0.08	0.13	0.11	0.13	0.10	0.10
Margalef	2.90	2.50	2.57	2.12	2.76	2.38	3.08	2.35	2.85	1.18	1.36	2.21	1.73	2.43	2.05	2.75	2.17	2.26

Chapter 7 Management Plan

Dredging is the major activity that increases water turbidity and suspended load thereby impacting plankton and productivity. Very high prevailing sedimentation in the Deendayal region necessitates huge quantity of maintenance dredging. A typical by product of dredging activities is the resuspension of sediments into the water column, which have effects on marine organisms. Further Dredging related suspended sediment plumes may differ in scope, timing, duration and intensity from those natural conditions, thus potentially causing conditions not normally experienced by the organisms (Snigdha, 2005). Effects of suspended sediments are highly species-specific and can vary greatly (Clarke and Wilber, 2000). Increase in suspended materials in the water column will diminish the light penetration with potential adverse effects on the photosynthetic capability of phytoplankton and other aquatic plants (Iannuzzi et al., 1996).

In general a comprehensive dredging management plan should be considered for any port environment so as to ensure that the project activities should be carried out with No or a very minimal effects to the environment. Dredging is the activity of removal of the substratum settled at the bottom of the water body. Dredging is carried out to deepen the water column for the smooth transport of vessels in the port area, particularly the navigation canal. The dredging process is intended to remove the soil or sediment which a complex constituted by a mixture of sand, clay and decomposing solid materials and a large number of benthic organisms. Further, in case of a marine environment, various physical characteristics including total suspended solids and turbidity plays a major role in affecting the water column which in turn affects the marine organisms. During dredging activities, there is a high chance of dispersal of suspended sediment load gets mixed up in the water column, thereby increasing the load of TSS.

Over the past few years, dredging has been practiced as a solution to upgrading the infrastructure to enable economic growth of the port and harbors in India however, the programme needs proper planning to achieve the objectives without environmental implications through adoption of proper management plans. Shifting and dislodging the sediment substratum at the bottom of coastal environment no doubt brings habitat loss to the communities which inhabit as well as those found in the water above for quite a long time and the management plan should include the following objectives.

1. Dredging should be undertaken in such a way that it does not harm the marine organisms breeding especially the ones which are economically important.
2. Dredging activities during bad weather conditions should be avoided.
3. Implementation of the use of suction dredger instead of bucket dredger can be a better option.
4. Dewatering of the fines suspended matter through sediment traps can be followed.
5. Dredging activity areas should be screened for the presence of presence of RET Species which are indigenous to the Gulf of Kachchh region.
6. Turbidity curtains, nowadays, are increasingly used during dredging operations as suggested by Researchers (Sawaragi, 1995; Elander and Hammar, 1998; Otoyo, 2003; Dreyer, 2006; Guo *et al.*, 2009; Ishizaki and Rikitake, 2010; Ueno, 2010, Trang and Keat, 2010) which could also be attempted based on its operational convenience. Moreover various other factors such as current speed, water depth and wave heights to be considered as these also play role in the efficiency of Turbidity curtains. Turbidity curtains allow suspended sediments to settle out of the water column in the dredging spot thus minimizing sediment transport towards the shore. Constructed with thermoplastic material, they serve as a primary method to control turbidity in dredging sites. There are various types of curtains like floating, hanging, solid diversion baffles and permeable and impermeable screens. However, they have proved to be an effective method to contain sediment load in ecologically sensitive areas such as mangroves and corals during dredging operations.
7. In order to ameliorate the likely impacts due to sediment load through changes in operational procedure such as appropriately timing the operation in tune with tides and tidal current direction) may be considered.
8. Similar to the current practice being followed, disposal of dredged materials continued to be done only in pre-designated sites.
9. The initial screening for evaluating disposal options is based on physical and chemical analysis for geotechnical character and the presence of contaminants in the sediments. Depending on the physical and chemical character of the dredged material, disposal may be confined, unconfined or treated prior to release in open water, along the shoreline, or on land.
10. Evaluation of the physical/chemical characteristics of dredged material that is dumped at the site to avoid and minimize potential impacts to the marine environment

that endanger the health of human through biomagnification and economic loss to the fishery sector.

11. To mitigate potential contaminant passing from the port area, it should be addressed through proper design of storm water handling and treatment facilities; placement of sewage and wastewater outfalls; compatibility of local land use (e.g. proximity of agriculture fields or mining operations), procedures for handling hazardous materials and types of industries permitted to operate in the port area.
12. Many management measures such as enhancing the biodiversity of the intertidal / subtidal areas by means of artificial reef structures and controlling water column turbidity by deploying mechanisms to trap silts arising out of dredging activity may be better options which can be implemented by the port authorities.
13. A program for monitoring the site of dredging as well as the site of dumping the material on regular basis depending the quantity of the material to be disposed, the presence of contaminants at the new site. The main purpose of a disposal site monitoring program is to determine whether dredged material site management practices, including disposal operations, at the site need to be changed to avoid unreasonable degradation or endangerment of human health or welfare or the marine environment.
14. The Bioavailability of the expected contaminants and their toxicity at the different life stages of important bioresources which are commercially important.
15. At the site designation stage, the emphasis is on selecting a site where disposal will not have a significant adverse impact on various amenities such as fisheries, coral reefs, endangered species, or on other uses of the marine environment.
16. There should be proper documentation of all data on the use of the site for inclusion in the site management plan or permits authorizing site usage from the Central and state government authorities.

Further, there are three elements which can act as building blocks for developing site management plans are

a. The disposal site's characteristics, as defined during the site designation process.
b. Compliance with the ocean dumping criteria, including the results of effects-based testing of the proposed dredged material; and
c. The ability to manage the disposal operation and monitor the site for changes.

Site management plans facilitate management action by the statutory bodies and whenever the site management plan is developed, it should be prepared jointly by the concerned bodies as well as the state or local government for managing the ocean dredged material disposal site. The site management plan should provide a clear, concise statement of management objectives and an overview of its purpose and function.

The focus and intensity of site management activities are likely to vary on a case-by-case basis and site management roles and responsibilities may change.

Disposal history information for management plan implementation requires

- Known historical uses of the proposed disposal site.
- Transportation and disposal methods use
- Monitoring findings.
- Enforcement activities.

A monitoring program should have the ability to detect environmental change and assist in determining regulatory and permit compliance. For which the program should be designed to provide the following:

(1) Information indicating whether the disposal activities are occurring in compliance with the permit and site restrictions

(2) Information indicating the short-term and long-term fate of materials disposed of in the marine environment

(3) Information concerning the short-term and long-term environmental impacts of the disposal.

Disposal site monitoring is a key component of site management. Continuous monitoring of all physical, chemical, and biological parameters and resources in and around a typical disposal site is not necessary. Monitoring programs should be structured to address specific questions (null hypotheses) and measure the conditions of key indicators and endpoints, particularly those identified during site designation, or major project-specific issues that arise.

The most effective monitoring programs for ocean disposal sites evaluate the fate and effect of dredged material disposal and its utilization following proper technology such as shoreline strengthening structures, artificial reefs, reclamation and restoration of coastal habitats and beach recharge activities. Discharge point and allowable tolerances in position; Debris removal provisions; Provisions to address spillage, and leakage of dredged material; Inspection and surveillance provisions and Record-keeping and reporting requirements should be incorporated in the plan.

The management plan should consider the anticipated use of the site over the long term, including the anticipated closure date for the site, if applicable, and any need for management of the site after the closure of the site. This can be achieved through Long-term Maintenance Dredging Management Plan (LMDMP) to document the status of responsibilities for managing natural sediment accumulation at the Port, in a way that ensures the safe and efficient operation of the Port and the ongoing protection of local environmental values.

Chapter 8 Conclusion and Recommendation

A typical by product of dredging activities is the resuspension of sediments into the water column, which have effects on marine organisms.Further Dredging related suspended sediment plumes may differ in scope, timing, duration and intensity from those natural conditions, thus potentially causing conditions not normally experienced by the organisms (Snigdha, 2005). Effects of suspended sediments are highly species-specific and can vary greatly (Clarke and Wilber, 2000). Increase in suspended materials in the water column will diminish the light penetration with potential adverse effects on the photosynthetic capability of phytoplankton and other aquatic plants (Iannuzzi et al., 1996).

Under the above condition, the monitoring for this year was conducted during three seasons, in the month of January 2022, April 2022 and September 2022 based on the data gathered, this Final report was prepared. During this period, marine water from the locations was also studied to understand the impact of the dredged material on the water column. The study was conducted in a systematic manner involving standard protocols and the gathered data on the physical, chemical constituents and biological characteristics were used for interpretation.

Overall, comparatively moderate biological community structure of the water and sediment was observed during this study similar to previous years such as 2019-2020 and 2020-2021. Hence regular monitoring of the sediment matrix and water column of a coastal environment is essential not just to understand the environmental health but will be helpful to find out the pattern and to contrivance appropriate management measures arising due to dredging impacts.

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Annexure -F

Annexure C

CSR Activities at Deendayal 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					
				64 of 30.08.2012	564.00 Lakh	564.00	Nil	Works completed
3	2013 -2014	99 of 30.09.2013	6.43 Cr					
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	32 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
	TOTAL	563.35

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
	TOTAL	206.22

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
	TOTAL	**88.00**

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 Meghvad 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
	TOTAL	**140.30**

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	**Rs. 39.80 Lakhs** *Approx. estimated Cost Rs.99.50 Lakhs, of which 40% to be contributed by DPT.*
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	**40 Lakhs**
6	Construction of internal roads at Bhaktinagar Society, Kidana	Smt Maltiben Maheshwari, MLA	**15 Lakh**
		TOTAL	**155.10**

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	**24.00**
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	**18.00**
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	**1.50**
4	CSR work for Providing Drainage Line at MeghparBorichi village, AnjarTaluka	Shri Vasanbhai Ahir, MLA, Gujarat Govt	**25.00**
5	CSR work for Construction of Health Centre at Kidana Village	Shri Vinod L Chavda, MP	**13.00**
6	CSR work to provide 4 Nos. of Big Dust Bin for MithiRoharJuth Gram Panchayat.	Shri Sarapanch, Mithi RoharJuth Gram Panchayat	**3.40**

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**
		TOTAL	**154.90**

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 Vasanbhai 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 (SardarValabhbhai 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**
		TOTAL	**1838.57**

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	**Appx Cost – Rs 25.00 Lakhs** **Cost for –** 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	**Appx cost –Rs 20.00 Lakhs** (Two times CSR works carried out at school by DPT)
3	CSR activities for the VadhiyarVankarSamajvaadi, NaviSunderpuriGim	SmtMaltiben K Maheswari, MLA	**Appx Cost Rs 6.00 Lakhs** 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.	**Appx Cost Rs 51.00 Lakhs** (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	**Appx Cost Rs. 25 Lakhs** **Cost for :-**

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
	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	**Cost Rs 25,000.00** (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.	**AppxCost Rs 20.00 Lakhs** (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	**Appx Cost Rs. 40.00 Lakhs** (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	**Cost Rs 1.50 Lakhs** (School Managed by G'dhamMaitry Mandal, Adipur)

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**
14	CSR activities for DONATION various Medical Equipment for the Hospital of Gandhidham Jain SevaSamiti, Adipur	Gandhidham Jain SevaSamiti, Adipur	**Cost for** :- 1) Fresenius Haemodialysis Machine Rs 38.00 Lakh 2) Maltislice Helical CT Scanner- Rs 52.00 Lakhs 3) Others Rs 54.00 Lakhs (**Total Appx Cost Rs 144 Lakhs**)
15	CSR activities for SHRI VIDI JUTH GRAM PANCHAYAT, Vidi, Anjar	Sarpanch, Vidi Gram	**Appx Cost Rs 30.00 Lakhs** Cost for- Drainage , Garbage vehicle, and Cattle shed (Already applied earlier at Sr-5/12)
16	CSR activities for SOS CHILDRESN'S VILLAGES INDIA, Madhapar, Bhuj	Director, SOS Children's Village of India-Bhuj	**Appx Cost Rs 31.00 Lakhs** (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 BOAD, GANDHINAGAR	**Requirement-** Financial Support from DPT for **AppxRs 1.88 Cr.** (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 Sharpanchs 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	**Appx Cost Rs 30 Lakhs** (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.	**Appx Cost Rs 31.36 Lakhs** (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	**Appx cost Rs 30 Lakhs.** (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	**Appx Cost Rs 80.00 Lakhs** (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	**Appx Cost Rs21.50 Lakhs** (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 **GauSevaSamiti-Tappar** at Gram-Tappar, Ta Anjar.	Shri Vinod Chavda, MP &Presedent , GauSevaSamiti, village Tappar, Ta-Anjar	**Appx Cost Rs84 Lakhs** (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	**Cost not mentioned.** (Facilities to be provided

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
	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.	**Cost not mentioned.** (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	As per CSR Guideline- ➢ 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 (**Appx Cost Rs67.00 Lakhs**) 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
	CSR Applications kept pending in last year Agenda:-		
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)	As per CSR Guideline- ➢ Env Sustainability ➢ Eradicating extreme hunger and poverty (to be Consider for health Center ,Drainage line, Water sump etc activities) **(Appx Cost - 51.00 Lakhs)** (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)	As per CSR Guideline- ➢ 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 (**Appx Cost Rs 67.00 Lakhs**) 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)	**AppxRs 5.00 Lakhs** As per CSR Guideline- ➢ Promotion of Education (to be consider for 20 Computers)

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
			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	**AppxRs 15.00 Lakhs** (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	**AppxRs 30.00 Lakhs** As per CSR Guideline- ➢ 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, **Mumbai.**	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 2nd Floor of Shri MaheswariMeghwadSamaj, Gandhidham. (Sr no-20)	Shri MaheswariMeghwadSamaj, Gandhidham	**AppxRs. 15.00 Lakhs** (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.	**AppxRs 22.00 Lakhs** (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- **Rs 539 Lakhs** 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 –Rs**88.75 Lakhs**)
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**Cost Rs 48 Lakhs**)