DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

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EG/WK/4660 (EC)/ Part V/ 60

Dated: 06/08/2025
07

To,
The Director (Env.) & Member Secretary,
Forest & Environment Department,
Govt. of Gujarat,
Gujarat Coastal Zone Management Authority,
Block No.14, 8th floor, Sachivalaya,
Gandhinagar – 382 010.

Sub: "Construction of 13th to 16th Cargo Berths at Kandla" by M/s Deendayal Port Authority (Erstwhile Deendayal Port Trust) – **Point wise Compliance to the stipulations in CRZ Recommendations reg.**

Ref.: 1) Director (Env)'s letter no.ENV-10-2006-138- P dated 14/2/2008
2) KPT letter no. EG/WK/4660 (EC)/Part III/1088 dated 9/12/2013
3) KPT letter no. EG/WK/4660 (EC)/Part III/252 dated 19/5/2014
4) KPT letter no. EG/WK/4660 (EC)/Part III/199 dated 14/11/2014
5) KPT letter no. EG/WK/4660 (EC)/Part III/255 dated 11/05/2015
6) KPT letter no. EG/WK/4660 (EC)/Part III/163 dated 15/10/2015
7) KPT letter no. EG/WK/4660 (EC)/Part III/132 dated 09/05/2016
8) KPT letter no. EG/WK/4660(EC)/Part IV/168 dated 26/12/2016
9) DPT letter no. EG/WK/4660(EC)/Part V/324 dated 26/06/2018
10) DPT letter no. EG/WK/4660(EC)/Part V/54 dated 14(16)/02/2019
11) DPT letter no. EG/WK/4660(EC)/Part V/206 dated 30(6)/11(12)/2019
12) DPT letter no. EG/WK/4660(EC)/Part V/108 dated 15/01/2021
13) DPT letter no. EG/WK/4660(EC)/Part V/91 dated 07/10/2021
14) DPA letter no. EG/WK/4660 (EC)/Part V dated 28/03/2022
15) DPA letter no. EG/WK/4660 (EC)/Part V/150 dated 19/07/2022
16) DPA letter no. EG/WK/4660 (EC)/Part V/231 dated 02/02/2023
17) DPA letter no. EG/WK/4660 (EC)/Part V/351 dated 14/08/2023
18) DPA letter no. EG/WK/4660 (EC)/Part V/38 dated 19/03/2024
19) DPA letter no. EG/WK/4660 (EC)/Part V/94 dated 24/07/2024
20) DPA letter no. EG/WK/4660 (EC)/Part V/06 dated 17/01/2025

Sir,

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

In this connection, it is to state, that Director (Environment), Forest & Environment Department, GoG vide above referred letter dated 14/2/2008 had granted CRZ Recommendations for the subject proposal. Accordingly, Deendayal Port Authority (Erstwhile Deendayal Port Trust) had regularly submitted point wise compliance report to the stipulated conditions in CRZ Recommendations.

...Cont.....

In this regard, as requested under General condition no. 21 in the above referred letter dated 14/2/2008 i.e. A six-monthly report on compliance of the conditions mentioned in this letter shall have to be furnished by the DPA on a regular basis to this Department and MoEF&CC, GoI, please find enclosed herewith compliance report of Deendayal Port Authority along with necessary annexure (**Annexure 1**) for the period from October, 2024 to March, 2025 for kind information and record please.

Further, as per the MoEF&CC, Notification S.O.5845 (E) dated 26.11.2018, 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 via e-mail ID gczma.crz@gmail.com & direnv@gujarat.gov.in.

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

Thanking you.

Yours faithfully,

XEN (EMC)
Deendayal Port Authority

Copy to:
Shri Amardeep Raju,
Scientist E, Ministry of Environment Forests & Climate change,
&Member Secretary (EAC-Infra 1),
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3rd Floor, Vayu Wing, Jor Bagh Road, Aliganj,
New Delhi – 110 003.
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Annexure -1

Annexure 1

Compliance Report for the Period October, 2024 to March, 2025.

Name of Work: Construction of 13th to 16th Cargo Berth at Kandla, District Kachchh.

CRZ Recommendations: Letter No. ENV-I0-2006-138-P dated 14/02/2008 of Director (Environment), Forest & Environment Department, GoG. Further, the Ministry of Environment & Forest–New Delhi, Govt. of India accorded the Environmental/ CRZ clearance vide letter no. 11-70/2006-IA.III dated Sep 2008 & the validity of the same had been extended by MoEF, GoI vide letter No.F.NO.11–70/2006–IA.III dated 7th February, 2014 for a further period of 5 years.

STATUS OF Berths:

13th Cargo Berth: Under operation since 18/2/2013.
15th Cargo Berth: Under Operation since 16/11/2013.
14th Cargo Berth: Under Operation since 8/4/2019.
16th Cargo Berth: Under Operation since 10/3/2019.

CONSENT TO OPERATE:

Consolidated Consent & Authorization (CC&A) issued by the GPCB (Consent Order no. AWH-110594 dated issue-8/12/2020, with a validity period up to 21/7/2025)– Detailed Order issued by the GPCB vide outward no. 581914 dated 22/1/2021 & subsequently, issued Correction in CC&A order vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/588116 dated 9/4/2021.

Sr. No.	Conditions in CRZ Recommendation Letter	Compliance
Specific Conditions		
1	The provisions of the CRZ notification of 1991 and subsequent amendments issued from time to time 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.	All the 4 berths are under operation. The provisions of the CRZ notification of 1991 and subsequent amendments issued from time to time are being strictly followed by Deendayal Port Authority (Erstwhile Deendayal Port Trust).
2	The KPT shall participate financially for installing and operating the Vessel Traffic Management System in the Gulf of Kachchh and shall also take lead in preparing and operationalizing and updating regularly after getting it vetted by the Indian Coast Guard.	DPA had already contributed an amount of Rs. 41.25 Crores for installing and operating the VTMS in the Gulf of Kachchh. VTMS has been handed over to the Directorate General of Lighthouse and Lightships, Ministry of Shipping, and GoI for operating and updating regularly to statutory authorities.
3	The KPT shall strictly ensure that no creeks or rivers are blocked due to any activity at Kandla.	All the four berths are under operation
4	Mangrove plantation in an area of 1000 ha. Shall be carried out by the KPT within 5 years in time bound manner on Gujarat coastline either within or outside the Kandla port Trust area at an appropriate place in consultation with the Forest and Environment Department. A six-monthly compliance report 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, to date, DPA has undertaken a Mangrove Plantation in an area of 1600 Hectares since the year 2005. The details have already been communicated with the earlier compliance reports submitted. Further DPA has assigned work to to M/s GUIDE, Bhuj vide work order dated 10/06/2024 for "Mangrove Plantation in an area of 50 Ha for Deendayal Port Authority" for the period of 10/06/2024 to 09/03/2025. The Final report submitted by GUIDE, Bhuj is attached herewith as **Annexure A**. It is also relevant to submit here that, as per the direction of the Gujarat Coastal Zone Management Authority, DPA had already prepared & submitted a report on mangrove conservation and management plan formulated by Gujarat Institute of Desert Ecology during the study period of Jan-April, 2015 (Report already submitted along with earlier compliance reports submitted).

		For regular monitoring, DPA vide work order dated 3/5/2021 has assigned work to M/s GUIDE, Bhuj, for Monitoring of mangrove plantation carried out by DPA (Period from 24/5/2021 to 23/5/2022). The final report submitted by GUIDE, Bhuj has already been communicated with the earlier compliance report submitted. Further DPA has assigned work to M/s GUIDE, Bhuj vide work order dated 10/06/2024 for "Monitoring of Mangrove Plantation 1600 Ha carried out by DPA" for the Period of 10/06/2024 to 09/06/2025. The inception report has already been communicated with earlier compliance report submitted.
5	No activities other than those permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.	All the four berths are under operation
6	No groundwater shall be tapped for any purpose during the proposed expansion modernization activities.	All the four berths are under operation
7	All necessary permissions from different Government Departments / agencies shall be obtained by the KPT before commencing the expansion activities.	DPA obtained Consolidated Consent & Authorization (CC&A) from the GPCB vide Consent Order no AWH-110594 date of issue-8/12/2020, with a validity period up to 21/7/2025– Detailed Order issued by the GPCB vide outward no. 581914 dated 22/1/2021 & subsequently, issued Correction in CC&A order vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/588116 dated 9/4/2021 (The copy of the Order has already been communicated with the earlier compliance report submitted).
8	No effluent or sewage shall be discharged into the sea/creek or in the CRZ area and It shall be treated to conform to the Norms prescribed by Gujarat Pollution Control Board and would be reused/recycled within the plant premises to the extent possible.	Generated sewage is treated in DPA's existing STP (1.5 MLD capacity). In addition to that, it also has septic tanks at places where STP is inaccessible. The treated sewage is being used for gardening and plantation purposes. DPA has been appointing a NABL-accredited laboratory to monitor environmental parameters, and reports are being submitted from time to the GPCB, IRO, MoEF&CC, GoI, and

		Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar, to regularly monitor 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 B**.
9	All the recommendations and suggestion given by the NIOT in their Comprehensive Environment Impact Assessment report for conservation / protection and betterment of environment shall be implemented strictly by the KPT.	Currently, all the four berths are under operation. As per the directions of the GCZMA and MoEF&CC, GoI, to date, DPA has undertaken a Mangrove Plantation in an area of 1600 Hectares since the year 2005. The details have already been communicated with the earlier compliance reports submitted. Further DPA has assigned work to to M/s GUIDE, Bhuj vide work order dated 10/06/2024 for "Mangrove Plantation in an area of 50 Ha for Deendayal Port Authority" for the period of 10/06/2024 to 09/03/2025. The Final report submitted by GUIDE, Bhuj is attached herewith as **Annexure A**. For regular monitoring, DPA vide work order dated 3/5/2021 has assigned work to M/s GUIDE, Bhuj for "Monitoring of mangrove plantation" carried out by DPA (Period from 24/5/2021 to 23/5/2022). The final report submitted by GUIDE, Bhuj, has already been communicated with the last compliance report submitted. Further DPA has assigned work to M/s GUIDE, Bhuj vide work order dated 10/06/2024 for "Monitoring of Mangrove Plantation 1600 Ha carried out by DPA" for the Period of 10/06/2024 to 09/06/2025. The inception report submitted by GUIDE has already been submitted with earlier compliance report. DPA assigned work to M/s GUIDE, Bhuj 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" since 2017.

		In continuation of same, DPA had issued work order to GUIDE, Bhuj for "Regular Monitoring of Marine Ecology in and around Deendayal Port Authority" for the year 2024-2027. The work is in progress. The First season report submitted by GUIDE is attached herewith as **Annexure C.** To control fugitive emissions, DPA has installed Mist Canon in the Port area. Further, regular sprinkling through tankers on roads and other staking yards is being done to control dust pollution in other areas. it is relevant to mention that Pollution under Control (PUC) Certificates have been made mandatory for vehicles in the port area. For waste generated from ships, DPA issued a Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" and for removal of "Dry Solid Waste (Non- Hazardous)" from Vessels calling at Deendayal Port through DPA contractors. Further, all ships are required to follow DG Shipping circulars regarding the reception facilities at the Swachch Sagar portal. Further, DPA vide work order dated 24/01/2023 has appointed GEMI, Gandhinagar, for "Preparation of Plan for Management of Plastic Wastes, Solid Waste including C&D waste, Hazardous wastes including Biomedical and Non-Hazardous Waste in the Deendayal Port Authority area". The Final report submitted by GEMI has already communicated with earlier compliance report. DPA has been appointing a NABL-accredited laboratory to monitor environmental parameters, and reports are being submitted from time to the GPCB, IRO, MoEF&CC, GoI, and Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar, to regularly monitor 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 B.**
10	The construction activities and dredging shall be carried out only under the constant supervision and guidelines of the NIOT.	All the four berths are currently under operation.
11	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 Kachchh.	Point noted
12	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.	All the 4 berths are currently under operation.
	General Conditions	
13	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.	All the 4 berths are currently under operation.
14	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.	Point noted
15	The KPT shall take up massive greenbelt development activities in and around Kandla and also within the KPT limits.	Deendayal Port Authority had taken up massive greenbelt development activities in and around Kandla, Residential colony, administrative building, etc. DPA had entrusted the work to the Forest Department, Gujarat, in August 2019 for developing a green belt in and around the Port area at a cost of Rs. 352 lakhs in an area of about 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) (5,000 plants)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The work is completed. Further, DPA assigned work to GUIDE, Bhuj, via a work order dated 23/06/2023 for "Green belt development in Deendayal Port Authority and its Surrounding Areas (Phase II) (10,000 plants). The Final report has already been submitted along with earlier compliance report.
16	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.	The details of CSR activities undertaken /to be undertaken by DPA are placed at **Annexure D.**
17	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.	The allocation made under the scheme of "Environmental Services & Clearance thereof other related Expenditure" during RBE 2024-25 is Rs. 585 Lakhs. The expenditure made under the "Environmental Services & Clearance of other related Expenditure" is Rs. 522 Lakhs from October 2024 to March 2025.
18	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 already has an Environment Management Cell. Further, the DPA has also appointed an expert agency to provide Environmental Experts from time to time. DPA appointed M/s Precitech Laboratories, Vapi, to provide Environmental Experts via a work order dated 5/2/2021 for a period of 3 years. Further, DPA appointed M.s Precitech Laboratories, Vapi, to Provide Environmental Experts via work order dated 4/10/2024. The work order is attached herewith as **Annexure E**. In addition, it is relevant to submit here that DPA has appointed a Manager (Environment) on a contractual basis for a period of 3 years, further extendable to 2 years (A copy of the details has

		already been communicated with the last compliance report submitted).
19	An Environmental report 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, GOI.	DPA has been appointing a NABL-accredited laboratory to monitor environmental parameters, and reports are being submitted from time to the GPCB, IRO, MoEF&CC, GoI, and Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar, to regularly monitor 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 B.**
20	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	Point noted
21	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 regularly submitted the compliance reports to GCZMA, Gandhinagar, MoEF&CC, and GOI. The last compliance report of the conditions stipulated in CRZ recommendations issued by GCZMA was submitted on 17/01/2025.
22	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.	Point noted

Annexure -A

FINAL REPORT

for the Project entitled

Mangrove Plantation in an area of 50 Hectares for Deendayal Port Authority, Kandla

(As per EC & CRZ Clearance Dt.01.01.2024. Annexure-B, Specific condition No.7)

DPA Work order No. EG/WK/4751/Part (Revamping-EC onwards)/69. Dt. 10.06.2024

Submitted by

Gujarat Institute of Desert Ecology

Mundra Road, Bhuj-370 001

Dist: Kachchh, Gujarat, India

Submitted to

Deendayal Port Authority

Gandhidham- 370201

Dist: Kachchh, Gujarat-, India

February
2025

Gujarat Institute of Desert Ecology

Certificate

This is state that the Final Report for project entitled "**Mangrove Plantation in an area of 50 Hectares for Deendayal Port Authority, Kandla**" has been prepared in line with the Work order issued by the Deendayal Port Authority Vide. Ref. No. EG/WK/4751/Part (Revamping-EC onwards)/69. Dt.10.06.2024. In order to comply with the stipulated condition of the EC & CRZ Clearance dated 1/1/2024 read with CRZ Recommendation dated 25/8/2023 – Condition no.7.

The work order is for a period of Nine months (10.06.2024 - 09.03.2025) for the above-mentioned study.

Authorized Signatory

DIRECTOR
Gujarat Institute of Desert Ecology
Bhuj - Kachchh.

Gujarat Institute of Desert Ecology Bhuj

Institute

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Project Team

Project Coordinator: Dr. V. Vijay Kumar, Director

Project Personnel

Principal Investigator

Dr. B. Balaji Prasath, Senior Scientist

Co-Investigator

Dr. Kapilkumar Ingle, Project Scientist-II

Team Members

Dr. L. Prabhadevi, Advisor

Mr. Dayesh Parmar, Senior Scientific Officer

Mr. Ketan Kumar Yogi, Junior Research Fellow

Contents

Snapshot of the Project," Mangrove Plantation in an area of 50 Hectares for Deendayal Port Authority, Kandla"

S.No	Components of the Study	Remarks
1	Deendayal Port letter sanctioning the project	EG/WK/4751/Part (Revamping-EC onwards)/69, dated 10.06.2024
2	Duration of the project	Nine months (10.06.2024 - 09.03.2025)
3.	Location of Mangrove Plantation Site	The location finalized for mangrove plantation is shown in Figure 1. Suitable site was selected based on water and sediment quality, intertidal fauna, and propagules.
4.	Total Area	50 Hectares
5.	EC & CRZ Clearance Reference	As per EC & CRZ Clearance Dt. 01.01.2024, Annexure-B, Specific condition No. 7
6	**Field Studies**	
6a	Site Overview	Inspection to understand site conditions and potential risks (e.g., grazing).
6b	Geographical Patterns	Study existing mangrove species to determine their distribution and identify suitable planting locations.
6c	Landscape Assessment	The stability of the root system of existing mangroves were be examined.
7	**Plantation Techniques**	
7a	Raised Bed Method (Otla Method)	Create earthen mounts to plant 15-30 seeds; suitable for areas with low to moderate water currents.
7b	Transplantation of Nursery Raised Saplings	Grow saplings in polythene bags; nature for 3-4 months before transplanting; higher success rate

1. Background of the study

Mangroves are among the most productive ecosystems, providing various ecosystem services and resources to both the ocean environment and humankind. This unique ecosystem occurs in the tropics and subtropics, where land meets the oceans, often bordering estuaries and backwaters. Mangrove forests have the remarkable ability to rise upward in place or move landward or seaward in response to sea level changes (Woodroffe *et al*. 2016). Mangroves typically grow on wet, muddy substrates with minimal water fluctuations, specifically in the mudflat regions of tropical and subtropical areas. These are dense forests of trees and shrubs that are tolerant to salt, usually flourishing in tidal areas. The importance derived from these forests is critical, including coastal protection, biodiversity conservation, and climate change mitigation. All mangroves produce fertilizer from rotting litter fall and root growth deceiving ambient water sediment. Mangrove ecosystems support various plant and animal species, breeding, nursery and feeding grounds for numerous marine and terrestrial organisms. Despite their ecological importance, mangrove forests face different threats such as deforestation, pollution, and climate change. Specific measures have been taken towards conserving these valuable ecosystems including them into biosphere reserves and Ramsar sites.

According to the Forest Survey of India (FSI, 2019), the global mangrove cover is approximately 14.79 million hectares. Asia leads with 5.55 million hectares, followed by Africa with 3.24 million hectares, North and Central America with 2.57 million hectares, and South America with 2.13 million hectares. South Asia has the highest mangrove area, constituting about 6.8% of the world's total mangrove cover. Anthropogenic pressures have reduced global range of these forests to less than even half of their original total cover throughout the globe as mentioned by Ragavan *et al.* (2016) while Singh (2020) observed that almost 75% of the tropical coast has been taken up by mangrove forests. India's mangrove ecosystems are incredibly important, covering around 4,992 km^2, which makes up about 0.15% of the country's total land area. Despite occupying a relatively small fraction of India's geographical area, mangroves are hotspots of biological activity, supporting a wide range of flora and fauna. They help in sequestering carbon, thus mitigating climate change effects. Major mangrove areas in India include the Sundarbans in West Bengal, which is the largest mangrove forest in the world.

The present study on "Mangrove Plantation in an area of 50 Hectares for Deendayal Port Authority, Kandla" is being conducted to comply with the specific conditions outlined in the EC & CRZ Clearance dated 01.01.2024 and CRZ Recommendation condition no. 7 as given in Annexure B.

1.1. Mangrove status in Gujarat and Gulf of Kachchh

Gujarat state has the longest coast (1650 km^2) with largest coastal area (28,000 km^2) under cover of mangroves. Gujarat mangrove ecosystem is the second largest after Sundarbans in West Bengal (ISFR 2019). Though contentious, around 15 mangrove species are reported from 13 coastal districts of Gujarat. Of these, the southern coast of Gulf of Kachchh and South Gujarat coast are important for mangrove diversity. The species *Avicennia marina* is the most populous along the Gujarat coast. Along the coastal stretch of Gulf of Kachchh (GoK) has the most considerable mangrove extent of 986 km^2 out of 1140 km^2. Kachchh district, constituting the northern coast (northern shore) of GoK alone has 798 km^2 of mangroves constituting 70% of the whole Gujarat mangroves. Waterlogged mud with low oxygen levels supports such vegetation in tropical and subtropical regions. In the Kachchh coast has various habitats such as expansive mudflats and small sandy beaches with different physico-chemical variables like extreme salinity temperature inundation factor. This vibrating ecosystem can allow the species to thrive and exhibit many adaptive modifications.

Biodiversity-oriented planting schemes aim to boost species richness through ongoing plantation and meticulous monitoring activities. Restoring mangrove ecosystems with dominant species like *Avicennia marina, Ceriops tagal,* and *Rhizophora mucronata* plays a crucial role in enhancing species diversity. By increasing the variety of plant species, these schemes not only create a more resilient and productive ecosystem but also help in providing essential resources and services to local populations, such as fish breeding habitats, wood, and other forest products. Continuous planting and monitoring ensure that these ecosystems remain healthy and sustainable, benefiting both the environment and the people living in coastal regions. Mangrove biodiversity seeks attention towards such spots on the Kachchh coast, which require supplementation of plant cover at selected sites. For instance, although successful efforts at restoring mangroves exist, the presence of *A. marina* alone in most parts corroborates the role of high salinity of the water because of limited fresh water influx annually. The arid coastal conditions lack of

continuous freshwater flow through the river inhibits the spread and growth of mangroves which are constantly exposed to tidal inundation. The plantation of mangroves as well as creation of awareness regarding the importance of mangrove and their ecosystem services are the crucial tasks to avoid such loss.

1.2. Rationale of the project

Deendayal Port Authority (DPA) has been one of India's largest ports in terms of cargo volume handled. Being located in Gujarat state on the northwest coast of India, the port is one of the biggest creek-based ports in India. In India, it is one among twelve major ports and situated at Gulf of Kachchh's tail end, Gujarat's western part. The greatest advantage of this location is a high semi-diurnal tidal range of about 6 to 7 meters which allows for sufficient draft in the dredged channels at the Port. DPA has been and still is undergoing continuous development and expansion particularly over recent times and is located in the creek environment encompassing mangroves (193.1 km^2) and mudflats (312.9 km^2).

Over the last seven decades, it should be noted that due to these vast resources available at its doorstep; the port authorities have a desire to conserve, protect and enhance these coastal habitats. The coastal belt in and around Kandla region is characterized by a network of creek systems and mudflats which are covered by sparse halophytic vegetation like scrubby to dense mangroves, creek water and salt encrusted land mass which forms the major land component. The surrounding environment in a radius of 10 km from the Port is mostly built-up areas consisting salt works, human habitations and Port related structures on west and north, creek system, mangrove formations and mudflats in the east and south.

Deendayal Port as part of the expansion of the infrastructure facility has significant movements of materials and people within the area and construction activities as well. Additionally, as part of the environmental policy intended to accomplish 50 ha mangrove plantation and the task is entrusted with the Gujarat institute of Desert ecology, Bhuj, Kachchh district Similar efforts towards conserving and preserving mangrove cover in the prospective areas have been implemented by the Deendayal Port Authority (DPA) to maintain numerous unheralded ecological services by these marine plants. Total mangrove plantation till date by DPA through several implementing agencies at Sat Saida Bet, Nakti Creek and Kantiyajal.. To ensure the project follows the

most contemporary standards and practices in the field. In accordance with the CRZ Recommendation Condition, Mr. Nischal Joshi of the Gujarat Ecology Commission (GEC) was consulted for his expert opinion during the initial stages of the work.

2. Objectives

Within the overall objective of mangrove plantation in the DPA port limits the following activity wise objectives are envisaged.

- Assess the technical suitability of the proposed land for mangrove plantation
- Assess the physico-chemical properties of soil and nearby water and tidal pattern in the proposed plantation site.
- Formulate site specific plantation strategy and execute it with the adopting appropriate techniques.

3. Study Area

The location finalized for mangrove plantation is shown in Figure 1, as per their suitability including water and sediment quality characteristics, occurrence of intertidal fauna, availability of propagules, signs of natural regeneration etc. Further, based on the water quality characteristics reported elsewhere, the site is better choice for the plantation of mangrove species, *A. marina*. In the studies conducted earlier, the salinity levels of this area is reported to be ranging between 35 - 40 ppt which is suitable for the selected species. The pH of the pour water is recorded to be in the range of 6.0 - 8.5. In addition to the above said criteria, plantation in general should be established in Intertidal areas where a good tidal flushing is happening atleast 15 days in a month.

Figure.1 Proposed location for Mangrove plantation activities at DPA area

4. Methodology

4.1. Field Studies

4.1.1. Site Overview:

- The inspection were provide an overall understanding of the site, not only for the plantation but also for potential risks (such as camel or cattle grazing).
- Accessibility for post-plantation monitoring were be evaluated to ensure ease of assessment.

4.1.2. Geographical Patterns:

- Existing mangrove species in the area were be studied to understand their presence and distribution.
- Geographical patterns were be analyzed to identify suitable locations for planting mangroves.

4.1.3. Landscape Assessment:

- Rainwater runoff into the creeks and the influencing zones were be observed to assess its impact on the mangrove ecosystem.
- The stability of the root system of existing mangroves were be examined.
- Sources of freshwater within the area were also be considered.

4.2. Plantation Techniques

Three methods preferred for the sake of mangrove plantation which were be as follows in this study period:

4.2.1. Raised bed method (Otla method)

- This is popular method of mangrove plantation in Gujarat useful for a few species such as *A. marina* and provide better result compare to other methods.
- In this method, earthen mounts of a specific height were be made which support to plant 15 to 30 seeds/ propagules.
- This method is suitable in the areas where the current of water is low and moderate (Plate 1).

4.2.2. Transplantation of nursery raised saplings (Poly bag method).

- This technique has higher success rate unlike other methods and therefore, nursery of the various species is required to grow the saplings (Plate 2).
- This technique is time consuming and laborious compared to direct dibbling and raised bed methods.
- On the open intertidal mudflats, the saplings were be grown in polythene bags through sowing the matured seeds or propagules.
- The saplings were be nurtured 3-4 months before transplantation and after attaining a height 30-45 cm in polythene bags.
- Site specific conditions were determining the number of saplings to be transplanted, however, 2500 saplings per ha is generally followed.
- In some occasions also nursery raised saplings were be used for gap filling and thereby increasing the survival rate of the plants table1.

After being successfully raised in the nursery, saplings between 30 and 45 cm tall should be chosen at different times to be transplanted at the intended location. Below are the specifics of the plantation's sapling height and germination period (plate 3). A total of 46 nursery beds were established, with each bed containing 800 to 1,200 polybags. Each polybag is sown with 3 to 4 seeds, facilitating optimal seedling production (Figures 8-13). In addition, otla raised method, in each bed sown 5 – 6 seeds were raised in plantation site (Figures 15-17)

Table 1: Details of sapling for plantation

Species	Germination period (days)	Germination percentage	Height (cm)of saplings
Avicennia marina	6-10	70-80	30-45
Rhizophora mucronata	30-35	50-60	60

With these methods, the extra seeds were also spreaded in the plantation area where the older trees are present and generally the area where natural regeneration of seeds happens.

5. Site visit

Before the initiation of mangrove plantation activity, a through pre-project survey was conducted to examine the proposed plantation site. In this survey, the crucial technical factors like land elevation, tidal pattern, physical and chemical properties of soil and water (by laboratory analysis), access to the site, level of protection such as cattle grazing, human disturbance and other potential risks, etc. were observed. This survey helps to decide the suitability of site for mangrove plantation in DPA port limit.

5.1. On-site observations

- The indicators of regular flooding of site by tide water was observed in on-site visit. The site area was wet and with plenty of mud which is required for plantation.
- There was no presence of very hard, dried soil surface in the site was observed anywhere.
- The presence of a few natural mangrove (*A. marina*) trees was observed around and in the plantation site which denotes the site is suitable for the plantation.
- The presence of crab holes and mudskippers holes is the indicator that the soil of the site is soft and regularly get wet due to tides.
- The pneumatophores of nearby mangroves were found in the nearby area which indicate that there is no sediment deposition and buried pneumatophores in this area.
- Nearby area also shows the presence of halophytic/ salt marsh plants such as *Sesuvium* and also *Salicornia* nearby creek.
- The *Sesuvium* leaves were green and fresh, also not thicker which represent the good condition of the site.
- The presence of sub-creek system may ensure the availability of tidal water which were be primary need of the plantation.
- A few natural regeneration plants were also observed in the site.
- The presence of the jackal foot marks observed which denotes the overall area have a good ecosystem and where the jackal food (crabs) sources are available.

5.2. Analysis of water and sediment samples

5.2.1. Water analysis

The water samples were collected from the plantation site in pre-cleaned polyethene bottles and rinsed with sample water, and transported to the laboratory in icebox for further analysis such as pH analysis by pH meter, salinity was determined by refractometer. The pH of water sample was found 7.25 and salinity 18 psu. Although there is no domestic freshwater source, and tidal water salinity generally higher, due to the rainy season the salinity shows lower values. However, the lower salinity is also in favour of germination of mangrove seeds.

5.2.2. Sediment/ soil analysis

Sediment samples were collected by using a non-metallic plastic spatula from random locations; three from each transect to cover the whole study area. The collected samples were air-dried at room temperature (Jackson, 1958), homogenized using an agate mortar and pestle, sieved through a standard sieve of 2 mm mesh (Tandon, 2005). The particles with size less than 2mm were retained in pre cleaned plastic bottles for further analysis for various parameters. Total Organic Carbon (TOC), pH, texture, bulk density, etc were analysed.

Texture of sediment: The texture of soil/sediment is one of the key factors when choosing a site for plantation mangroves. Generally, mangrove ecosystems typically have the types of soils which includes muds or clay or sandy mud, etc. The texture of soil significantly impacts the survival and growth of mangroves. The presence of clay texture which makes soil muddy may expected to offer a stable base for mangrove roots to flourish under tidal conditions. Thus, evaluating the soil conditions at the plantation site is crucial before starting mangrove planting activities. Here we collected 3 samples, and all shows good amount of clay percentage in them which may be favourable for the plantation.

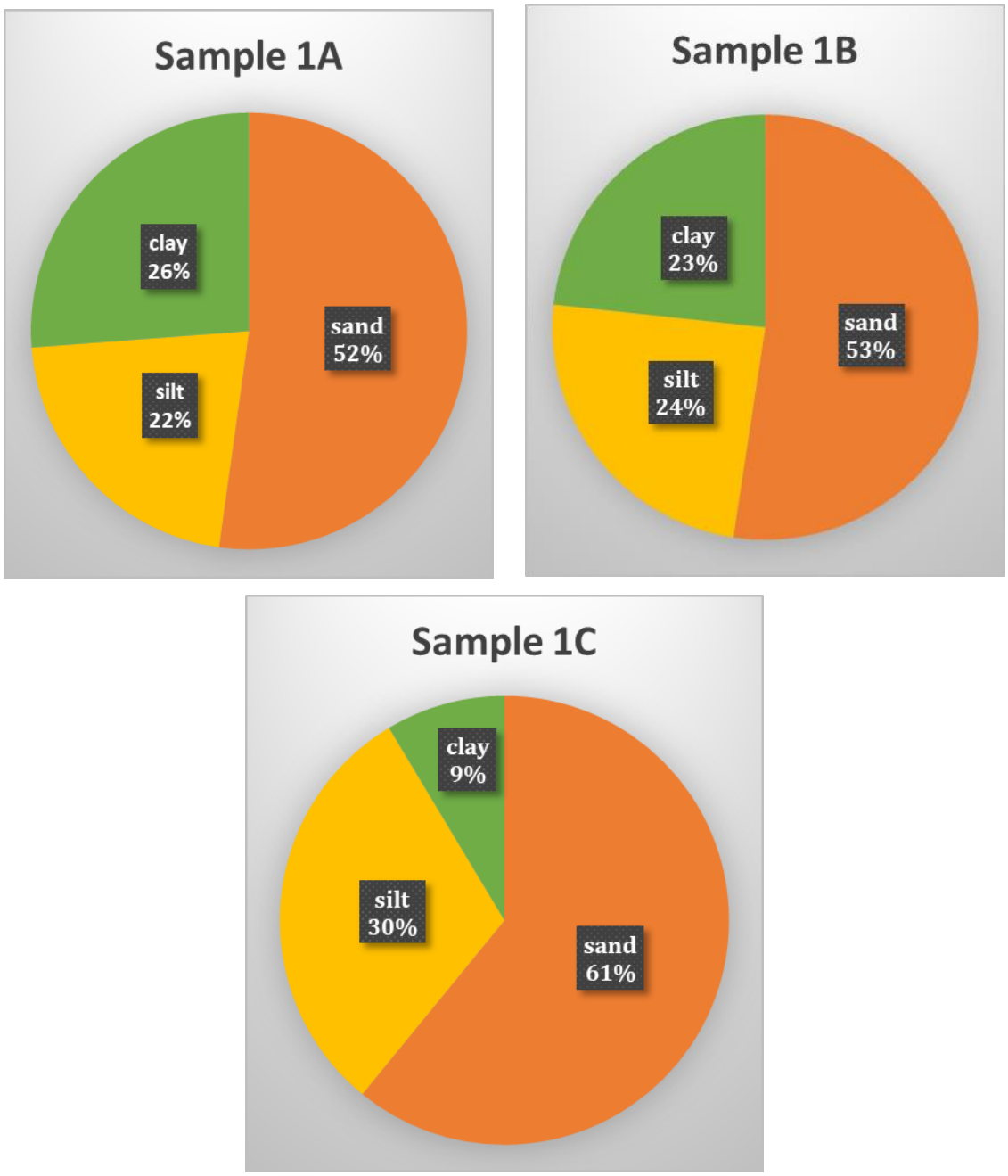

Figure 2: Sediment textural composition in the sampling sites

Bulk density of soil: It refers to the amount of soil organic matter within a given volume of soil. This property can vary significantly and is influenced by the soil's texture, structure, and organic matter content. Soils with high organic matter tend to have lower bulk density, while compacted soils exhibit higher bulk density.

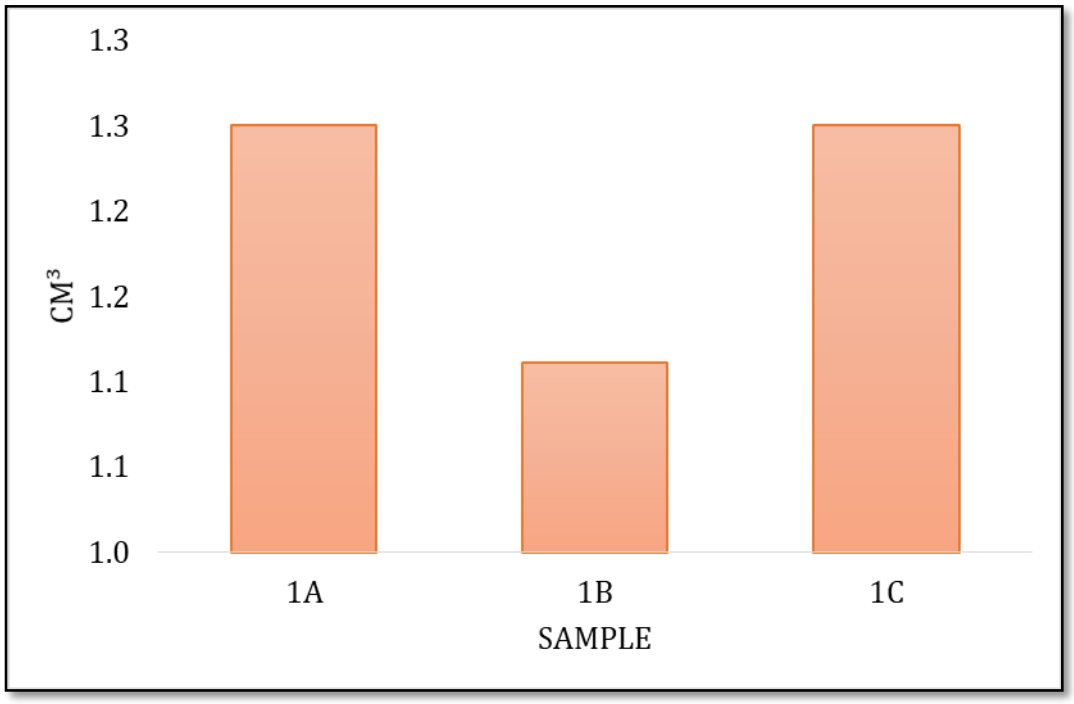

Figure 3: Bulk density of sediment samples

Total Organic Carbon: Organic carbon levels are influenced by living organisms, and the diversity of life forms in mudflats affects the total organic carbon (TOC) estimates. In all samples, the TOC percentage was ranged from 2.7 % to 2.85%

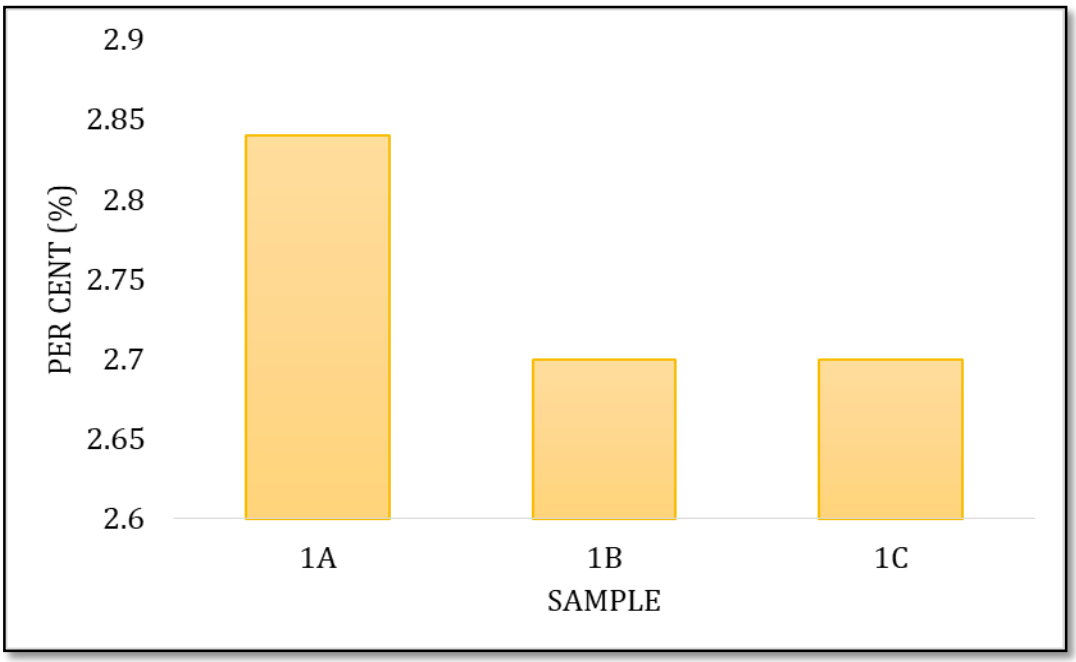

Figure 4: Total Organic Carbon content of sediment samples

Plate 1: Selection of suitable sites for mangrove plantation in DPA area based on sediment characteristics, tidal pattern, cattle grazing etc

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Plate 20: Labour Involvement in *A. marina* Plantation during GUIDE Team Visit to Kandla on 15th January, 2025

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Plate 22: Mangrove outplanting, including row establishment and saplings placing inside hole, levelling soil surface at Kandla on 10th February, 2025

6. Summary of the Report

The aim of the report is to assess the situation of growing mangrove saplings at DPA Gulf of Kutch. In order to comply with the stipulated condition of the EC & CRZ Clearance dated 1/1/2024 accorded by the MoEF&CC, GoI read with CRZ Recommendation dated 25/8/2022 for "Augmentation of Liquid Cargo Handling capacity from 8 to 23.8 MMTPA through modernization of existing Pipeline network at Oil Jetty area of DPA, Kandla"), DPA assigned work of "Mangrove Plantation in an area of 50 Hectares for Deendayal Port Authority reg.", to GUIDE, Bhuj vide work order dated 10/6/2024.

The DPA has initiated a program for plantation of mangroves to improve these ecosystems within the limits of its port. The general focus of this project is to evaluate mangrove plantation in an area of 50 Hectares for Deendayal Port Authority, site conditions for planting, study the soil and water characteristics, and formulate and execute a site-specific planting plan utilizing nursery grown transplant, otla method and other forms. The objective is to increase the mangrove species, improve the resilience of the ecosystem and provide the local population with valuable resources and services, all while ensuring the sustainability of mangrove cover over the long term. The increased ecological stability and productivity of the region, and provide necessary resources and services to the local and marginalized communities throughout the work in a selected, defined and timetabled manner to observe the speed of the work done. The Mangrove Plantation in an area of 50 Hectares of *Avicennia marina* and *Rhizophora mucronata* at scientifically identified location (Satsaida bet) is completed.

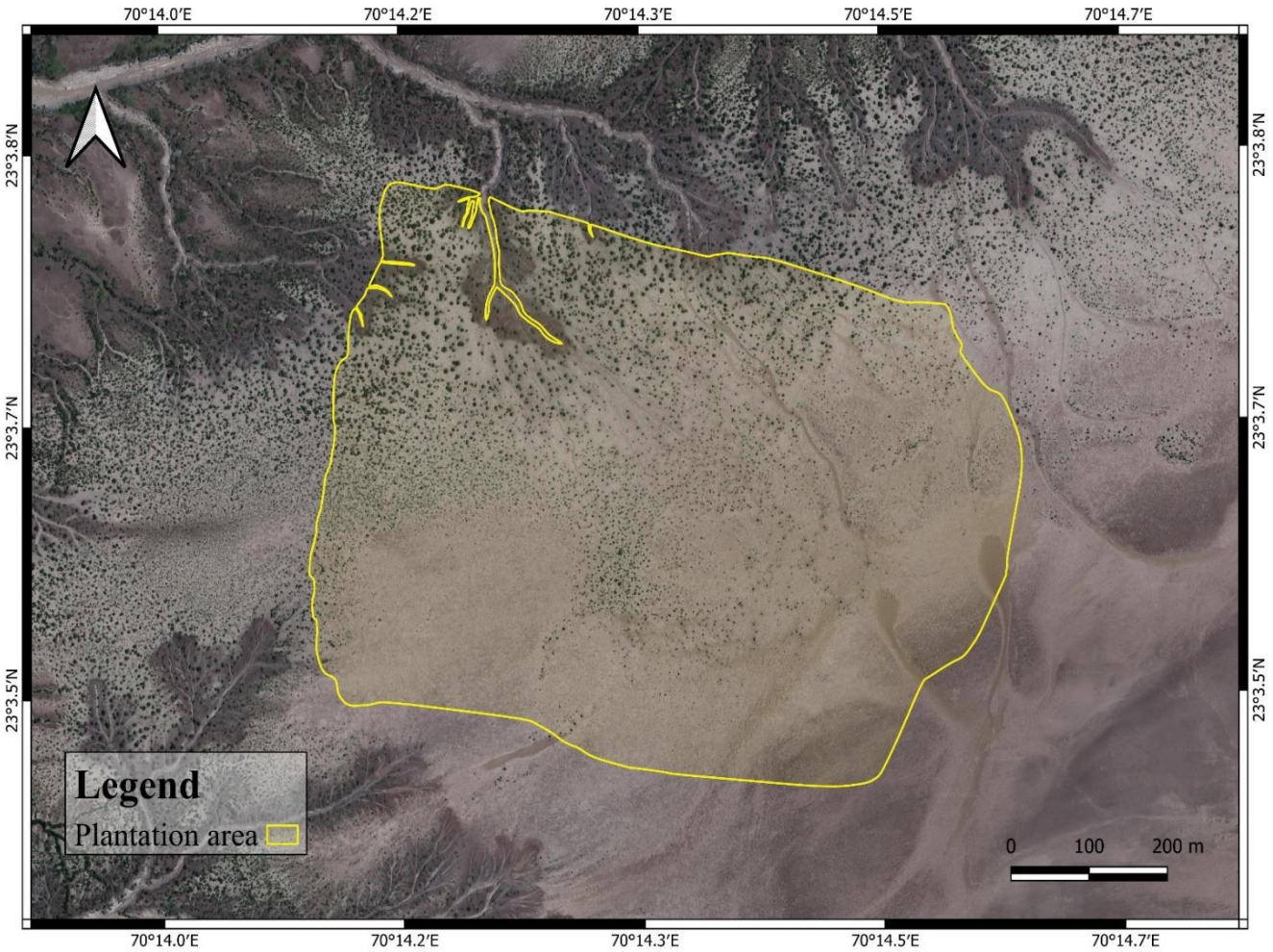

Figure 5: Mangrove plantation site area at Kandla, Gujarat, India

Plate 24: Growing saplings during GUIDE Team Visit to Kandla on 10th February, 2025

Plate 25: Labour Involvement plantation the *Rhizophora mucronata* at Kandla on 31st January to 28th March, 2025

Table: 2 GPS Points of Mangrove Project Site at Kandla, Gujarat, India

No	Point No.	Longitude	Latitude
1	**K-18**	70.243	23.062
2	**K-19**	70.244	23.06
3	**K-23**	70.243	23.058
4	**K-25**	70.241	23.057
5	**K-27**	70.239	23.057
6	**K-28**	70.235	23.058
7	**K-31**	70.235	23.061
8	**K-33**	70.235	23.062
9	**K-35**	70.237	23.064
10	**K-37**	70.24	23.063

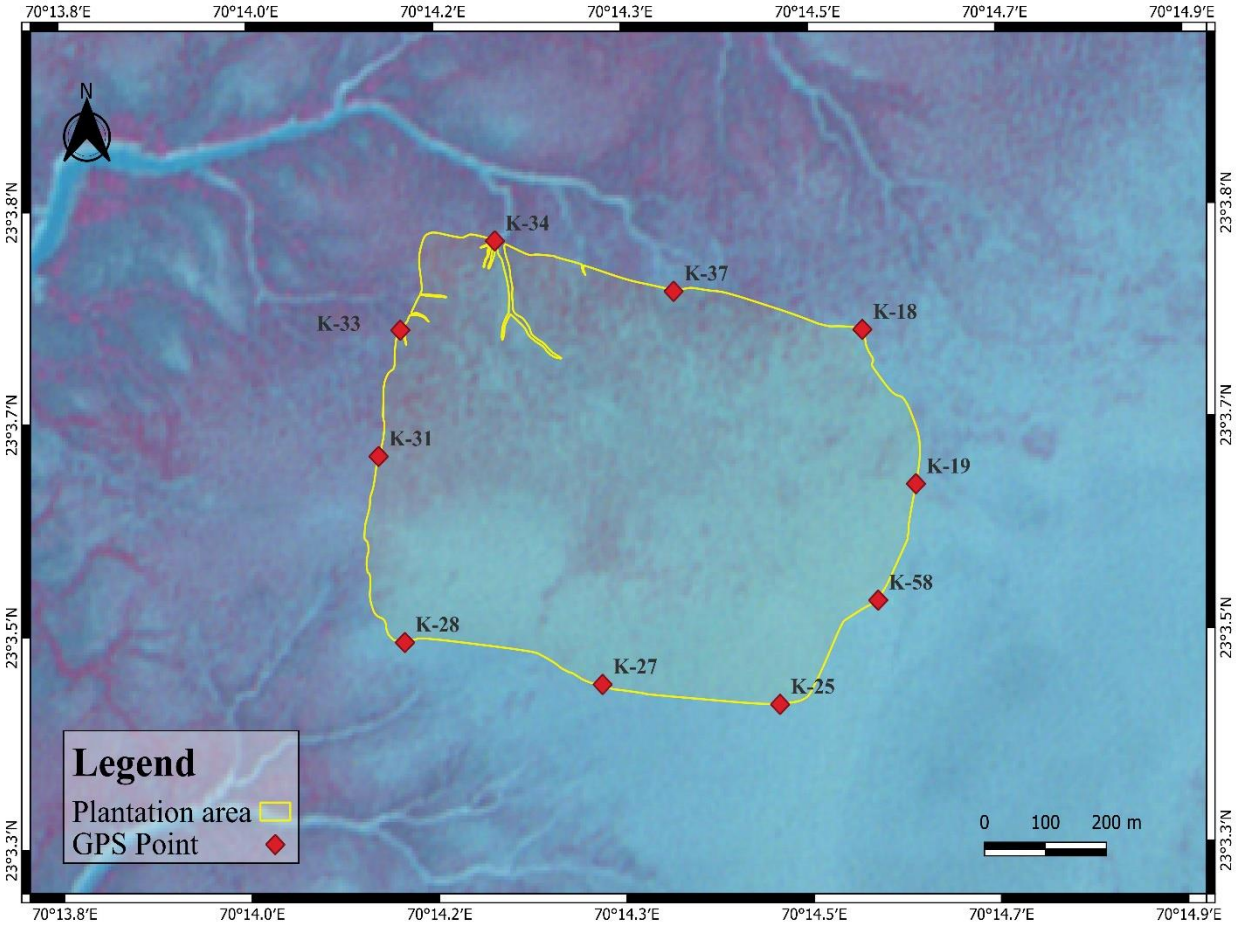

Figure 6: Mangrove plantation site area with GPS location points at kandla, Gujarat, India

7. Future Considerations for Mangrove Plantation

DPA needs to focus on the mangrove plantation project in Kandla. In ensuring that, this report puts forward the steps that need monitoring for the future.

7.1. Carry out regular monitoring of mangrove plantation

The regular monitoring of mangrove plantations is must in the plantation site to ensure growth status of the planted mangroves. It will also help in detection of any signs of disease or damage early. Regular monitoring also helps to understand any threats to mangrove such as potential erosion or grazing etc, also help to protect the local ecosystem and biodiversity. It will useful in the measurement of effectiveness of conservation efforts.

7.2. Regular gap filling to be done

Maintenance of the plantation is crucial for its continued success. Regular upkeep is needed, including filling in gaps where plants may have failed to establish. In addition to *Avicennia marina*, it's important to plant a variety of mangrove species to boost biodiversity. This increased diversity enhances the ecosystem's resilience to environmental changes, such as fluctuations in salinity, temperature, and sea level rise. Regular monitoring and management practices ensure the plantation's long-term health and ecological stability, contributing to the protection of coastal areas and marine life habitats.

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Annexure -B

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: December 2024 -January 2025)

Document Ref No.: GEMI/DPA/782(2)(4)/2024-25/165

Submitted to:

Deendayal Port Authority (DPA), Kandla

Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

GEMI Bhavan, 246-247, GIDC Electronic Estate, Sector-25, Gandhinagar-382025

"AN ISO 9001:2015, ISO 14001:2015 AND ISO 45001:2018 Certified Institute"

Certificate

This is to certify that the Monthly Environment Monitoring Plan (EMP) report for the period 15th December 2024 to 14th January 2025 for the work entitled, **"Preparing and Monitoring of Environmental Monitoring and Management Plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years"** has been prepared in line with the work order no. **EG/WK/EMC/1023/2011/iii/239** dated 15/02/2023 allotted by Deendayal Port Authority.

The report has been delivered as per the terms and conditions of the work order Sr. No. 4(2).

S. S. O. & Lab Head

Authorized Signatory

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 (DPA) at Kandla and Vadinar for a period of 3 years" by DPA, Kandla. Under the said project the report titled *"Environment Monitoring Report (Dec-2024-Jan-2025)"* is prepared.

- **Name of the Report:** *Environment Monitoring Report (Dec-2024-Jan-2025)*
- **Date of Issue:** 15/02/2025
- **Version:** 1.0
- **Report Ref.:** GEMI/DPA/782(2)(4)/2024-25/165

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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 near the city of Gandhidham in Gujarat state in western India. Located on the Gulf of Kachchh, it is one of major ports on the western coast, and is located at 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. 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. Deendayal Port Authority (DPA), India's busiest major port in recent years, is gearing up to add substantial cargo handling capacity with private sector participation. DPA has created new record by handling 137 MMTPA (at Kandla and Vadinar) during the financial year 2022-23. The 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, with a capacity of 54 MMTPA. Further, significant Quantum of infrastructural upgradation has been carried out & excellent maritime infrastructure has been created at Vadinar for the 32 MMTPA Essar Oil Refinery in Jamnagar District.

1.2 Green Ports Initiative

DPA 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.

DPA had also appointed GEMI as an Advisor for "Making Deendayal Port a Green Port-Intended Sustainable Development under the Green Port Initiatives. DPA 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 DPA. 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.sd

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 should indicate the details of various measures are taken 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 not only during the construction and operational phases of the new port but also for operation of existing ports to ensure the effectiveness of the mitigation measures implemented and to further provide guidance as to the most appropriate way of dealing with any unforeseen impacts.

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 essential 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 environmental monitoring done during the period from 17th December-16th January 2024-2025.

1.4 Objectives and scope of the Study

In line with the work order, the key objective of the study is to carry out the Environmental Monitoring and preparation the Management Plan for Kandla and Vadinar for a period of 3 years". Under the project, Environmental monitoring refers to systematic assessment of ambient air, water (drinking and surface), soil, sediment, noise and ecology in order to monitor the performance and implementation of a project in compliance with Environmental quality standards and/or applicable Statutory norms.

The scope of work includes not limited to following:

1. To review the locations/stations of Ambient Air, Ambient Noise, drinking water, and Marine Water, Soil and Sediments monitoring 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 locations (18 at Kandla and 2 at Vadinar) 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. Weekly sample collection and analysis of inlet & Outlet points of the Sewage Treatment Plant (STP) to check the water quality being discharged by DPA as per the CC&A.
9. Carrying out monthly Noise monitoring; 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, hence precise and continuous data collection is of utmost importance. Meteorological data on wind speed, wind direction, temperature, relative humidity, solar radiation and

rainfall shall be collected from one permanent station at DPA, Kandla and one permanent station at Vadinar.

11. To suggest 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 based on Monitoring programme and findings of the study.

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 Gujarat. The Major Port Authorities Act 2021 is the governing statute for Administration of Major Ports, under which, Deendayal Port Trust (DPT) has become Deendayal Port Authority (DPA). At Kandla, DPA has sixteen (16) cargo berths for handling various types of Dry Bulk Cargo viz, fertilizer, food grains, Coal, sulphur, etc.

- **Climatic conditions of Kandla**

Kandla has a semi-desert climate. Temperature varies from 25°C to 44°C during summer and 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 Gujarat state in India located at coordinates 22° 27' 16.20" N - 069° 40' 30.01". DPA 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, with a capacity of 54 MMTPA. The OOT of the DPA contributes in a large way to the total earnings of this port. Vadinar is now notable due to the presence of two refineries-one promoted by Reliance Industries and Essar Oil Ltd.

DPA also handled 43.30 MMT at Vadinar (which includes transhipment), the containerized cargo crossed 4.50 lakh TEU, grossing a total of 100 MMT overall. Major commodities handled by the Deendayal Port are Crude Oil, Petroleum product, Coal, Salt, Edible Oil, Fertilizer, etc.

- **Climatic conditions of Vadinar**

Vadinar has a hot semi-arid climate. 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 i.e., Jamnagar. The annual mean temperature is 26.7 °C. Rainy season with extremely erratic monsoonal rainfall that averages around 630 millimetres. The winter season is from October-to-February remains hot during the day but has negligible rainfall, low humidity and cool nights.

The Kandla and Vadinar port have been depicted in the **Map 1** as follows:

Map 1: Locations of Kandla and Vadinar Port

Map 2: Locations of Kandla Port

Map 3: Locations of Vadinar Port

2.2 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 identifying any deterioration in environmental conditions, thereby assist in recommending 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 a well-defined monitoring program. Environmental Monitoring is vital 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 have been mentioned below:

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

GEMI has been entrusted by DPA to carry out the monitoring of the various aforementioned environmental aspects at the port, so as to verify effectiveness of prevailing Environment Management plan, if it confirms to the statutory and/or 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, interpretation and communication of results. The analysis was carried out in GEMI's NABL/MoEF accredited/recognized laboratory.

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 whole process of management through effective decision-making and problem solving. The methodology adopted for the present study is shown in **Figure 1** as given below:

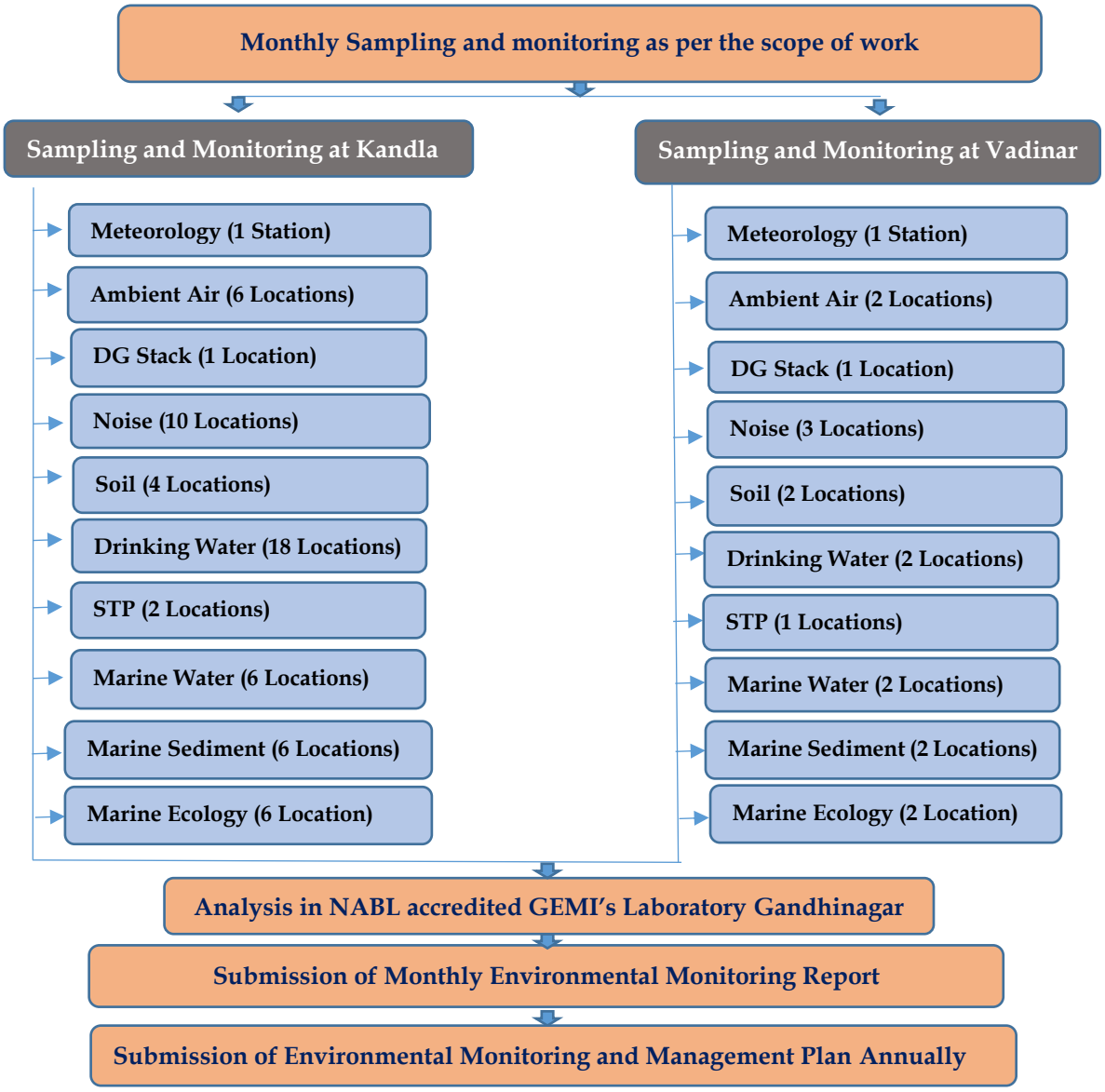


Figure 1: Methodology flow chart

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 as well as 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 make (Model: WM280) were installed at both the sites of Kandla and Vadinar at 10 m above the ground. The details of the AWS installed 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

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 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	^{o}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 sampling period of at both the observatory site.

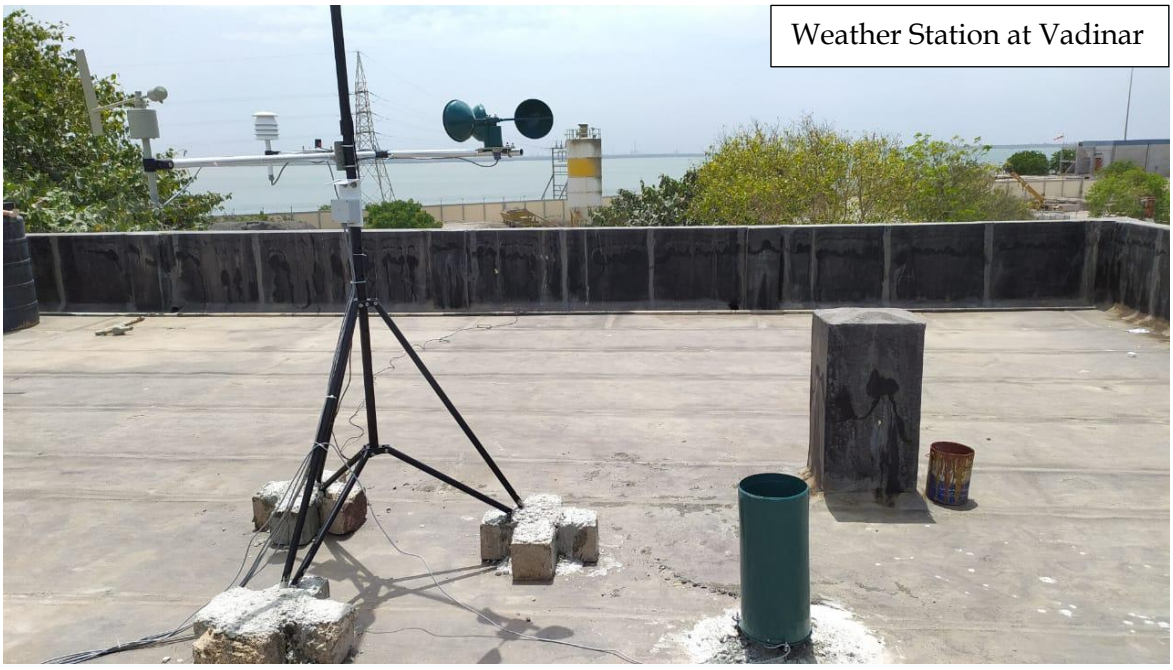


Figure 2: Photographs of Automatic Weather Monitoring Station at Kandla and Vadinar

3.2 Results and discussion

The summary of hourly climatological observations recorded at Kandla and Vadinar during the monitoring period, with respect to significant parameters has been mentioned in **Table 3** as follows**:**

Table 3: Meteorological data for Kandla and Vadinar

Details of Micro-meteorological data at Kandla Observatory												
Monitoring Period	**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**			
December-January, 2024-2025	7.25	48	3.12	20.27	34.1	13.5	52.38	78	27.8	57.19	South	0
Details of Micro-meteorological data at Vadinar Observatory												
Monitoring Period	**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**			
December-January, 2024-2025	7.91	74.7	2.96	20.90	27.3	14.1	60.62	104.1	29.4	69.28	South-West	0

3.3 Data Interpretation and Conclusion

- **Temperature**

a. **Kandla:** The ambient temperature for the monitoring period varies between the range of 13.5–34.1 °C for Kandla, with average temperature of 20.27°C.
b. **Vadinar:** The ambient temperature for the monitoring period varies between the range of 14.1-27.3°C for Vadinar, with average temperature of 20.90°C.

- **Relative Humidity**

a. **Kandla**: The Relative Humidity recorded between the range of 27.8–78, with average Humidity of 52.38%.
b. **Vadinar:** During the study period, the Relative Humidity varies between 29.4-101.1%, with average Humidity of 60.62%.

- **Rainfall**

a. **Kandla:** 0 rainfall was observed at Kandla.
b. **Vadinar:** 0 rainfall was observed at Vadinar.

- **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 3.12–48 Km/hr.
b. **Vadinar:** During the monitoring period, the Wind speed recorded ranges between 2.96–74.7 Km/hr.

- **Solar Radiation:**

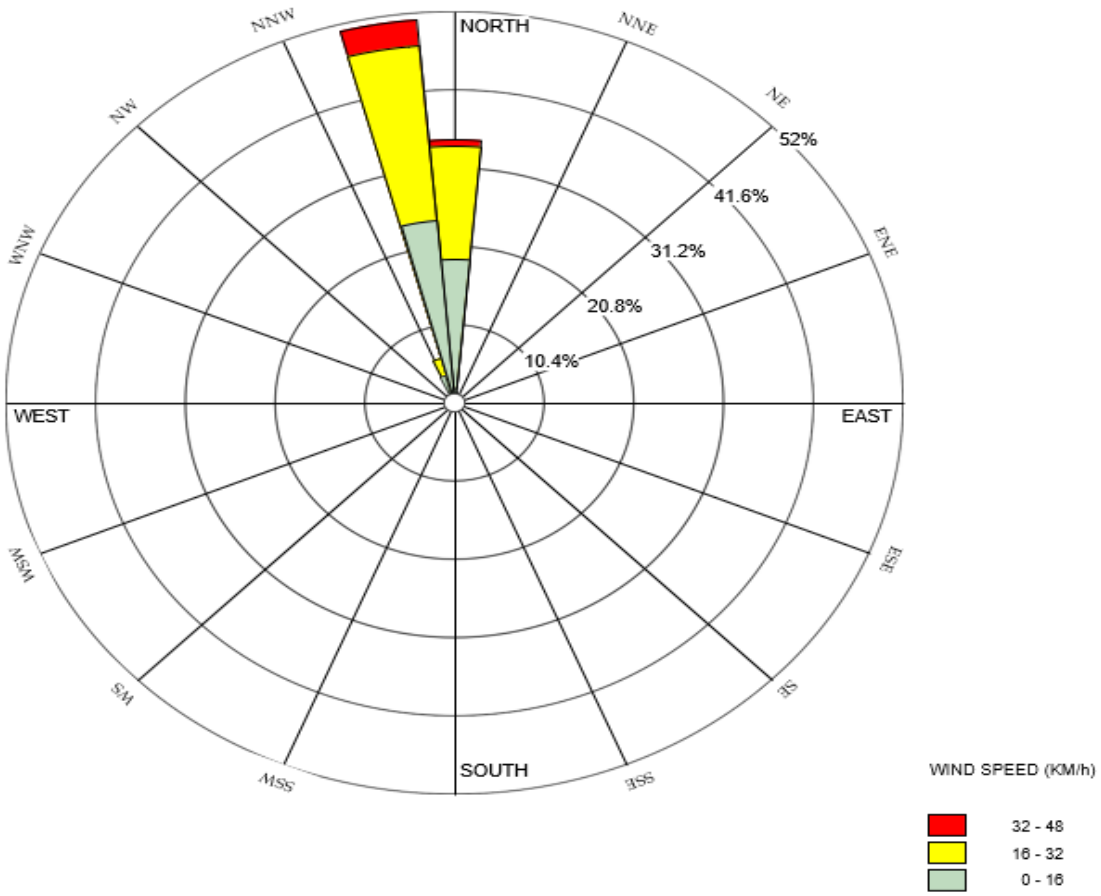
a. **Kandla:** The average Solar Radiation for the monitoring period was recorded as 57.19 W/m^2.
b. **Vadinar:** The average Solar Radiation was recorded as 69.28 W/m^2.

- **Wind rose diagram -**

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

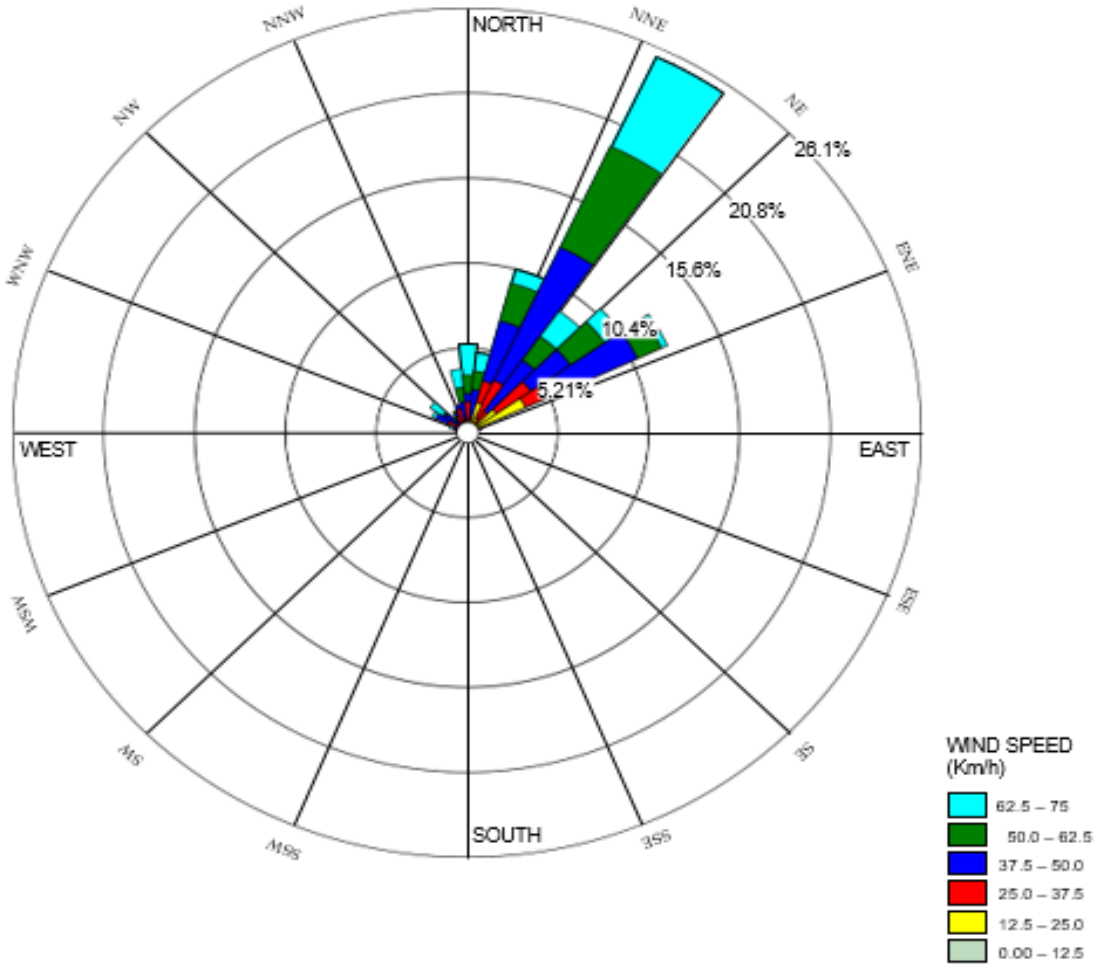
This Wind Rose Diagram reveals that at Kandla and Vadinar, during the monitoring period, the prevailing winds predominantly blow from the West South West direction at Kandla, whereas, high speed winds were also observed to blow from South direction. At Vadinar, the winds were observed to blow from South-West direction.

Wind Rose Plot M/s Deendayal Port Authority Site: Kandla Port (Environment Laboratory)	Display: Wind Direction Wind Speed (Km/hr)



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

Wind Rose Plot M/s Deendayal Port Authority Site: Vadinar Port (Canteen Area)	Display: Wind Direction Wind Speed (Km/hr)



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

CHAPTER 4: AMBIENT AIR QUALITY MONITORING

4.1 Ambient Air Quality

It is necessary to monitor the ambient air quality of the study area, in order to determine the impact of the shipping activities and port operations on the ambient air quality. The prime objective of ambient air quality monitoring is to assess the present air quality and its conformity to National Ambient Air Quality Standards i.e. NAAQS, 2009. Ambient air quality has been monitored from 17th December 2024 to 16th January 2025.

Methodology

The study area represents the area occupied by DPA and its associated Port area. 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. Considering the below factors, under the study, as per the scope specified by DPA eight locations wherein, 6 stations at Kandla and 2 at Vadinar have been finalized within the study area

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

The description of various air quality stations monitored at Kandla and Vadinar have been specified 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	Liquid containers and 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 and dust emission
4.		A-4	Marine Bhavan	23.007653N 70.222197E	Construction and vehicular 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 map in **Map 4 and 5** respectively.

Ambient Air monitoring photos

Kandla

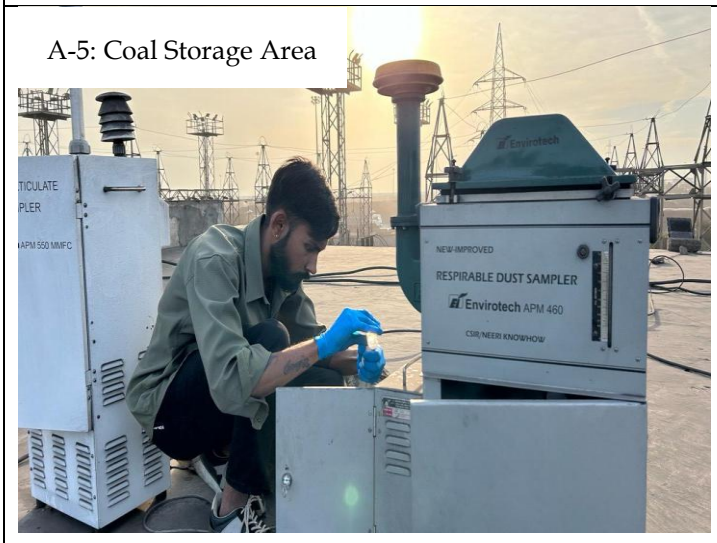
A-1: Oil Jetty No. 1

A-2: Oil Jetty No. 7

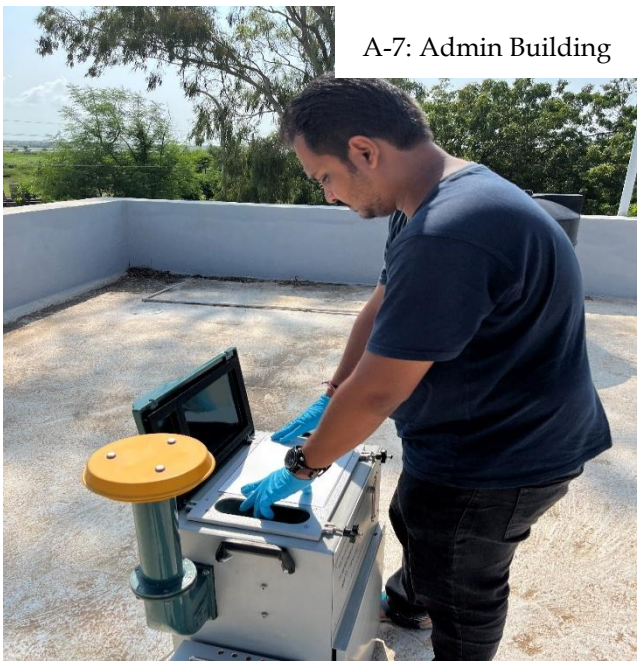
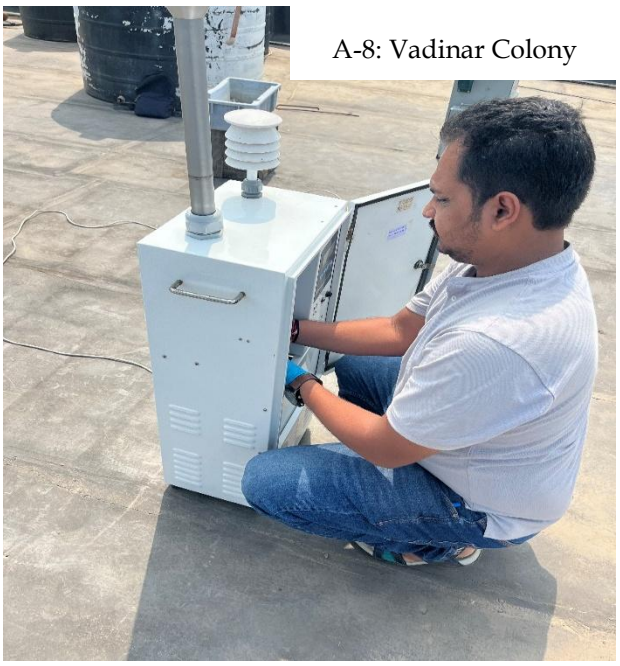
A-3: Kandla Port Colony

A-4: Marine Bhavan

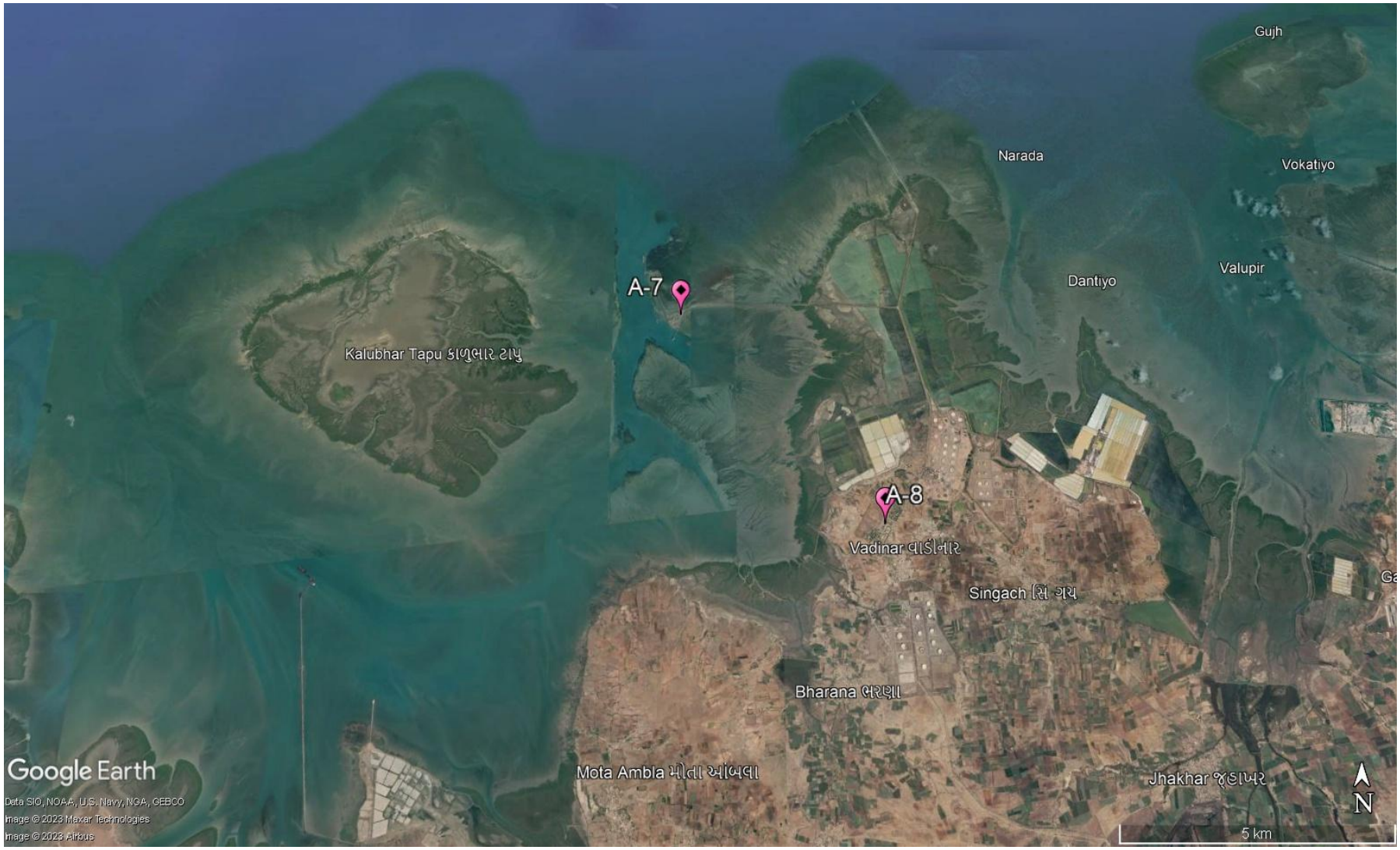
A-5: Coal Storage Area



A-6: Gopalpuri Hospital

Vadinar	
 A-7: Admin Building	 A-8: Vadinar Colony

Map 4: Locations for Ambient Air Monitoring at Kandla



Map 5: Locations for Ambient Air Monitoring at Vadinar

Frequency

The sampling for Particulate matter i.e. PM_{10} and $PM_{2.5}$ and the gaseous components like SO_x, NO_x, CO as well as the Total VOCs were monitored twice in a week for a period of 24 hours a day. Whereas, the sampling for the components of PAH, Benzene and non-Methane VOCs was conducted on monthly basis.

Sampling and Analysis

The Sampling of the Ambient Air Quality parameters and analysis is conducted as per the 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 of size 8"x 10" were utilized, where the Gaseous attachment of the make Envirotech instrument was attached with Respirable Dust Sampler for the measurement of SO_x and NO_x. The Fine Particulate Sampler for collection of $PM_{2.5}$ was utilized for the 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 measured flow rate of 1 liter/minute (L/min). Similarly, NO_x 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 carried out twice a week. 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 (LVS) 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 LVS during two hours monitoring is approx. 24 L.

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, Benzene, 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/m³	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/m³	IS:5182 (Part:24):2019	Fine Particulate Sampler (FPS) conforming to IS:5182 (Part-24): 2019	
3.	Sulphur Dioxide (SO_x)	µg/m³	IS 5182 (Part:2): 2001	Gaseous Attachment conforming to IS:5182 Part-2	
4.	Oxides of Nitrogen (NO_x)	µg/m³	IS:5182 (Part-6): 2006	Gaseous Attachment conforming to IS:5182 Part-6	
5.	Carbon Monoxide (CO)	mg/m³	GEMI/SOP/AAQM/11 ; Issue no 01, Date 17.01.2019: 2019	Sensor based Instrument	
6.	VOC	µg/m³	IS 5182 (Part 17): 2004	Low Flow Air Sampler	
8.	PAH	µg/m³	IS: 5182 (Part 12): 2004	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-12): 2004	Monthly
7.	Benzene	µg/m³	IS 5182 (Part 11): 2006 RA: 2017	Low Flow Air Sampler	
9.	Non-methane VOC	µg/m³	IS 5182 (Part 11): 2006	Low Volume Sampler	

4.2 Result and Discussion

The summarized results of ambient air quality monitoring for the study period are presented in **Table-6 to 9** along with the graphical representation from **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}, $PM_{2.5}$, SO_2, NO_x, VOC and CO for Ambient Air quality monitoring

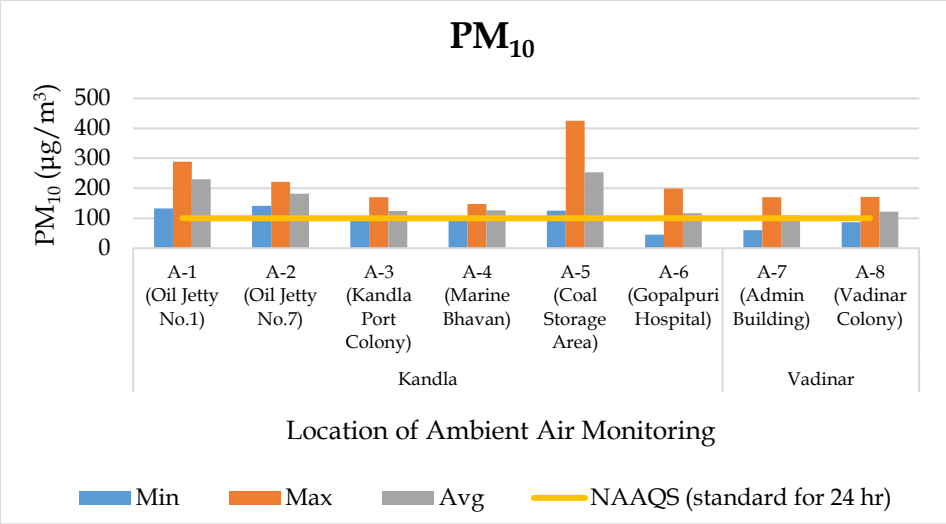
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	**PM_{10} (µg/m³)**	**$PM_{2.5}$ (µg/m³)**	**SO_2 (µg/m³)**	**NO_X (µg/m³)**	**VOC (µg/m³)**	**CO (mg/m³)**
	Duration	**(24 hr)**				**(2 hr)**	**(1 hr)**
	NAAQS by CPCB / **Monitoring days**	**100**	**60**	**80**	**80**	**-**	**2**
A-1: Oil Jetty No.1, Kandla	16-12-2024	288.45	59.98	53.31	33.23	0.05	0.88
	18-12-2024	284.13	76.86	50.42	24.14	0.06	0.63
	23-12-2024	285.33	68.85	13.09	21.12	0.12	0.83
	26-12-2024	132.58	23.08	9.45	10.48	0.17	0.79
	30-12-2024	154.79	62.87	16.62	21.43	0.1	0.82

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
	02-01-2025	260.09	80.83	20.07	27.43	0.12	0.81
	06-01-2025	210.54	60.52	13.86	18.97	0.2	0.82
	07-01-2025	221.02	56.07	14.78	23.16	0.21	0.81
	Minimum	**132.58**	**23.08**	**9.45**	**10.48**	**0.05**	**0.63**
	Maximum	**288.45**	**80.83**	**53.31**	**33.23**	**0.21**	**0.88**
	Average	**229.62**	**61.13**	**23.95**	**22.50**	**0.13**	**0.80**
	Std. Deviation	**60.85**	**17.62**	**17.51**	**6.57**	**0.06**	**0.07**
A-2: Oil Jetty No.7, Kandla	16-12-2024	157.04	47.49	14.12	18.32	0.16	0.84
	18-12-2024	190.54	74.27	12.34	12.52	0.20	0.88
	23-12-2024	208.91	80.64	28.18	20.47	0.19	0.89
	26-12-2024	158.75	23.69	8.56	14.75	0.14	0.81
	30-12-2024	221.71	60.32	14.96	11.16	0.07	0.84
	02-01-2025	141.48	67.90	17.16	13.84	0.13	0.84
	06-01-2025	187.49	51.67	16.66	32.53	0.11	0.85
	07-01-2025	186.94	44.70	13.05	7.47	0.09	0.88
	Minimum	**141.48**	**23.69**	**8.56**	**7.47**	**0.07**	**0.81**
	Maximum	**221.71**	**80.64**	**28.18**	**32.53**	**0.20**	**0.89**
	Average	**181.61**	**56.34**	**15.63**	**16.38**	**0.14**	**0.85**
	Std. Deviation	**27.34**	**18.37**	**5.75**	**7.67**	**0.05**	**0.03**
A-3: Kandla Port Colony, Kandla	16-12-2024	103.64	26.50	10.26	27.56	0.25	0.76
	18-12-2024	115.94	30.87	14.83	20.56	0.10	0.79
	23-12-2024	142.12	24.10	28.78	10.32	0.06	0.82
	26-12-2024	136.52	24.26	12.69	15.27	0.14	0.86
	30-12-2024	127.02	15.86	11.58	17.60	0.18	0.87
	02-01-2025	169.82	21.33	20.57	12.37	0.20	0.81
	06-01-2025	100.35	33.68	13.54	8.53	0.24	0.85
	07-01-2025	101.56	21.41	24.56	11.30	0.16	0.77
	Minimum	**100.35**	**15.86**	**10.26**	**8.53**	**0.06**	**0.76**
	Maximum	**169.82**	**33.68**	**28.78**	**27.56**	**0.25**	**0.87**
	Average	**124.62**	**24.75**	**17.10**	**15.44**	**0.17**	**0.82**
	Std. Deviation	**24.30**	**5.64**	**6.75**	**6.31**	**0.07**	**0.04**
A-4: Marine Bhavan, Kandla	16-12-2024	112.54	27.08	9.54	8.76	0.14	0.79
	18-12-2024	106.87	13.67	15.68	11.74	0.21	0.83
	23-12-2024	126.95	25.34	12.45	10.37	0.18	0.89
	26-12-2024	145.50	15.98	21.89	11.52	0.11	0.76
	30-12-2024	135.26	19.57	22.42	13.90	0.08	0.81
	02-01-2025	125.63	24.68	16.74	12.39	0.07	0.88
	06-01-2025	110.25	18.76	19.85	5.75	0.10	0.81
	07-01-2025	147.32	15.48	11.02	18.20	0.12	0.86
	Minimum	**106.87**	**13.67**	**9.54**	**5.75**	**0.07**	**0.76**
	Maximum	**147.32**	**27.08**	**22.42**	**18.20**	**0.21**	**0.89**
	Average	**126.29**	**20.07**	**16.20**	**11.58**	**0.13**	**0.83**
	Std. Deviation	**15.66**	**5.06**	**4.93**	**3.65**	**0.05**	**0.05**

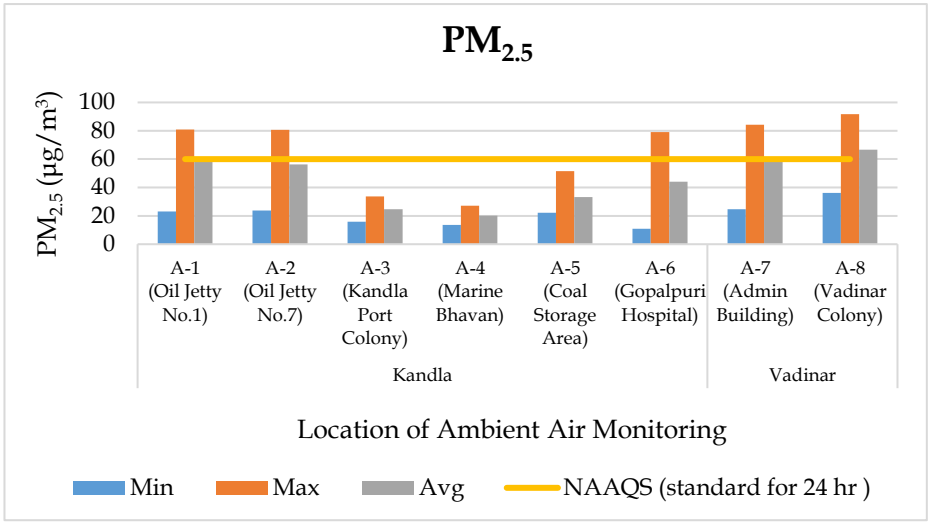
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
A-5: Coal Storage Area, Kandla	16-12-2024	159.63	36.38	26.58	8.84	0.29	0.93
	18-12-2024	125.48	29.31	14.67	9.78	0.07	0.98
	23-12-2024	169.84	40.28	13.52	30.62	0.23	1.02
	26-12-2024	415.26	22.13	19.64	11.40	0.16	0.97
	30-12-2024	425.68	51.64	20.15	28.51	0.17	0.88
	02-01-2025	348.61	27.88	12.06	19.77	0.19	0.92
	06-01-2025	228.78	24.65	8.4	24.39	0.13	0.96
	07-01-2025	157.62	34.58	26.87	13.28	0.10	0.99
	Minimum	**125.48**	**22.13**	**8.40**	**8.84**	**0.07**	**0.88**
	Maximum	**425.68**	**51.64**	**26.87**	**30.62**	**0.29**	**1.02**
	Average	**253.86**	**33.36**	**17.74**	**18.32**	**0.17**	**0.96**
	Std. Deviation	**123.55**	**9.57**	**6.74**	**8.70**	**0.07**	**0.04**
A-6: Gopalpuri Hospital, Kandla	16-12-2024	56.81	16.60	4.94	15.15	0.05	0.75
	18-12-2024	45.26	21.16	36.41	14.27	0.09	0.70
	23-12-2024	112.63	10.92	4.87	10.10	0.10	0.69
	26-12-2024	154.21	18.61	4.37	7.73	0.19	0.68
	30-12-2024	199.56	79.04	13.01	<6	0.13	0.64
	02-01-2025	183.59	73.01	21.16	27.47	0.17	0.61
	06-01-2025	104.11	66.03	13.01	6.42	0.07	0.62
	07-01-2025	76.55	67.61	13.51	27.9	0.17	0.6
	Minimum	**45.26**	**10.92**	**4.37**	**6.42**	**0.05**	**0.60**
	Maximum	**199.56**	**79.04**	**36.41**	**27.90**	**0.19**	**0.75**
	Average	**116.59**	**44.12**	**13.91**	**15.58**	**0.12**	**0.66**
	Std. Deviation	**57.60**	**29.58**	**10.78**	**8.86**	**0.05**	**0.05**
A-7: Admin Building, Vadinar	16-12-2024	60.52	24.61	12.03	6.12	0.08	0.70
	18-12-2024	92.96	54.94	11.45	<6	0.19	0.60
	23-12-2024	160.57	79.35	11.37	17.11	0.15	0.62
	26-12-2024	169.87	82.15	12.66	6.65	0.16	0.62
	30-12-2024	86.86	46.73	12.67	<6	0.14	0.63
	02-01-2025	82.64	69.48	45.56	12.19	0.17	0.62
	06-01-2025	91.27	29.82	14.91	<6	0.16	0.56
	07-01-2025	125.49	84.19	26.28	7.01	0.13	0.72
	Minimum	**60.52**	**24.61**	**11.37**	**6.12**	**0.08**	**0.56**
	Maximum	**169.87**	**84.19**	**45.56**	**17.11**	**0.19**	**0.72**
	Average	**108.77**	**58.91**	**18.37**	**9.82**	**0.15**	**0.63**
	Std. Deviation	**39.18**	**23.59**	**12.05**	**4.75**	**0.03**	**0.05**
A-8: Vadinar Colony, Vadinar	16-12-2024	87.32	36.57	11.71	<6	0.20	0.65
	18-12-2024	120.29	65.04	10.78	<6	0.14	0.55
	23-12-2024	149.90	81.26	10.73	<6	0.20	0.55
	26-12-2024	171.58	76.15	12.81	6.02	0.15	0.58
	30-12-2024	116.51	60.18	12.99	<6	0.18	0.55
	02-01-2025	109.79	91.70	40.11	12.07	0.13	0.56

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
	06-01-2025	111.08	36.25	11.96	7.14	0.17	0.63
	07-01-2025	112.69	85.93	18.23	9.60	0.08	0.65
	Minimum	**87.32**	**36.25**	**10.73**	**6.02**	**0.08**	**0.55**
	Maximum	**171.58**	**91.70**	**40.11**	**12.07**	**0.20**	**0.65**
	Average	**122.40**	**66.64**	**16.17**	**8.71**	**0.16**	**0.59**
	Std. Deviation	**26.26**	**21.30**	**9.96**	**2.69**	**0.04**	**0.05**

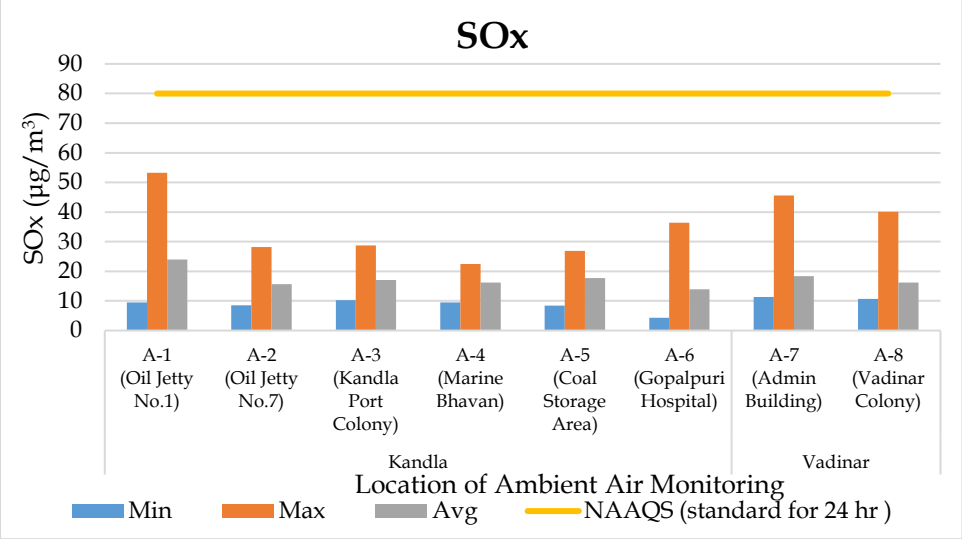
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar



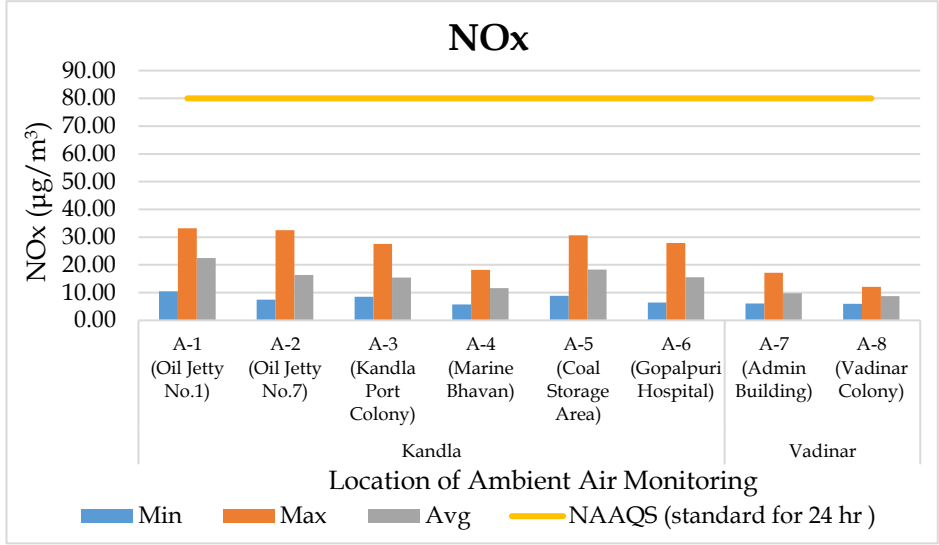
Graph 1: Spatial trend in Ambient PM_{10} Concentration



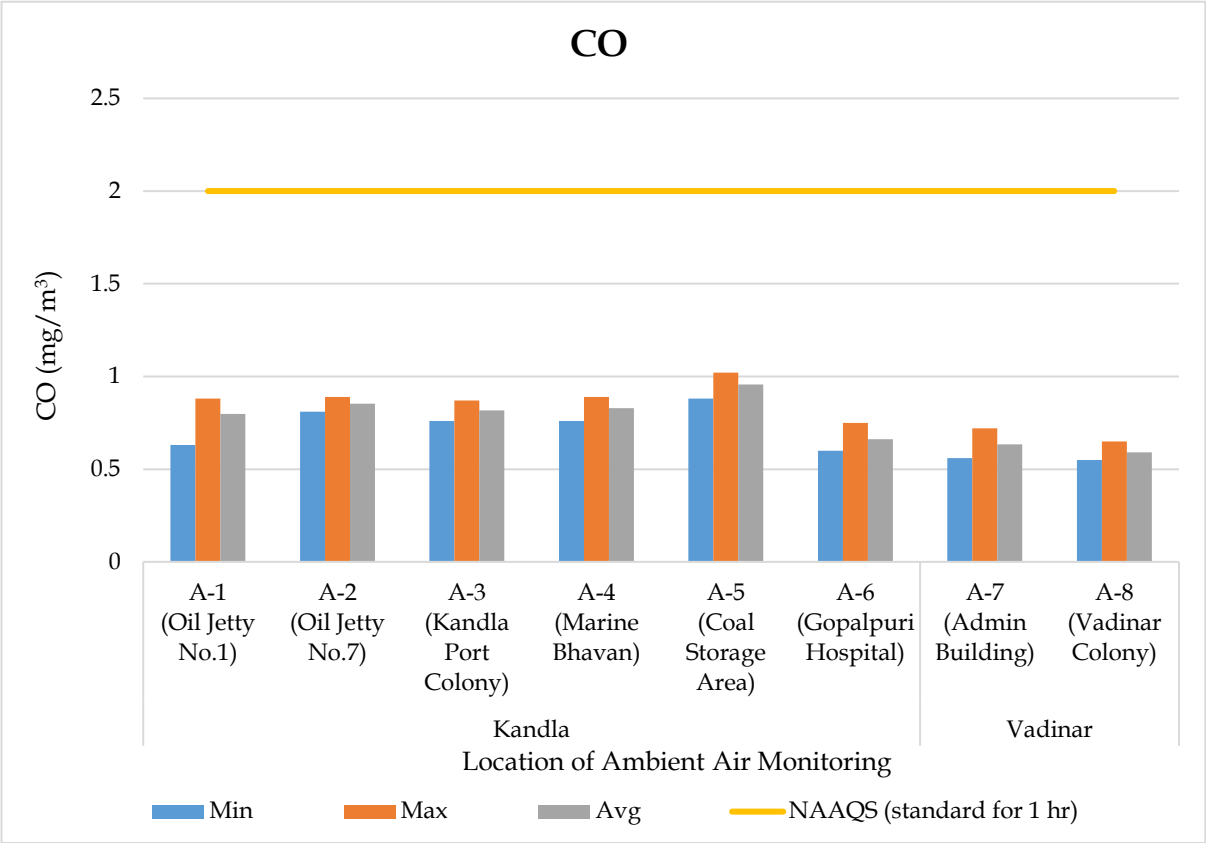
Graph 2: Spatial trend in Ambient $PM_{2.5}$ Concentration



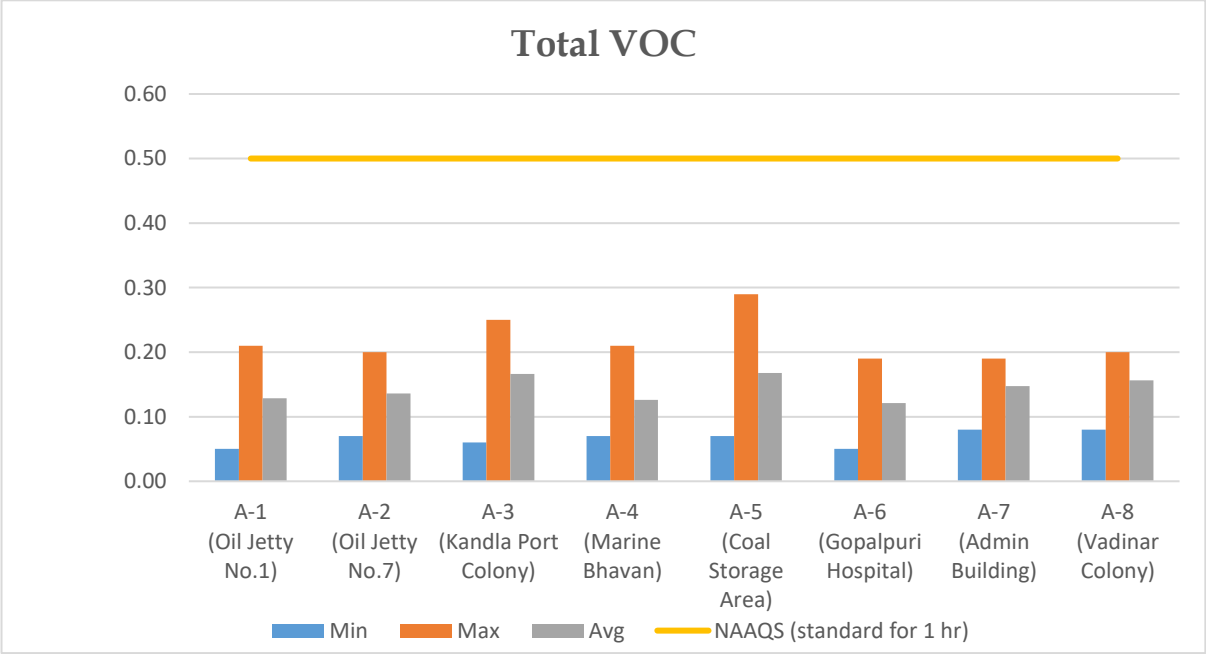
Graph 3: Spatial Trend in Ambient SOx Concentration



Graph 4: Spatial trend in Ambient Nox Concentration



Graph 5: Spatial trend in Ambient CO Concentration



Graph 6: Spatial trend in Ambient Total VOCs

Table 7: Summarized results of Benzene for Ambient Air quality monitoring

Benzene (µg/m³)								
Sr. No	Kandla						Vadinar		NAAQS standards (24 hr)
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	0.05	0.02	0.04	0.01	0.08	0	0	0	5 µg/m³

Table 8: Summarized results of Polycyclic Aromatic Hydrocarbons

Sr. No.	Components	Kandla						Vadinar	
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	Napthalene	1.10	1.52	0.02	1.53	1.2	0.01	0.46	0.41
2	Acenaphthylene	0.59	0.72	0.07	0.87	0.31	0.01	0.00	0.00
3	Acenaphthene	0.58	0.61	0.18	0.19	0.26	0.14	0.00	0.00
4	Fluorene	0.05	0.45	0.01	0.54	0.62	0.58	0.00	0.01
5	Anthracene	0.11	0.05	0.01	0.21	0.23	0.01	0.02	0.02
6	Phenanthrene	0.05	0.02	0.03	0.01	0.00	0.10	0.00	0.00
7	Fluoranthene	0.02	0.41	0.05	0.25	0.02	0.36	0.00	0.01
8	Pyrene	0.16	0.59	0.42	0.29	0.48	0.06	0.00	0.00
9	Chrycene	1.22	0.98	0.25	0.40	0.02	1.20	0.00	0.00
10	Banz(a)anthracene	0.22	0.26	0.36	0.27	0.02	0.15	0.00	0.00
11	Benzo[k]fluoranthene	3.7	0.20	2.6	0.2	1.02	1.68	0.00	0.04
12	Benzo[b]fluoranthene	0.02	0.06	0.02	0.02	0.05	0.03	0.00	0.02
13	Benzopyrene	1.74	0.93	3.56	0.01	0.63	0.05	0.00	0.00
14	Indeno [1,2,3-cd] fluoranthene	0.52	0.75	0.71	0.55	0.98	1.49	0.00	0.11
15	Dibenz(ah)anthracene	0.00	0.01	0.25	0.00	0.18	0.05	0.00	0.00
16	Benzo[ghi]perylene	1.3	8.9	28.1	13.2	9.3	12.8	0.00	0.00

Table 9: Summarized results of Non-methane VOC

Sr No	Kandla						Vadinar	
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	0.92	0.96	1.13	1.26	1.56	1.10	1.45	1.12

4.3 Data Interpretation and Conclusion

The results were compared with the National Ambient Air Quality Standards (NAAQS), 2009 of Central Pollution Control Board (CPCB).

- The concentration of PM_{10} at Kandla varies in the range of **45.26 to 425.68 µg/m³** with an average value of **172.10 µg/m³**. PM_{10} exceeded NAAQS of all the monitoring locations in Kandla. Whereas, at Vadinar, the concentration varies from **60.52 to 171.58 µg/m³**, with an average value of **115.68 µg/m³**, and complies with the stipulated norm (100 µg/m³).

- The elevated PM_{10} concentration at location A-5, the Coal Storage Area, can be attributed to several factors. Heavy vehicular traffic in upwind areas significantly contributes to the dispersion of particulate matter into the ambient air. The process of unloading coal directly onto trucks using grabs leads to the emission of coal dust into the air and its subsequent settling on the ground. This settled dust is re-entrained into the atmosphere as trucks travel through the area. Additionally, coal-loaded trucks are often not adequately covered with tarpaulin sheets, which exacerbates the suspension of coal particles during transit from vessels to the storage yard or site. These factors collectively contribute to increased PM_{10} levels in and around the Coal Storage Area and Marine.
- The **$PM_{2.5}$** concentrations at Kandla varies from **10.92 to 80.83 µg/m³** with average **39.96 µg/m³**. The **$PM_{2.5}$** concentration falls within the NAAQS limit for all locations of Kandla. Whereas, at Vadinar its concentration varies from **24.61 to 91.70 µg/m³** with average **62.77 µg/m³**. During winter, the concentrations of particulate matter (PM10 & PM2.5) are seen to increase. Also due to construction and demolition all around the port contributing in increased particulate matter levels.
- The concentration of **SO_x** varies from **4.37 to 53.31 µg/m³** with average concentration as **17.42 µg/m³** at Kandla and **10.73 to 45.56 µg/m³** with average as **17.27 µg/m³** at Vadinar. The average concentration of SO_x complies with the prescribed limit of NAAQS (80 µg/m³) for both the monitoring site.
- The concentration of **NO_x** varies from **5.75 to 33.23 µg/m³** with average **16.63 µg/m³** at Kandla and **6.02 to 17.11 µg/m³** with average **9.26 µg/m³** at Vadinar. The concentration of **NO_x** falls within the prescribed limit of NAAQS i.e. 80 µg/m³ at both the monitoring site of Kandla and Vadinar.
- The concentration of **CO** varies from **0.60 to 1.02 µg/m³** with average **0.82 µg/**m³ at Kandla and **0.55 to 0.72 µg/m³** with average **0.61 µg/m³** at Vadinar. The concentration falls within the norm of 2 mg/m³ specified by NAAQS at both the monitoring sites
- The concentration of **Total VOCs** levels was recorded in range of **0.05 to 0.29 µg/m³** at Kandla and **in range of 0.08 to 0.20 µg/m³** at the location of Vadinar respectively. The main source of VOCs in the ambient air may be attributed to the burning of Gasoline and Natural gas in Vehicle exhaust and burning fossil fuels, and garbage that release VOCs into the atmosphere. During the monitoring period, the wind flows towards South direction at Kandla, and hence the wind direction and speed also contribute to increased dispersion of pollutants from the upward areas towards the downward areas.
- **Benzene** was detected on the location of Kandla in the range of **0 to 0.08 (µg/m3)** whereas not detected on the location of Vadinar.
- **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. These locations are commercial areas where Vehicular activity and dust emission is common. PAHs are a class of chemicals that occur naturally in coal, crude oil, and gasoline. The higher

concentration which results from burning coal, oil, gas, road dust, etc. Other outdoor sources of PAHs may be the industrial plants in-and-around the DPA premises.

- The Ambient air Monitoring location of Kandla recorded the **Non-methane VOC** (NM-VOC) concentration in the range of **0.92 to 1.56 µg/m³**. While at Vadinar, the concentration of NM-VOC falls is found to be **1.12 to 1.45 mg/m³** at both the location.

With reference to the Ambient Air Quality monitoring conducted under the study, it may be concluded that the particulate matter PM_{10}, were reported in higher concentration and apparently exceeds the NAAQS particularly at locations of Kandla., whereas $PM_{2.5}$ complies with the NAAQS at majority of the locations. For both the ambient air monitoring parameters (PM_{10} and $PM_{2.5}$), the major exceedance was observed at location A-5 i.e. Coal Storage Area. The gaseous pollutants (NO_x, SO_x, CO, VOCs etc.) falls within the permissible limit. The probable reasons contributing to these emissions of pollutants into the atmosphere in-and-around the port area are summarized as follows: -

1. **Port Machinery:** Port activities involve the use of various machinery and equipment, including cranes, for lifts, tugboats, and cargo handling equipment. These machines often rely on diesel engines, which can emit pollutants such as NO_x, Particulate matter, and CO. Older or poorly maintained equipment tends to generate higher emissions.
2. **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.
3. Apart from that, construction and demolition activities majorly contribute to particulate matter pollution.

4.4 Remedial Measures:

To improve air quality, DPA has implemented a number of precautionary measures, such as maintaining Green zone, initiated Inter-Terminal Transfer of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and unpaved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port. To address air pollution from port shipping activities, various measures that can be implemented are as follows:

- 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 will help to reduce the suspension of pollutants in air.
- Frequent water sprinkling on roads to reduce dust suspension due to vehicular movement, this can be use during transporting coal to avoid suspension 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 construction site could considerably reduce dust emission. Prohibition of use of heavy diesel oil as fuel could be possibly reduce

pollutants. Encouraging use of low-sulfur fuels (viz. Marine Gas Oil (MGO)/Liquefied Natural Gas (LNG), can significantly reduce sulfur and PM emissions from ships.

- 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.
- 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.

CHAPTER 5: DG STACK MONITORING

5.1 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_2, 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 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 10** as follows:

Table 10: Details of DG Stack 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 6 and 7** as follows:

Map 6: Locations for DG Stack monitoring at Kandla

Map 7: Locations for DG Stack monitoring at Vadinar

Methodology:

Under the study, the list of parameters to be monitored under the projects for DG Stack Monitoring has been mentioned in **Table 11** as follows:

Table 11: DG stack parameters

Sr. No.	Parameter	Unit	Instrument
1.	Suspended Particulate Matter	mg/Nm^3	Stack Monitoring Kit
2.	Sulphur Dioxide (SO_2)	PPM	Sensor based Flue Gas Analyzer (Make: TESTO, Model 350)
3.	Oxides of Nitrogen (NO_x)	PPM	
4.	Carbon Monoxide	%	
5.	Carbon Dioxide	%	

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

The monitoring of DG Stack is carried out as per the IS:11255 and USEPA Method. The Stack monitoring kit is used for collecting representative samples from the stack to determine the total amount of pollutants emitted into the atmosphere in a given time. Source sampling is carried out from ventilation stack to determine the emission rates/or characteristics of pollutants. Sample collected must be such that it truly represents the conditions prevailing inside the stack. Whereas the parameters Sulphur Dioxide, Oxides of Nitrogen (NO_x), Carbon Monoxide and Carbon Dioxide, the monitoring is carried out by using the sensor-based Flue Gas Analyzer.

Frequency

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

5.2 Result and Discussion

The sampling and monitoring of DG stack emission was carried out at Kandla and Vadinar and its comparison with CPCB or Indian standards for Industrial Stack Monitoring the flue gas emission from DG set has given in **Table 12.**

Table 12: DG monitoring data

Sr. No.	Stack Monitoring Parameters for DG Sets	Stack Monitoring Limits / Standards As per CPCB	DG- 1 (Kandla)	DG-2 (Vadinar)
1.	Suspended Particulate Matter (SPM) (mg/Nm^3)	150	71.45	37.48
2.	Sulphur Dioxide (SO_2) (PPM)	100	1.17	N.D.
3.	Oxides of Nitrogen (NO_x) (PPM)	50	25.49	9.04
4.	Carbon Monoxide (CO) (%)	1	0.15	0.011
5.	Carbon Dioxide (CO_2) (%)	-	1.19	1.41

5.3 Data Interpretation and Conclusion

The results of DG stack emission are compared with the permissible limits mentioned in the consent issued by GPCB, and have been found within the prescribed limit for all the monitored parameters.

CHAPTER 6: NOISE MONITORING

6.1 Noise Monitoring

Noise can be defined as an unwanted sound, and 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 the subsequent activities may affect surrounding environment impacting the fauna and as well as the human population. 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 not only confined to commercial areas of DPA but also the residential areas of DPA.

The details of the noise monitoring stations are mentioned in **Table 13** and locations have been depicted in the **Map 8 and 9** as follow:

Table 13: 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

Map 8: Locations for Noise Monitoring at Kandla

Map 9: Locations for Noise Monitoring at Vadinar

Methodology:

The intensity of sound energy in the environment is measured in a logarithmic scale and is expressed in a decibel (dB(A)) scale. The 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). Whereas, 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. Noise levels were measured using an integrated sound level meter of the make Envirotech Sound Level Meter (Class-I) (model No. SLM-109). 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.

Frequency

Monitoring was carried out at each noise monitoring station for Leq. noise level (Day and Night), which was recorded for 24 hours continuously at a monthly frequency with the help of Sound/Noise Level Meter (Class-1). The details of the noise monitoring have been mentioned in **Table 14**.

Table 14: Details of the Noise Monitoring

Sr. No.	Parameters	Units	Reference Method	Instrument
1.	Leq (Day)	dB(A)	IS 9989: 2014	Noise Level Meter (Class-I) model No. SLM-109
2.	Leq (Night)	dB(A)		

Standard for Noise

Ministry of Environment & Forests (MoEF) has notified the noise standards vide the Gazette notification dated February 14, 2000 for different zones under the Environment Protection Act (1986). The day time noise levels have been monitored from 6.00 AM to 10.00 PM and night noise levels were measure from 10.00 PM to 6.00 AM at all the thirteen locations (10 at Kandla and 3 at Vadinar) monthly. The specified standards are as mentioned in **Table 15** as follows:

Table 15: 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

6.2 Result and Discussion

The details of the Noise monitoring conducted during the monitoring period have been summarized in the **Table 16** as below:

Table 16: 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	53.4	33.8	43.6	70	45.7	32.1	38.9
2	N-2	West Gate No.1	A	75	61.8	44.2	53	70	50.2	41.2	45.7
3	N-3	Canteen Area	B	65	54.2	43.5	48.8	55	47.2	32.4	39.8
4	N-4	Main Gate	A	75	71.9	44.6	58.2	70	50.2	33.7	41.9
5	N-5	Main Road	A	75	70.5	37.3	53.9	70	48.5	35.1	41.8
6	N-6	Marin Bhavan	B	65	61.7	42.8	52.2	55	49.8	32.9	41.3
7	N-7	Port & Custom Building	B	65	59.1	34.9	47	55	48.1	34.7	41.4
8	N-8	Nirman Building	B	65	62.5	35.6	49.0	55	47.2	32.9	40
9	N-9	ATM Building	B	65	56.9	36	46.4	55	50.2	33.4	41.8
10	N-10	Wharf Area/ Jetty	A	75	60.4	41.9	51.1	70	47.1	38.1	42.6
11	N-11	Near Main Gate	A	75	63.4	55.3	59.3	70	56.2	45.7	50.9
12	N-12	Near Vadinar Jetty	A	75	65.2	58.5	61.8	70	56.5	51.9	54.2
13	N-13	Port Colony Vadinar	C	55	43.3	38.4	40.8	45	39.7	34.2	36.9

6.3 Data Interpretation and Conclusion

The noise level at both the locations (Kandla and Vadinar) was compared with the standard limits specified in NAAQS by CPCB. During the Day Time, the average noise level at all 10 locations at Kandla ranged from **33.8 dB(A) to 71.9 dB(A)**, while at Vadinar, he noises levels for the three-location ranged from **38.4 dB(A) to 65.2 dB(A).** Whereas, during Night Time the average Noise Level ranged from **32.1 dB(A) to 50.2 dB(A)** at Kandla and **34.2 dB(A) to 56.5 dB(A)** at Vadinar.

6.4 Remedial Measures

Though, the noise levels detected at the locations of Kandla and Vadinar, are found within the prescribed norms, the noise can further be considerably reduced by adoption of low noise equipment or installation of sound insulation fences. Green belt of plants can be a good barrier. If noise exceeds the applicable norms, then the working hours may be altered as a possible means to mitigate the nuisances of construction activities.

CHAPTER 7: SOIL MONITORING

7.1 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 17:**

Table 17: Details of the Soil quality monitoring

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

Methodology

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 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 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, Gandhinagar 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 18** as follows:

Frequency

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

Table 18: Soil parameters

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	Kg/Hectare	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
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		

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

Map 10: Locations for Soil Quality Monitoring at Kandla

Map 11: Locations for Soil Quality Monitoring at Vadinar

7.2 Result and Discussion

The analysis results of physical analysis of the soil samples collected during environmental monitoring mentioned in **Table 19** are shown below:

Table 19: Soil Quality for the sampling period

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	-	8.73	8.25	8.51	8.44	7.85	8.38
2	Conductivity	µS/cm	12210	13780	2630	15690	271	231
3	Inorganic Phosphate	Kg/ha	0.68	1.62	1.94	1.28	0.87	0.86
4	Organic Carbon	%	0.41	0.39	0.3	0.78	0.35	0.82
5	Organic Matter	%	0.71	0.67	0.52	1.35	0.6	1.42
6	SAR	meq/L	18.31	12.29	1.31	13.21	0.10	0.13
7	Aluminium	mg/Kg	12387	11554	8105	11739	34107	31358.80
8	Chromium	mg/Kg	52.24	52.52	49.18	58.81	69.59	71.12
9	Nickel	mg/Kg	22.89	15.87	21.32	28.84	28.84	32.53
10	Copper	mg/Kg	77.03	85.80	70.86	24.96	89.51	76.23
11	Zinc	mg/Kg	73.96	95.08	61.84	63.50	62.67	63.70
12	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
14	Arsenic	mg/Kg	0.95	0.93	2.31	3.86	0.35	0.72
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	52	47.2	48.8	60	47.2	65.59
17	Sand	%	61.69	67.68	70.4	57.69	78.24	78.96
18	Silt	%	26	32	21.28	39.99	20	14
19	Clay	%	12.32	0.32	8.32	2.32	1.76	7.04
20	Texture	-	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	Loamy sand

7.3 Data Interpretation and Conclusion

Soil samples were collected from 6 locations (4 at Kandla and 2 at Vadinar) and further analysed for its physical & chemical characteristics. Each of the parameters have been given an interpretation based on the observations as follows:

- The value of **pH** ranges from **8.25-8.73,** highest at location S-1 (Oil Jetty 7) and lowest at S-2 (IFFCO Plant); while the average pH for Kandla was observed to be 8.48. Whereas, at Vadinar the pH value observed at S-5 i.e., Near SPM (7.85) and at S-6 i.e.,

Near Jetty Area (8.38). As per the observation the pH was found to be **moderately to strongly alkaline** both the monitoring station of Kandla and Vadinar**.**

- At entire monitoring locations of Kandla the value of **Electrical Conductivity** ranges from **2630-15690 µs/cm**, highest at location S-4 (Nakti Creek) with the average as **11077.5 µs/cm**. Whereas, at Vadinar the range of conductivity was between the range of **231 to 271 µs/cm** with an average value of **251 µs/cm**.

- At Kandla, the concentration of **Inorganic Phosphate** varied from **0.68-1.94 Kg/ha**, with average **1.38 Kg/ha**. Whereas, at the locations of Vadinar, the Inorganic Phosphate was observed at S-5 i.e., Near SPM (**0.87 Kg/ha**) and detected at S-6 i.e., near Jetty Area (**0.86 Kg/ha**). The phosphorus availability in soil solution is influenced by a number of factors such as Organic matter, clay content, pH, temperature, etc.

- The concentration of **Total Organic Carbon** ranges from **0.30-0.78**% while the average TOC at Kandla was detected as **0.47%.** Whereas, at Vadinar the average TOC was found to be **0.58**% where the observed TOC value found at S-5 i.e. Near SPM (**0.35**%) and S-6 i.e. near Jetty Area to be **0.82** % and below quantification limit respectively.

- The concentration of **Water Holding Capacity** in the soil samples of Kandla and Vadinar varies from **47.2-60**% and **47.2-65.59**% respectively.

- The concentration of **Sodium Adsorption Ratio** ranges from **1.31-18.31 meq/L** with an average value **11.28 meq/L** at Kandla. Whereas, at Vadinar, the average SAR was found to be **0.11 meq/L**. A component of conductivity is the SAR. A high SAR indicates a large concentration of sodium ions in the soil, which raises conductivity.

Sandy Loam to loamy sand **Soil Texture** was observed at all the monitoring locations of Kandla and Vadinar.

Heavy Metals

For the sampling period, the concentration of **Aluminium** varied from **8105 to 12387 mg/kg** at Kandla and **31358.8 to 34107.4 mg/kg** at Vadinar and the average value was observed to be **10946.25 and 32733.1 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Chromium** varied from **49.18 to 58.81 mg/kg** at Kandla and **69.59 to 71.12 mg/kg** at Vadinar and the average value was observed to be **53.18 and 70.35 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Nickel** varied from **15.87 to 28.84 mg/kg** at Kandla and **28.84 to 32.53 mg/kg** at Vadinar and the average value was observed to be **22.23 and 30.68 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Zinc** varied from **61.84 to 95.08 mg/kg** at Kandla and **62.67 to 63.70 mg/kg** at Vadinar and the average value was observed to be **73.59 and 63.18 mg/kg** at Kandla and Vadinar monitoring station, respectively

- The concentration of **copper** varied from **24.96 to 85.80 mg/kg** at Kandla and **76.23 to 89.51 mg/kg** at Vadinar and the average value was observed to be **64.66 and 82.87 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Arsenic** varied from **0.93 to 3.86 mg/kg** at Kandla and the average value was observed to be **2.01** at Kandla Vadinar and the average value was observed to be **0.35 and 0.72 mg/kg** at Kandla and Vadinar monitoring station.

- While other heavy metals in the Soil i.e., **Mercury, Lead and Cadmium** were observed "Below Quantification Limit" for majority of the soil samples collected at Kandla and Vadinar.

CHAPTER 8: DRINKING WATER MONITORING

8.1 Drinking Water Monitoring

It is necessary to check with the drinking water sources regularly so as to know whether water quality conforms to the prescribed standards for drinking. Monitoring the drinking water quality is essential to protect human health and the environment. With reference to the scope specified by DPA, a total of 20 locations (18 at Kandla and 2 at Vadinar) were monitored to assess the Drinking Water quality. The DW-2 location was replaced by Shramdeep due to demolition of past sampling location (port & custom building)

The details of the drinking water sampling stations have been mentioned in **Table 20** and the locations have been depicted through Google map in **Map 12 and 13.**

Table 20: 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	Shramdeep	23.009631N, 70.220877E
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

Map 12: Locations for Drinking Water Monitoring at Kandla

Map 13: Locations for Drinking Water Monitoring at Vadinar

Methodology

The water samples were collected from the finalized sampling locations and analyzed for physico-chemical and microbiological parameter, for which the analysis 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 parameters finalized to assess the drinking water quality have been mentioned in **Table 21** as follows:

Table 21: 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.	Colour	Hazen	APHA, 23rd Edition, 2120 B:2017	Color Comparator
3.	EC	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
4.	Turbidity	NTU	APHA, 23rd Edition (Section -2130 B):2017	Nephlo Turbidity Meter
5.	TDS	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with filtration assembly and Oven
6.	TSS	mg/L	APHA, 23rd Edition, 2540 D: 2017	
7.	Chloride	mg/L	APHA, 23rd Edition (Section-4500-Cl-B):2017	Titration Apparatus
8.	Total Hardness	mg/L	APHA, 23rd Edition (Section-2340 C):2017	
9.	Ca Hardness	mg/L	APHA, 23rd Edition (Section-3500-Ca B):2017	
10.	Mg Hardness	mg/L	APHA, 23rd Edition (Section-3500-Mg B):2017	
11.	Free Residual Chlorine	mg/L	APHA 23rd Edition, 4500	
12.	Fluoride	mg/L	APHA, 23rd Edition (Section-4500-F-D):2017	UV- Visible Spectrophotometer
13.	Sulphate	mg/L	APHA, 23rd Edition (Section 4500-SO4-2-E):2017	
14.	Sodium	mg/L	APHA, 23rd Edition (Section-3500-Na-B):2017	Flame Photometer
15.	Potassium	mg/L	APHA,23rd Edition, 3500 K-B: 2017	
16.	Salinity	mg/L	APHA, 23rd Edition (section 2520 B, E.C. Method)	Salinity /TDS Meter
17.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3- B: 2017	UV- Visible Spectrophotometer

Sr. No.	Parameters	Units	Reference method	Instrument
18.	Nitrite	mg/L	APHA, 23rd Edition, 4500 NO2-B: 2017	
19.	Hexavalent Chromium	mg/L	APHA, 23rd Edition, 3500 Cr B: 2017	
20.	Manganese	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES
21.	Mercury	mg/L	EPA 200.7	
22.	Lead	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
23.	Cadmium	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
24.	Iron	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
25.	Total Chromium	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
26.	Copper	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES
27.	Zinc	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
28.	Arsenic	mg/L	APHA ICP 23rd Edition (Section-3120 B):2017	
29.	Total Coliforms	MPN/ 100ml	IS 15185: 2016	LAF/ Incubator

8.2 Result and Discussion

The drinking water quality of the locations at Kandla and Vadinar and its comparison with the to the stipulated standard (Drinking Water Specifications i.e., IS: 10500:2012) have been summarized in **Table 22** as follows:

Table 22: Summarized results 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	-	8.40	7.20	7.54	7.41	7.02	7.99	7.36	7.16	6.91	6.93	7.99	7.15	7.50	6.96	6.99	7.10	7.08	6.76	6.90	6.79
2.	Colour	Hazen	5	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.	EC	µS/ cm	-	-	125.5	279	23.1	43.9	50	149	23	25.4	61.4	217	138	212	65.4	203	174.4	49.2	29.7	126.8	165.3	105.6
4.	Salinity	PSU	-	-	0.06	0.13	0.02	0.03	0.03	0.06	0.02	0.02	0.03	0.11	0.09	0.10	0.04	0.10	0.09	0.03	0.02	0.06	0.08	0.05
5.	Turbidity	NTU	1	5	0.59	0.64	0.56	0.71	0.64	0.65	0.65	0.69	0.73	BQL	0.98	BQL	0.52	0.71	BQL	BQL	0.63	0.83	BQL	BQL
6.	Chloride	mg/L	250	1000	28.58	60.12	7.88	13.80	11.50	111.97	7.88	7.88	16.75	45.33	109.97	45.33	17.74	48.29	43.36	15.77	9.86	35.48	20.70	13.80
7.	Total Hardness	mg/L	200	600	16	40	2	2	5	180	2	2.5	7	42	160	34	8	26	10	4	2	6	54	22
8.	Ca Hardness	mg/L	-	-	8	18	1.5	1.5	3	100	1.5	2	4	24	90	18	2	12	8	2.5	1.5	4	26	12
9.	Mg Hardness	mg/L	-	-	8	22	BQL	BQL	2	80	BQL	BQL	3	18	70	16	6	14	2	1.5	BQL	2	28	10
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	66	92	12	22	26	342	12	14	32	112	346	108	34	106	90	26	16	66	84	54
12.	TSS	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
13.	Fluoride	mg/L	1.0	1.5	BQL	BQL	BQL	0.62	BQL	0.435	BQL	BQL	BQL	BQL	0.349	BQL	BQL	BQL	0.35	BQL	BQL	BQL	BQL	BQL
14.	Sulphate	mg/L	200	400	BQL	15.25	BQL	BQL	BQL	36.66	BQL	BQL	BQL	11.59	35.50	10.59	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
15.	Nitrate	mg/L	45	-	BQL	1.635	BQL	BQL	1.040	5.851	BQL	BQL	BQL	1.236	5.470	1.246	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
16.	Nitrite	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	0.033	BQL	BQL	BQL	BQL	0.263	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17.	Sodium	mg/L	-	-	19.91	30.35	BQL	BQL	7.26	76.79	BQL	BQL	BQL	17.55	71.89	16.59	5.08	19.27	16.79	BQL	BQL	5.25	8.67	5.06
18.	Potassium	mg/L	-	-	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
19.	Hexavalent Chromium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
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	9.792	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	0.0072	BQL	BQL	BQL	0.0080	0.0062	BQL	0.0058	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.0086
24.	Iron	mg/L	0.3	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.139	BQL	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	0.00335	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	BQL	BQL
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
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*	MPN/ 100ml	Shall not be detected		150	BQL	BQL	BQL	BQL	BQL	BQL	10	BQL	BQL	85	BQL	65	40	110	20	BQL	170	235	BQL

A: Acceptable, P:Permissible, BQL: Below Quantification limit; Turbidity (QL=0.5 NTU), Free Residual Chlorine (QL=2 mg/L), Total Suspended Solids (QL=2 mg/L), Fluoride (QL=0.3 mg/L), Sulphate (QL=10 mg/L), Nitrate as NO_3 (QL=1 mg/L), Nitrite as NO_2 (QL=0.1mg/L), Sodium as Na (QL=5mg/L), Potassium as K (QL=5mg/L), Hexavalent Chromium (QL=0.01 mg/L), Arsenic (QL=0.005 mg/L), Cadmium (QL=0.002 mg/L), Copper (QL=0.005 mg/L), Iron (QL=0.1mg/L), Lead (QL=0.002 mg/L), Manganese (QL=0.04 mg/L), Mercury (QL=0.0005 mg/L), Total Chromium (QL=0.005 mg/L), Zinc (QL=0.5 mg/L), Total Coliforms (QL=1 MPN/ 100ml)

AQL: Above Quantification Limit; Total Coliforms (QL=1000000)

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

8.3 Data Interpretation and Conclusion

Drinking water samples were taken at 20 locations (18 at Kandla and 2 at Vadinar), and their physical and chemical properties were analyzed. The analysis's results were compared with standard values as prescribed in IS 10500:2012 Drinking Water Specification.

- **pH:** The pH values of drinking water samples in Kandla were reported to be in the range of **6.76 to 8.40** with an average pH of **7.30.** In Vadinar, its values ranged from **6.90 to 6.79,** with an average pH of **6.85.** remarkably, the pH values at project locations are within the permissible range of 6.5 to 8.5. specified under IS: 10500:2012, expect DW-19 and DW-20.
- **Colour:** The value of Color in Drinking water sample at Kandla is found to be **1 Hazen** in each sample. In Vadinar the color value is found to be **1 Hazen** in both the locations.
- **Turbidity:** At the drinking water locations of Kandla, the turbidity was found to be in the range of **0.52 to 0.98** with an average of **0.68.** Whereas, in Vadinar the value of turbidity was reported BQL for both the monitoring location.
- **Total Dissolved Solids (TDS):** Monitoring TDS is crucial because it provides an indication of overall quality of the water. During the monitoring period, the TDS concentrations in Kandla were observed to vary in a wide range i.e., between **12 to 346 mg/L,** with an average concentration of **84.55 mg/L**. while in Vadinar, it ranged from **84 to 54 mg/L,** with average at **69 mg/L.**

  It is important to note that the TDS concentrations in both Kandla and Vadinar fall well within the acceptable limit of 500 mg/L.
- **Electrical Conductivity (EC):** It is a measure of the ability of a solution to conduct electric current, and it is often used as an indicator of the concentration of dissolved solids in water. During the monitoring period, the EC values for samples collected in Kandla were observed to range from **23 to 279 µS/cm**, with an average value of **110.87 µS/cm**. In Vadinar, the EC values showed variation from **105.6 to 165.3 µS/cm,** with an average value of **135.45 µS/cm**. It's important to regularly monitor EC levels in drinking water as it can provide valuable information about water quality and presence of dissolved substances.
- **Chlorides:** The concentrations in the drinking water samples collected from Kandla and Vadinar were within acceptable limits, as specified by the BIS. The chloride in Kandla varied from **7.88 to 111.97 mg/L**, with an average value of **35.41 mg/L**. In Vadinar, it ranged from **13.80 to 20.70 mg/L**, with an average value of **17.25 mg/L.** It's important to note that all the recorded chloride concentrations in both Kandla and Vadinar were well below the acceptable limit of 250 mg/L except for location DW-5, DW-11.
- **Total Hardness (TH):** Total Hardness varied from **2 to 180 mg/L**, with the average value as **30.47 mg/L**. While at Vadinar, the variation was observed from **22 to 54 mg/L**; with the average conc. At **38 mg/L**. It's important to note that all the recorded chloride concentrations in both Kandla and Vadinar were well below the acceptable limit of 200 mg/L.

- **Sulphate:** During monitoring period in Kandla and Vadinar, the sulphate concentrations were found to be within the acceptable limits i.e., 200 mg/L as per the specified norms. In Kandla, the sulphate concentrations varied from **10.59 to 36.66 mg/L,** with an average value of **21.92 mg/L**. In Vadinar, the sulphate concentration was observed below quantification limit.
- **Sodium:** During the monitoring period, at Kandla variation in the concentration of sulphate was observed to be in the range of **5.08 to 76.79 mg/L**, with the average concentration of **26.06 mg/L**. While at Vadinar, the concentration recorded **8.67 mg/L at DW-19** and **5.06 mg/L at DW-20** with the average concentration of **6.87 mg/L**.
- **Nitrate:** During the monitoring period, at Kandla & Vadinar variation in the concentration of Nitrate was observed to be in the range of **1.04 to 5.85 mg/L**, with the average concentration of **2.74 mg/L** also majority of the location recorded as "**BQL".** While at Vadinar, the concentration recorded as below Quantification limit.
- **Fluoride:** The concentration was found to be BQL in majority of the monitoring location except for location DW-4 (Workshop) i.e. 0.62 mg/L, DW-6 (West Gate 1) i.e. 0.43 mg/L, DW-11 (Wharf area/Jetty) i.e. 0.34 mg/L at Kandla. While at Vadinar its value also reported to be BQL for both the monitoring location.
- **Nitrite:** The Concentration was found to be **BQL** in all of the monitoring location except for location DW-6 (West Gate 1) i.e. 0.033 mg/L, DW-11 (Wharf Area/Jetty) i.e. 0.263 mg/L at Kandla. While at Vadinar its value also reported to be BQL for both the Monitoring location.
- **Iron:** The Concentration was found to be **BQL** in all of the monitoring location except for location DW-18 (Hospital Gopalpuri) i.e. 0.139 mg/L at Kandla.
- **Copper:** The Concentration was found to be **BQL** in all of the monitoring location except for location DW-5 (Canteen Area) i.e. 0.00720 mg/L, DW-10 (Port Colony Kandla) i.e. 0.00623 mg/L, DW-12 (Hospital Kandla) i.e. 0.00587 mg/L, at Kandla. While at Vadinar, the concentration recorded BQL at DW-19 and 0.00868 mg/L at DW-20 with the average concentration of 0.00868 **mg/L**.
- The parameters such **as Free Residual Chlorine, Lead, Potassium, Total Suspended Solids, Manganese, Hexavalent Chromium**, and **the metals Arsenic, Cadmium, Total Chromium and Zinc** were all observed to have concentrations "Below the Quantification Limit (BQL)" at majority of the locations during the monitoring period.
- **Total Coliforms:** During the monitoring period, at Kandla variation in the concentration of sulphate was observed to be in the range of **10 to 170 MPN/100ml**, with the average concentration of **81.25 MPN/100ml**. While at Vadinar, the concentration recorded **235 MPN/100ml** at DW-19 and **BQL** at DW-20.

8.4 Remedial Measures

Appropriate water treatment processes should be administered to eradicate coliform bacteria. The methods of disinfection such as **chlorination, ultraviolet (UV), or ozone** etc, apart from that, filtration systems can also be implemented to remove bacteria, sediment, and other impurities.

The following steps can be implemented to ensure that the water being supplied is safe for consumption:

- Regular monitoring should be carried out to assess 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 contaminants in the drinking water.
- It is necessary to carry out a system assessment to determine whether the drinking-water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets identified targets. This also includes the assessment of design criteria of the treatment systems employed.
- Identifying control measures in a drinking-water system that will collectively control identified risks and ensure that the health-based targets are met. For each control measure identified, an appropriate means of operational monitoring should be defined that will ensure that any deviation from required performance (water quality) is rapidly detected in a timely manner.
- Management and communication plan should be formulated describing actions to be taken during normal operation as well as during incident conditions (such as drinking water contamination) and documenting the same.

CHAPTER 9: SEWAGE TREATMENT PLANT MONITORING

9.1 Sewage Treatment Plant (STP) Monitoring:

The principal objective of STP 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 STP Monitoring is to be carried out weekly at three locations, one at Kandla, one at Gopalpuri and one STP at Vadinar. The samples from the inlet and outlet of the STP have been collected weekly. The details of the locations of STP to be monitored for Kandla and Vadinar have been mentioned in **Table 23** as follows:

Table 23: Details of the monitoring locations of STP

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 GPCB were referred for the details of the STP for Kandla and Gopalpuri. The CC&A of Kandla and Gopalpuri entails that the treated domestic sewage should conform to the norms specified in **Table 24**. 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 24: Treated effluent Standards (as per CC&A of Kandla STP)

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 3 and 4** as follows:

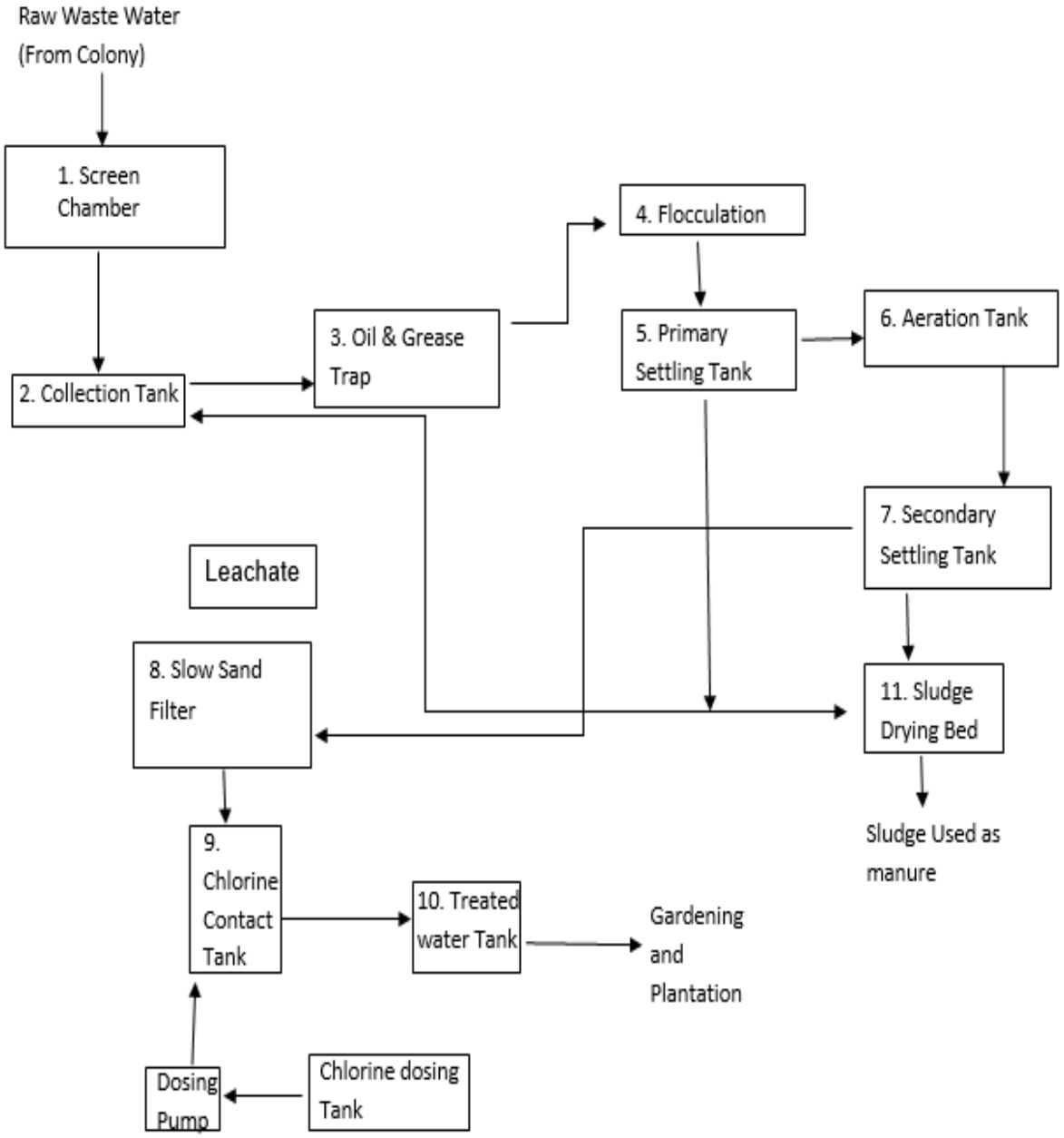


Figure 3: Process flow diagram of STP at Kandla

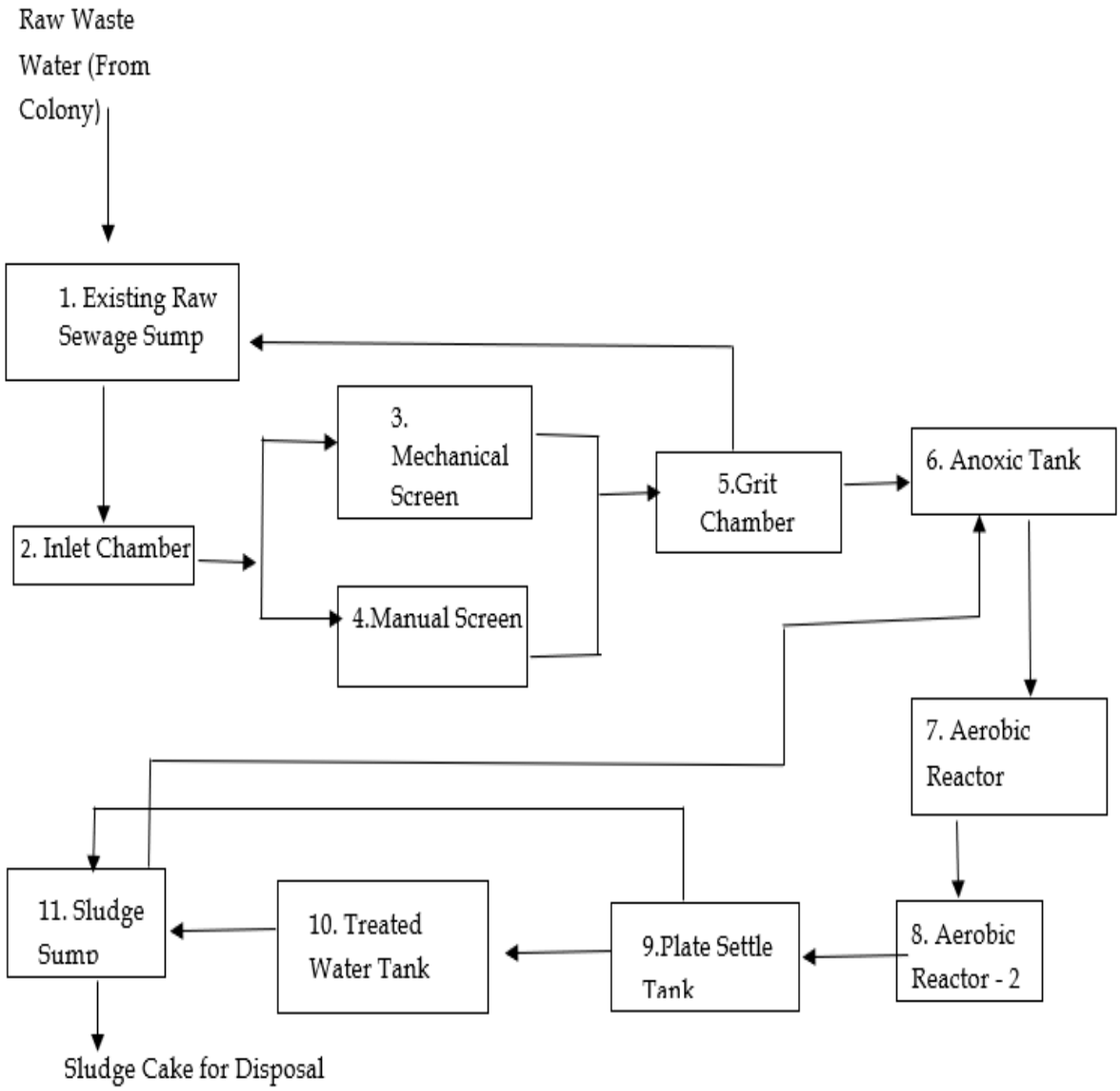


Figure 4: Process flow diagram of STP at Gopalpuri

STP at Vadinar

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 GPCB has been referred for the details of the said STP. The CC&A of the Vadinar STP suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 25**. 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 25: Norms of treated effluent as per CC&A of Vadinar STP

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 5** as follows:

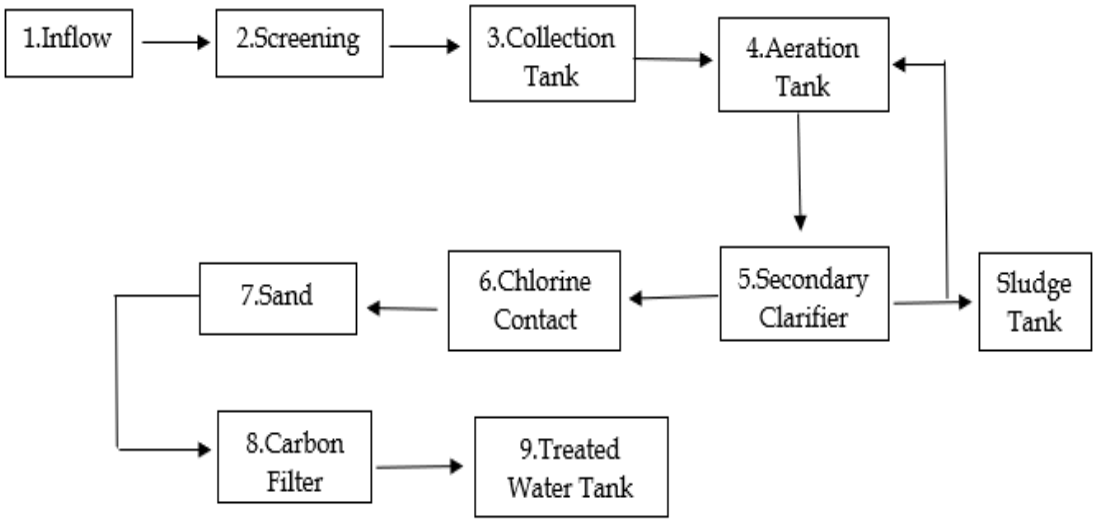
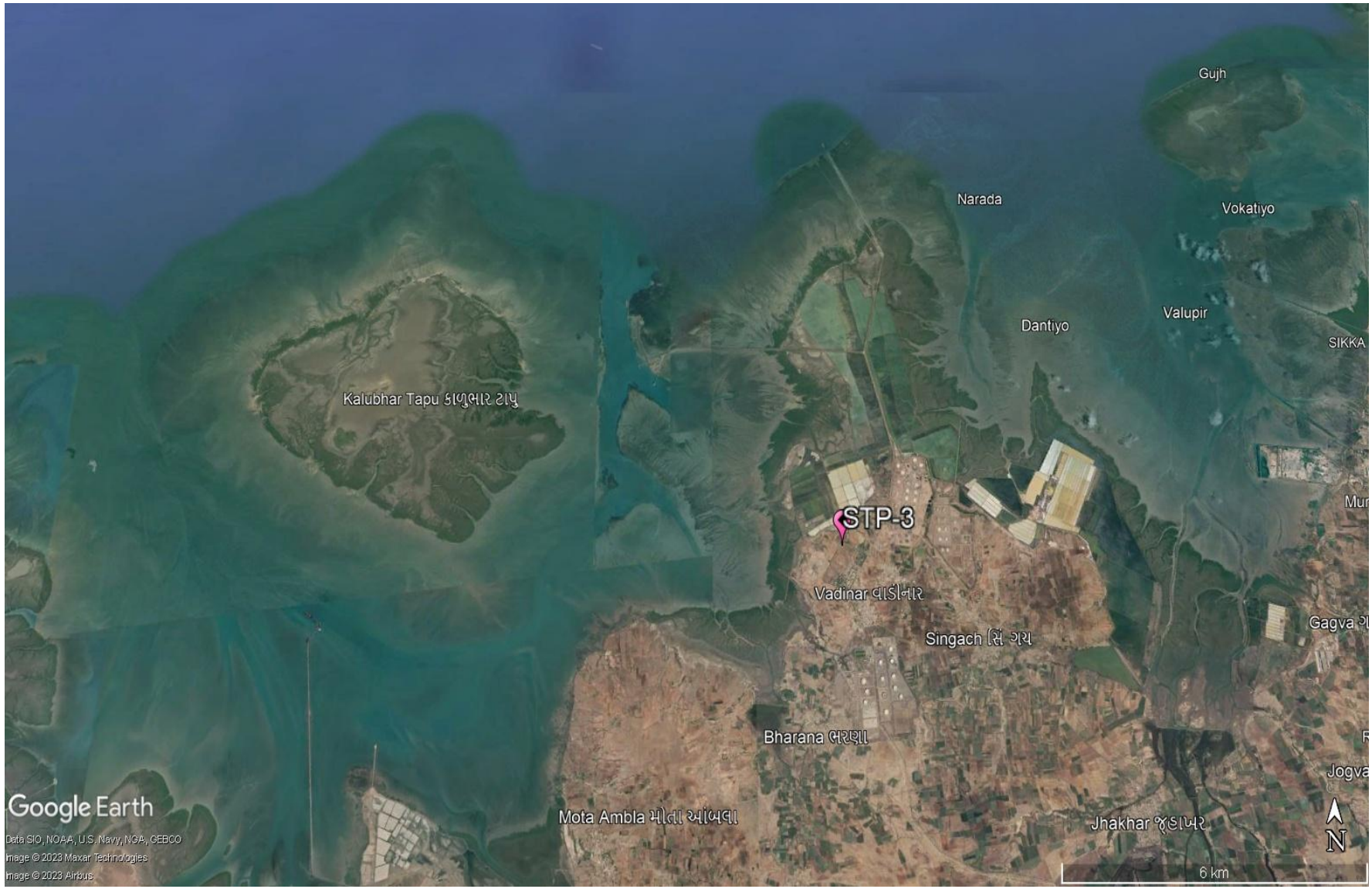


Figure 5: Process flowchart for the STP at Vadinar

The map depicting the locations of STP to be monitored in Kandla and Vadinar have been shown in **Map 14 and 15** as follows:

Map 14: Locations for STP Monitoring at Kandla



Map 15: Locations for STP Monitoring at Vadinar

Methodology

As per the defined scope by DPA, the sampling and analysis of water samples from the inlet and outlet of the STP's 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 26** as follows:

Frequency

Monitoring is required to be carried out once a week for monitoring location of Kandla and Vadinar i.e., two STP station at Kandla and one STP station at Vadinar.

Table 26: 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

9.2 Result and Discussion

Analytical results of the STP samples collected from the inlet and the outlet of the STP's of Kandla and Vadinar have been summarized in **Table 27 & 28**. Further it was compared with the standard norms specified in the CC&A of the respective STPs.

Table 27: Water Quality of inlet and outlet of STP of Kandla

Sr No.	Parameter	Units	GPCB Norms (Kandla)	Kandla															
				Week 3 of December				Week 4 of December				Week 1 of January				Week 2 of January			
				STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)
1.	pH	-	**6.5-8.5**	7.14	7.12	7.17	7.23	7.1	7.08	7.01	7.38	7.20	7.11	7.07	7.41	7.45	7.16	7.08	7.40
2.	TDS	mg/L	-	1352	1321	1398	1518	1458	1324	1464	1450	1358	1316	1430	1390	1467	1364	1340	1410
3.	TSS	mg/L	**100**	31	20	108	16	41	16	70	12	64	14	220	18	48	12	280	26
4.	COD	mg/L	-	180	73.2	316.0	48.0	248	164	247.0	51.8	176.7	72.3	441.3	72.9	196.0	56.0	842.0	76.6
5.	DO	mg/L	-	BQL	3.2	BQL	3.7	BQL	1.5	BQL	1.7	BQL	3.4	BQL	1.7	BQL	2.5	BQL	2.0
6.	BOD	mg/L	**30**	42.58	26.8	98.75	6.0	36.54	12.74	77.19	6.47	29.46	9.04	132.39	7.29	45.34	8.40	252.60	7.66
7.	SAR	meq/L	-	11.15	9.30	7.56	9.14	9.87	5.68	5.90	4.62	9.36	8.68	8.65	10.82	12.32	10.10	6.99	6.94
8.	Total Coliforms	MPN/ 100ml	**<1000**	1600	240	1600	1600	1600	280	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600

Table 28: Water Quality of inlet and outlet of STP of Vadinar

Sr No.	Parameter	Units	GPCB Norms (Vadinar)	Week 3 of December		Week 4 of December		Week 1 of January		Week 2 of January	
				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	-	**6.5-8.5**	7.28	7.44	7.15	7.20	6.52	7.12	7.03	7.16
2.	TDS	mg/L	-	408	382	488	374	418	362	424	358
3.	TSS	mg/L	**20**	8	4	72	10	90	6	38	4
4.	COD	mg/L	**50**	168.0	56.0	293.2	52.2	498.0	32.4	196.8	36.1
5.	DO	mg/L	-	1.2	8.4	0.7	7.0	BQL	6.0	1.5	6.9
6.	BOD	mg/L	**10**	50.40	5.60	91.63	6.53	149.40	3.24	59.04	3.61
7.	SAR	meq/L	-	2.21	2.60	1.37	2.31	2.13	2.21	2.45	1.96
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), Biochemical Oxygen Demand (QL=3 mg/L)

9.3 Data Interpretation and Conclusion

For physicochemical analysis, the treated sewage water was gathered from the Kandla STP, Gopalpuri STP, and Vadinar STP and the analytical results were compared with the standards mentioned in the Consolidated Consent and Authorization (CC&A) by GPCB.

- The **pH** of treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) conform to their respective stipulated norms of **7.08 to 7.41** at Kandla and **7.12 to 7.44** at Vadinar respectively.
- The **TDS** of treated sewage at Kandla was ranges from **1316 to 1518 mg/L**, whereas for Vadinar it ranges from **358 to 382 mg/L**.
- The **TSS** of the Treated effluent for the STP-1 and STP-2 at Kandla and STP-3 at Vadinar falls within the stipulated norms of **4 and 26 mg/L** respectively as mentioned in their respective CCA.
- **COD** value for Kandla was observed in the range of **48 to 164 mg/L**. Whereas for Vadinar the value of COD falls within the range of **32.4 to 56 mg/L**.
- The value of **DO** was observed in the range of **1.50 to 3.70 mg/L** at Kandla, whereas for Vadinar it was observed in the range of **6.0 to 8.4 mg/L.**
- The **BOD** of the outlet for the STPs of Kandla and Vadinar falls within the stipulated norms.
- The value of **SAR** for Kandla was observed in the range of **4.62 to 10.82 meq/L**, whereas for Vadinar, it was observed in the range of **1.96 to 2.6 meq/L**.
- The value of **Total Coliforms** for Kandla was observed in the range of **240 to 1600 MPN/100 ml**, whereas for Vadinar, it was observed in the range of **1600 MPN/100 ml**.

During the monitoring period, only Total Coliforms were observed to be exceeding the limits at STPs of Kandla and Vadinar while rest of the treated sewage parameters for STP outlet were within norms as specified under the CCA at both the monitoring sites. Regular monitoring of the STP performance should be conducted on regular basis to ensure adequate treatment as per the norms.

9.4 Remedial Measures:

- The quantum of raw sewage (influent) entering the STP should be monitored by installation of the 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 results show the presence of total coliforms; hence the method of disinfection (Chlorination) sodium or calcium Hypochlorite can be used.
- Effectiveness of any technology depends on factors such as the specific pollutants in the wastewater, plant size, local regulations, and available resources. There are several processes that may be implemented such as - Advanced oxidation process involve using strong oxidants to break down complex organic compounds. Methods like Fenton's reagent (hydrogen peroxide and iron catalyst) and UV/H_2O_2 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.

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 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 has been 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. Details of the locations to be monitored have been mentioned in **Table 29:**

Table 29: 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 for Kandla and Vadinar have been mentioned in **Map 16 and 17** as follows:

Map 16: Locations for Marine Water Monitoring at Kandla

Map 17: Locations for Marine Water Monitoring at Vadinar

Methodology

The methodology adopted for the sampling and monitoring of Marine Water was carried out as per the '**Sampling Protocol for Water & Wastewater'** developed by GEMI. The water samples collected through the Niskin Sampler are collected in a clean bucket to reduce the heterogeneity. The list of parameters to be monitored under the project for the Marine Water quality have been mentioned in **Table 30** along with the analysis method and instrument.

Frequency:

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

Table 30: 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	
14.	Sulphate	mg/L	APHA, 23rd Edition, 4500 SO4-2 E: 2017	
15.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3-B: 2017	

Sr. No	Parameters	Units	Reference method	Instrument
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	µg/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	µg/L	APHA, 23rd Edition, 3500 Cr B: 2017	
22.	Hexavalent Chromium	µg/L		UV- Visible Spectrophotometer
23.	Copper	µg/L	APHA, 23rd Edition, ICP Method 3120 B: 2017	ICP-OES
24.	Cadmium	µg/L		
25.	Arsenic	µg/L		
26.	Lead	µg/L		
27.	Zinc	mg/L		
28.	Mercury	µg/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

10.2 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 31**. The said water quality has been represented in comparison with the standard values as stipulated by CPCB for Class SW-IV Waters.

Table 31: Results of Analysis of Marine Water Sample for the sampling period

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	1.02	1.02	1.021	1.022	1.021	1.02	1.021
2.	pH	-	6.5-9.0	8.13	8.11	8.19	8.24	8.12	8.2	8.19	8.24
3.	Color	Hazen	No Noticeable	5	5	5	5	5	5	5	5
4.	EC	µS/cm	-	51,500	52,300	54,100	54,300	52,400	51,800	54,100	54,300
5.	Turbidity	NTU	-	97	125	4.12	3.42	131	112	4.12	3.42
6.	TDS	mg/L	-	33,326	37,182	32,478	33,142	34,109	33,806	32,478	33,142
7.	TSS	mg/L	-	347	421	115	195	332	411	115	195
8.	COD	mg/L	-	32.7	30.9	47.89	51.26	31.56	33.11	47.89	51.26
9.	DO	mg/L	3.0 mg/L	5.9	6.3	6.1	5.7	6.1	5.8	6.1	5.7
10.	BOD	mg/L	5.0 mg/L	8.15	8.3	7.42	7.13	10.2	9.92	7.42	7.13
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	2364.6	2684.7	2897.4	3157.3	2739.8	2457.3	2897.4	3157.3
13.	Nitrate	mg/L	-	4.63	3.48	3.41	2.980	3.86	4.12	3.41	2.980
14.	Nitrite	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
15.	Phosphate	mg/L		BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
16.	Silica	mg/L	-	3.01	2.71	0.93	0.79	3.83	2.76	0.93	0.79
17.	Sodium	mg/L	-	9485	9206	9,827	9,541	9642	9468	9,827	9,541
18.	Potassium	mg/L	-	360.21	320	421.7	391.40	347.60	247.67	421.7	391.40
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	-	BQL	6.22	BQL	BQL	6.68	BQL	BQL	BQL
24.	Iron	mg/L	-	1.831	2.281	0.586	0.378	1.819	2.192	0.586	0.378
25.	Lead	mg/L	-	3.16	3.22	2.412	2.984	2.41	3.36	2.412	2.984
26.	Manganese	mg/L	-	92.18	134.29	42.57	BQL	92.74	116.68	42.57	BQL
27.	Total Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	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.	Particulate Organic Carbon	mg/L	-	1.08	0.68	0.55	0.72	0.98	1.18	0.65	0.72
31.	Total Coliforms	MPN/ 100ml	500/100 ml	16	15	10	24	10	15	10	24

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

10.3 Data Interpretation and Conclusion

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 monitoring period. The detailed interpretation of the parameters in comparison to the Class SW-IV for Harbour Waters is as follows:

- **Density** at Kandla was observed in the range of **1.20 to 1.023 kg/m³**, with the average of **1.021 kg/m³.** Whereas for the location of Vadinar, it was observed **1.020 kg/m³** at MW-7 and **1.021 kg/m³** at MW-8, with the average of **1.020 kg/m³**.
- **pH** at Kandla was observed in the range of **8.04 to 8.21**, with the average pH as **8.13**. Whereas for the locations of Vadinar, it was observed in the range of be **8.19 to 8.24**, with the average pH as **8.21**. For the monitoring location of both the study areas, pH was found to comply with the norms of 6.5-8.5.
- **Color** range varied from **5 Hazen** at all the monitoring locations in Kandla, and for Vadinar, it found **5 Hazen** for the both of the location.
- **Electrical conductivity (EC)** was observed in the range of **51,400 to 52,400 µS/cm**, with the average EC as **51,850 µS/cm** for the locations of Kandla, whereas for the locations of Vadinar, it was observed in the range of **54,100 to 54,300 µS/cm**, with the average EC as **54,200 µS/cm**.
- For all monitoring locations of Kandla the value of **Turbidity** was observed in the range of **97 to 210 NTU**, with average value of **137.08 NTU**. For Vadinar it ranges from **4.12 to 3.42 NTU**, with average of **3.77 NTU**. Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and microscopic organisms. Turbidity affects the amount of light penetrating to the plants for photosynthesis.
- For the monitoring locations at Kandla the value of **Total Dissolved Solids (TDS)** ranged from **32,189 to 37,182 mg/L**, with an average value of **34048.66 mg/L**. Similarly, at Vadinar, the TDS values ranged from **32,478 to 33,142 mg/L**, with an average value of **32,810 mg/L**.
- **TSS** values in the studied area varied between **289 to 421 mg/L** at Kandla and **115 to 195 mg/L** at Vadinar, with the average value of **363.5 mg/L and 155 mg/L** respectively for Kandla and Vadinar.

- **COD** varied between **30.9 to 33.11 mg/L** at Kandla and **47.89 to 51.26 mg/L** at Vadinar, with the average value as **31.98 and 49.57 mg/L** respectively for Kandla and Vadinar.
- **DO** level in the studied area varied between **5.8 to 6.3 mg/L** at Kandla and **5.7 to 6.1 mg/L** at Vadinar, with the average value of **6.01 mg/L and 5.9 mg/L** respectively for Kandla and Vadinar. Which represents that the marine water is suitable for marine life.
- **BOD** observed was observed in the range of **8.15 to 10.2 mg/L**, with average of **8.95 mg/L** for the location of Kandla and for the locations of Vadinar, it was observed in the range of **7.42 to 7.13 mg/L**, with an average value of **7.27 mg/L**.
- **Sulphate** concentration in the studied area varied between **2364.6 to 3246.3 mg/L** at Kandla and **2897.4 to 3157.3 mg/L** at Vadinar. The average value observed at Kandla was **2680.63 mg/L**, whereas **3027.35 mg/L** was the average value of Vadinar. Sulphate is naturally formed in inland waters by mineral weathering or the decomposition and combustion of organic matter.
- **Nitrate** in the study area was observed in the range of **3.38 to 4.89 mg/L**, with the average of **4.06 mg/L**. Whereas for the Vadinar, recorded value was observed in the range of **2.98 to 3.41 mg/L**, with the average of **3.19 mg/L.**
- In the study area of Kandla the concentration of **Potassium** varied between **247.67 to 360.21 mg/L** and **391.40 to 421.70 mg/L** at Vadinar, with the average value as **324.88 mg/L and 406.55 mg/L** respectively for Kandla and Vadinar.
- **Silica** in the studied area varied between **2.71 to 3.83 mg/L**, with the average of **3.10 mg/L**, at Kandla. Vadinar, observed value was found to be **0.93 mg/L** at location MW-7 and **0.79 mg/L** at MS-8 location.
- **Sodium** in the study area varied between **9206 to 9887 mg/L**, with average of **9513.83 mg/L**, at Kandla whereas at Vadinar the sodium concentration value was observed in the range of **9541 to 9827 mg/L**, with the average value of **9684 mg/L**.
- **Odour** was observed **1** for all locations of Kandla and Vadinar.
- **Copper** at the Kandla and Vadinar location was detected **below the quantification limit (BQL)"** for the all-sampling location.
- **Iron** in the studied area varied between **1.749 to 2.431 mg/L**, with the average of **2.050 mg/L,** at Kandla, and for Vadinar value were recorded **0.586 mg/L** for location MW-7 and **0.378 mg/L** for location MW-8.
- **Lead** concentration varied **0.00241 to 0.00336 mg/L**, with an average of **0.00293 mg/L** at Kandla. At Vadinar location MW-7 observed **0.00241 mg/L** and MW-8 observed **0.00298 mg/L** with an average of **0.00269 mg/L**
- **Manganese** in the studied area varied between **0.0921 to 0.134 mg/L**, with the average of 0.110 mg/L, at Kandla. At Vadinar location MW-7 observed **0.0425 mg/L** and MW-8 observed **BQL.**
- **Particulate Organic Carbon** in the study area was observed in the range of **0.55 to 1.18**, with the average value of **0.86**. Whereas for the Vadinar, the value observed was **0.65** at MW-7 and **0.72** at MW-8, with the average of **0.68**.
- **Oil & Grease, Nitrite, Phosphate, Hexavalent Chromium, Arsenic, Cadmium, Total Chromium, Zinc, Mercury and Floating Material (Oil grease scum, petroleum**

products) were observed to have concentrations **"Below the Quantification Limits (BQL)"** for most of the locations of Kandla and Vadinar.

- **Total Coliforms** were detected complying with the specified norm of 500 MPN/100ml for all the locations of Kandla and Vadinar.

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).

However, as a safeguard towards marine water pollution prevention, 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 are 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.

Methodology

As defined in the scope by 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 (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 locations of Marine Sediment to be monitored under the study are mentioned in **Table 32** as follows:

Table 32: Details of the sampling locations for Marine Sediment

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 at Kandla and Vadinar have been mentioned in **Map 18 and 19** as follows:

Map 18: Location of Marine Sediment Monitoring at Kandla

Map 19: Locations 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 33** as follows:

Table 33: List of parameters to be monitored for Sediments at Kandla and Vadinar

Sr. No.	Parameters	Units	Reference method	Instruments
1.	Texture		Methods Manual Soil Testing in India January 2011,01	Hydrometer
2.	Organic Matter	%	Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934)	Titration apparatus
3.	Inorganic Phosphates	mg/Kg	Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017	UV- Visible Spectrophotometer
4.	Silica	mg/Kg	EPA METHOD 6010 C & IS: 3025 (Part 35) – 1888, part B	
5.	Phosphate	mg/Kg	EPA Method 365.1	
6.	Sulphate as SO^{4-}	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 during the monitoring period has been summarized in the **Table 34.**

Table 34: Summarized result 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/ ha	4.41	10.27	22.43	8.63	15.6	14.5	3.16	2.17
2.	Phosphate	mg/Kg	1055.2	1862.2	1586.7	653.7	816.3	667.1	203.5	247.4
3.	Organic Matter	%	0.81	0.31	0.27	0.51	0.73	0.33	0.65	0.87
4.	Sulphate as SO^{4-}	mg/Kg	190.09	170.70	210.19	155.27	92.28	101.26	84.17	115.9
5.	Calcium as Ca	mg/Kg	2165.50	2439.90	1890.90	2947.40	1693.10	2368.70	2427.7	2389.6
6.	Magnesium as Mg	mg/Kg	1584.50	1725.00	1826.00	1623.00	1421.10	1089.30	1198.2	1478
7.	Silica	g/Kg	582.9	476.3	421.3	291.71	236.4	325.63	290.1	408.3
8.	Nitrite	mg/Kg	0.32	0.64	0.39	0.41	0.49	0.59	0.16	0.3
9.	Nitrate	mg/Kg	21.48	18.36	29.31	23.63	14.51	16.13	13.2	7.96
10	Sodium	mg/Kg	3514	2453	2619	3219	3442	2916	6136	8643
11	Potassium	mg/Kg	2084	1967.9	2819	3071.2	2741	2613.7	2938	2481
12	Copper	mg/Kg	2283.3	1826.7	1278.5	2379.5	1628.3	1347.8	1493.78	1681.39
13	Aluminium	mg/Kg	49.51	38.7	36.83	49.1	47.2	51.3	53.6	29.7
14	Chromium	mg/Kg	3.11	3.57	4.07	3.91	4.97	5.27	4.58	3.78
15	Nickel	mg/Kg	43.35	38.9	21.47	28.11	22.64	24.39	14.79	26.87
16	Zinc	mg/Kg	61.16	54.6	49.3	47.7	51.26	40.65	23.68	42.96
17	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
18	Lead	mg/Kg	4.97	5.02	3.84	5.11	4.76	4.26	4.76	5.22
19	Arsenic	mg/Kg	4.47	2.55	5.2	3.63	2.98	3.21	2.83	3.42
20	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Texture	-	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loam

11.3 Data Interpretation and Conclusion

The Marine sediment quality at Kandla and Vadinar has been monitored for various physico-chemical parameters during the monitoring 2024. The detailed interpretation of the parameters is given below:

- **Inorganic Phosphate** for the sampling period was observed in range of **4.41 to 22.43** Kg/ha for Kandla. Whereas for Vadinar the value observed at location MS-7 (Nakti creek) is 3.16 Kg/ha and MS-8 (Near Vadinar Jetty) is 2.17 Kg/ha. For Kandla and Vadinar the average value of Inorganic Phosphate was observed 12.64 and 2.66 Kg/ha respectively.
- The concentration of **Phosphate** was observed in range of **653.7 to 1862.2 mg/Kg** for Kandla and for Vadinar the value observed at location MS-7 (Nakti creek) as 203.5 mg/Kg and MS-8 (Near Vadinar Jetty) as 247.4 mg/Kg. For Kandla and Vadinar the average concentration of Phosphate was observed 1106.86 and 225.45 mg/Kg respectively.

- The **Organic Matter** for the sampling period was observed in the range of **0.27 to 0.81** % for Kandla with the average value of 0.49% and for Vadinar the value recorded at location MS-7 and MS-8 was observed 0.65% & 0.87% respectively, with average concentration as 0.76 %.
- The concentration of **Sulphate** was observed in the range of **92.28 to 210.19 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 84.17 mg/Kg and at MS-8 is 115.9 mg/Kg. For Kandla and Vadinar the average value of Sulphate was observed 153.29 and 100.03 mg/Kg respectively.
- The value of **Calcium** was observed in the range of **1693.1 to 2947.4 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 2427.7 mg/Kg and at MS-8, is 2389.65 mg/Kg. The average value of Calcium for the monitoring period was observed 2250.91 mg/Kg and 2408.65 mg/Kg at Kandla and Vadinar, respectively.
- The value of **Magnesium** for the sampling period was observed in the range of **1089.3 to 1826 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 1198.2 mg/Kg and at MS-8, is 1478 mg/Kg. For Kandla and Vadinar the average value of Magnesium was observed 1544.81 mg/Kg and 1338.1 mg/Kg respectively.
- For the sampling period **Silica** was observed in the range of **236.4 to 582.9 mg/Kg** for Kandla with average value 389.04 mg/Kg and for Vadinar the value observed to be 290.1 and 408.3 mg/Kg at MS-7 and MS-8, respectively with average 349.2 mg/Kg.
- The value of **Nitrate** was observed in the range of **14.51 to 29.31 mg/Kg** for Kandla with average value 20.57 mg/Kg and for Vadinar the value observed to be 13.2 and 7.96 mg/Kg at MS-7 and MS-8, respectively with average 10.58 mg/Kg.
- The value of **Nitrite** was observed in the range of **0.32 to 0.64 mg/Kg** for Kandla with average value 0.47 mg/Kg and for Vadinar the value observed to be 0.16 and 0.30 mg/Kg at MS-7 and MS-8, respectively with average 0.23 mg/Kg.
- The value of **Sodium** was observed in the range of **2453 to 3514 mg/Kg** for Kandla with average value 3027.16 mg/Kg and for Vadinar the value observed to be 6136 and 8643 mg/Kg at MS-7 and MS-8, respectively with average 7389.5 mg/Kg.
- The value of **Potassium** was observed in the range of **1967.9 to 3071.2 mg/Kg** for Kandla with average value 2549.46 mg/Kg and for Vadinar the value observed to be 2938 and 2481 mg/Kg at MS-7 and MS-8, respectively with average 2709.5 mg/Kg.
- The value of **Aluminium**, was observed in the range of **1278.5 to 2379.5 mg/Kg** for Kandla with average value 1790.68 mg/Kg and for Vadinar the value observed to be 1493.78 and 1681.39 mg/Kg at MS-7 and MS-8, respectively with average 1587.58 mg/Kg.
- The value of **Mercury** was observed "Below the Quantification Limit" at all the eight-monitoring location of Kandla and Vadinar.
- Texture was observed to be "**Sandy Loam**" at location MS-1, MS-2, MS-3, MS-4, MS-5, MS-6 in Kandla. "**Sandy Loam**" at location MS-7 & "**loam"** at location MS-8 in Vadinar during sampling period.

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 35.**

Table 35: 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)

Table 36: Comparison of Heavy metals with Standard value in Marine Sediment

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Arsenic	mg/Kg	4.47	2.55	5.2	3.63	2.98	3.21	2.83	3.42
2.	Copper	mg/Kg	3.11	3.57	4.07	3.91	4.97	5.27	4.58	3.78
3.	Chromium	mg/Kg	49.51	38.7	36.83	49.1	47.2	51.3	53.6	29.7
4.	Nickel	mg/Kg	43.35	38.9	21.47	28.11	22.64	24.39	14.79	26.87
5.	Lead	mg/Kg	4.97	5.02	3.84	5.11	4.76	4.26	4.76	5.22
6.	Zinc	mg/Kg	72.65	61.16	54.6	49.3	47.7	51.26	23.68	42.96
7.	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

- **Arsenic** was observed in the range of **2.55 to 5.20 mg/Kg** for Kandla with average value 3.67 mg/Kg and for Vadinar the value observed to be 2.83 and 3.42 mg/Kg at MS-7 and MS-8, respectively with average 3.12 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to arsenic falls in moderately polluted class.
- **Copper** was observed in the range of **3.11 to 5.27 mg/Kg** for Kandla with average value 4.15 mg/Kg and for Vadinar the value observed to be 4.58 and 3.78 mg/Kg at MS-7 and MS-8, respectively with average 4.18 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to copper falls in non-polluted class.
- **Chromium** was observed in the range of **36.83 to 51.3 mg/Kg** for Kandla with average Value 45.44 mg/Kg and for Vadinar the value observed to be 53.6 and 29.7 mg/Kg at MS-7 and MS-8, respectively with average 41.65 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to chromium falls in moderately polluted class.

- **Nickel** was observed in the range of **21.47 to 43.35 mg/Kg** for Kandla with average value 29.81 mg/Kg and for Vadinar the value observed to be 14.79 and 26.87 mg/Kg at MS-7 and MS-8, respectively with average 20.83 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to nickel falls in moderately polluted class.
- **Lead** was observed in the range of **3.84 to 5.11 mg/Kg** for Kandla with average value 4.66 mg/Kg and for Vadinar the value observed to be 4.76 and 5.22 mg/Kg at MS-7 and MS-8, respectively with average 4.99 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to lead falls in Not polluted class.
- **Zinc** was observed in the range of **40.65 to 61.16 mg/Kg** for Kandla with average value 50.77 mg/Kg and for Vadinar the value observed to be 23.68 and 42.96 mg/Kg at MS-7 and MS-8, respectively with average 33.32 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to zinc falls in non-polluted class.
- **Cadmium** was observed BQL for all locations at Kandla and Vadinar during sampling period. With reference to the guidelines mentioned in table 35, the sediment quality with respect to cadmium falls in non-polluted class.

Analysis of the sediments indicates moderate 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.

The presence of anthropic activity in the coastal areas has an effect upon the marine water and sediment. One of the primary risks associated with contaminated sediments is bioaccumulation in benthic organisms, which is a route of entry into the food chain. Generally adopted sediment remediation approaches include dredging, capping of contaminated areas, and monitored natural recovery (MNR). Dredging can remove contaminated sediments, but it requires large areas of land for sediment disposal. It is expensive and may cause secondary contamination of the water column during re-suspension. MNR relies on ongoing naturally occurring processes to decrease the bioavailability or toxicity of contaminants in sediment. These processes may include physical, biological, and chemical mechanisms that act together to reduce the environmental risks posed by contaminated sediments. MNR require longer monitoring time and can be even more expensive than for dredging and capping. Capping consists of in situ covering of clean or suitable isolating material over contaminated sediments layer to limit leaching of contaminants, and to minimize their re-suspension and transport. Hence appropriate remedial measures for the polluted sediment sites may be implemented, to reduce the concentration of the heavy metals.

CHAPTER 12: MARINE ECOLOGY MONITORING

12.1 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 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 37** as follows:

Table 37: 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 20 and 21** as follows:

Map 20: Locations of Marine Ecological Monitoring at Kandla

Map 21: Locations of Marine Ecological Monitoring at Vadinar

The various parameters to be monitored under the study for Marine Ecological Monitoring are mentioned in **Table 38** as follows:

Table 38: 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

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 Estimation**

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

phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (*Bacillariophyceae*) and Dinoflagellates (*Dinophyceae*). 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 Estimation**

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.

- **Benthic Organisms Estimation**

Benthic macroinvertebrates are small aquatic animals and the aquatic larval stages of insects. They include dragonfly and stonefly larvae, snails, worms, and beetles. Use of benthic macroinvertebrates has been in vogue as indicator organisms for water quality monitoring since long. Traditional methods of water quality monitoring incorporates mostly monitoring of physicochemical parameters. Benthic macroinvertebrates are

majorly insects that dwell on the floor of water bodies. They are found in all water bodies, as they have a wide range of pollution tolerance among various species. The benthic macro-invertebrate's community structure depends on the exposure to pollution it receives. Benthic macroinvertebrates have been used as indicator organisms to measure the water quality of water bodies across the world. Evaluating the abundance and variety of benthic macroinvertebrates in a waterbody gives us an indication of the biological condition of that waterbody. Generally, waterbodies in healthy biological condition support a wide variety and high number of macroinvertebrate taxa, including many that are intolerant of pollution. Samples yielding only pollution–tolerant species or very little diversity or abundance may indicate a less healthy waterbody. Biological condition is the most comprehensive indicator of waterbody health. When the biology of a waterbody is healthy, the chemical and physical components of the waterbody are also typically in good condition.

- **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.

1. **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.

2. **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

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:

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

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. **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

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.

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

The basic idea of 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.

12.2 Result and Discussion

The details of Marine Ecological Monitoring conducted for the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 39.**

Table 39: Values of Biomass, Net Primary Productivity (NPP), Gross Primary Productivity (GPP), Pheophytin and Chlorophyll for Kandla and Vadinar

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
1.	Biomass	mg/L	121	76	65	116	98	94	86	125
2.	Net Primary Productivity	mg/L/hr	BQL	BQL	BQL	BQL	0.91	BQL	BQL	BQL
3.	Gross Primary Productivity	mg/L/hr	1.12	0.79	1.21	1.63	1.18	0.69	0.88	1.23
4.	Pheophytin	mg/m^3	BQL	BQL	0.75	1.25	1.33	0.51	1.2	1.31
5.	Chlorophyll-a	mg/m^3	0.69	0.96	1.52	1.26	1.55	1.19	1.77	1.43
6.	Particulate Oxidisable Organic Carbon	mg/L	0.86	1.11	0.69	0.79	1.28	0.89	0.7	0.78
7.	Secchi Depth	ft	0.58	0.70	0.54	0.44	0.49	0.76	1.17	1.24

- **Biomass:**
  With reference to the **Table 39**, the concentration of **Biomass** reported from location ME-1 to ME-6 in range between **65-121 mg/L** where lowest biomass presents in ME-3 (Near Coal Berth) and highest biomass present in ME-1 (Near Passenger Jetty One) during sampling period. In Vadinar, the value of biomass was observed **86 mg/L** at ME-7 (Near SPM) and **125 mg/L** in ME-8 (Near Vadinar Jetty) monitoring station.

- **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 location of Kandla reported GPP value in range between **0.69 to 1.63 mg/L/48 Hr** where the highest value recorded for ME-4 (Khori Creek) and lowest recorded at ME-6(Nakti creek (near NH-8A)). In Vadinar, the value of **GPP** was observed **0.88** at ME-7 (Near SPM) and **1.23** at ME-8 (Near Vadinar Jetty) monitoring station.

  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 recorded in as **BQL (Below Quantification Limit).** While in Vadinar, the value of **NPP** was observed **BQL (Below Quantification Limit).** at ME-7 (Near SPM) and ME-8 (Near Vadinar Jetty) monitoring station.

- **Pheophytin**
  The level of Pheophytin was detected in the range from **0.51 to 1.33 mg/m^3** where the highest value observed at ME-5 (Nakti Creek (near Tuna Port)) and the lowest value observed at ME-6 (Nakti Creek (near NH - 8A)). While in Vadinar, the value of Pheophytin was observed **1.20 mg/m^3** at ME-7 and **1.31 mg/m^3** at ME-8 monitoring station.

- **Chlorophyll-a**
  In the sub surface water, the value of Chlorophyll-a reported in range from **0.69 to 1.55 mg/m^3**. The highest value observed at ME-5 (Nakti creek (near KPT Colony)) while the lowest value observed at ME-1 (Near Passenger Jetty One). In Vadinar, the value of chlorophyll-a was observed **1.77 mg/m^3** at ME-7 (Near SPM) and **1.43 mg/m^3** in ME-8 (Near Vadinar Jetty) monitoring station.

- **Particulate Oxidisable Organic Carbon**
  During the sampling period, the particulate oxidisable organic carbon falls within the range of **0.69 to 1.28 mg/L** from monitoring location ME-1 to ME-6 at Kandla, whereas for Vadinar, the value of POC observed **0.70 mg/L** at ME-7 (Near SPM) and **0.78 mg/L** in ME-8 (Near Vadinar Jetty) monitoring station.

- **Secchi Depth**
  In monitoring station of Kandla (ME-1 to ME-6) the level of Secchi Depth was observed between **0.44 to 0.76 ft** whereas at Vadinar, the value recorded at ME-7 i.e. Near SPM is **1.17 ft** and in Near Vadinar Jetty is **1.24 ft**.

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 during the study period. 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 40**.

Table 40: 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.	212	-	-	202	-	436	-	187
Biddulphia sp.	-	315	235	137	118	-	268	159
Chaetoceros sp.	317	166	-	-	-	561	186	-
Chlamydomonas sp.	185	-	188	-	298	-	-	319
Cyclotella sp.	126	468	-	266	125	-	408	107
Coscinodiscus sp.	-	-	426	-	-	286	-	160
Ditylum sp	-	225	-	271	-	-	270	-
Fragilaria sp.	486	174	142	158	210	153	-	181
Bacteriastrum sp.	252	-	-	-	119	146	161	-
Pleurosigma sp.	-	-	308	-	-	-	125	212
Navicula sp.	147	-	-	147	374	252	-	183
Merismopedia sp.	-	156	177	-	-	-	-	-
Synedra sp.	-	-	-	-	-	-	232	-
Skeletonema sp.	239	-	-	256	415	118	-	329
Oscillatoria sp.	-	201	355	-	-	-	178	-
Thallassiosira	187	-	158	-	175	123	163	280
Gomphonema sp.	-	345	-	178	-	-	135	-
Density-Units/L	**2151**	**2050**	**1989**	**1615**	**1834**	**2075**	**2126**	**2117**
No. of genera	**9**	**8**	**8**	**8**	**8**	**8**	**10**	**10**

The phytoplankton community of the sub surface water in the Kandla and Vadinar was represented by, Diatoms, green algae and filamentous Cynobacteria. Diatoms were represented by 15 genera; green algae were represented by 1 genera and filamentous Cynobacteria were represented by 1 genera during the sampling period.

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from **1615 to 2151 units/L,** while for Vadinar its density of phytoplankton observed **2126 units/L at ME-7 and 2117 units/L at ME-8.** During the sampling, phytoplankton communities were dominated, *Cyclotella sp, Fragilaria sp, Navicula sp & Thallassiosira* in Kandla, while *Cyclotella sp.* in Vadinar

The details of Species richness Index and Diversity Index in Phytoplankton is mentioned in **Table 41**.

Table 41: 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	9	8	8	8	8	8	10	10
Individuals	2151	2050	1989	1615	1834	2075	2126	2117
Shannon diversity	2.11	1.96	1.93	1.75	1.81	1.89	2.22	2.23
Simpson 1-D	0.87	0.86	0.86	0.87	0.85	0.83	0.89	0.89
Species Evenness	0.96	0.94	0.93	0.84	0.87	0.91	0.96	0.97
Margalef richness	1.04	0.92	0.92	0.95	0.93	0.92	1.17	1.18
Berger-Parker	0.23	0.23	0.21	0.17	0.23	0.27	0.19	0.16
Relative abundance	0.42	0.39	0.40	0.50	0.44	0.39	0.47	0.47

- **Shannon- Wiener's Index (H)** of phytoplankton communities was in the range of **1.75 to 2.11** between selected sampling stations from ME-1 to ME-6 with an average value of **1.91** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of phytoplankton communities recorded to be **2.22** at location ME-7 and **2.23** at ME-8 with an average value of **2.23**. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla.

- **Simpson diversity index (1-D)** of phytoplankton communities was ranged between **0.83 to 0.87** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.86** Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was **0.89** at location ME-7 and **0.89** at ME-8 with an average of **0.89**.

- **Margalef's diversity index** (Species Richness) of phytoplankton communities in Kandla and nearby creeks sampling stations was varying from **0.92 to 1.04** with an average of **0.95** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of phytoplankton communities observed **1.17** at ME-7 and **1.18** at ME-8 with an average value of **1.18**.

- **Berger-Parker Index (d)** of phytoplankton communities was in the range of **0.17 to 0.27** between selected sampling stations from ME-1 to ME-6 with an average value of **0.22** at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of **0.19 to 0.16** with an average value of **0.18**. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.84 to 0.96** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed **0.96** at location ME-7 & **0.97** at ME-8 location.

- During the sampling period, **Relative Abundance** of phytoplankton communities was in range of **0.39 to 0.50** between selected sampling stations from ME-1 to ME-6 with an average value of **0.42** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **0.47** at ME-7 and **0.47** at ME-8 with an average value **0.47**, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

The details of variation in abundance and diversity in zooplankton communities is mentioned in **Table 42**.

Table 42: 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.	-	1	1	1	-	2	2	-
Acrocalanus	1	-	1	-	1	-	2	-
Amoeba	-	1	1	2	-	1	1	2
Brachionus sp.	2	1	-	-	1	2	-	1
Calanus sp.	2	1	1	2	2	-	-	-
Cladocera sp.	1	-	-	-	-	-	1	-
Cyclopoid sp.	-	1	3	2	1	1	1	3
Copepod larvae	1	2	-	1	-	1	1	1
Diaptomus sp.	-	-	1	-	2	-	1	-
Eucalanus sp.	2	1	-	1	-	1	-	2
Mysis sp.	-	-	2	-	1	-	-	1
Paracalanus sp.	1	1	-	-	-	1	1	1
Density Unit/L	**10**	**9**	**10**	**9**	**8**	**9**	**10**	**11**
No. of genera	**7**	**8**	**7**	**6**	**6**	**7**	**8**	**7**

A total of 12 groups/taxa of zooplankton were recorded in Kandla and Vadinar during the study period which mainly constituted by *Mysis*, *brachionus*, *Calanus*, fish and shrimp larval forms. *Cladocera, Mysis* and *Paracalanus* 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 **8 to 10 units/L**, while for Vadinar its density of zooplankton observed **10 units/L at ME-7** and **11 units/L at ME-8**. During the sampling, zooplankton communities were dominated by *Cyclopoid sp, Calanus sp, Amoeba* in Kandla, while *Cyclopoid sp* and *Calanus sp* had the largest representation at monitoring location of Vadinar.

The details of Species richness Index and Diversity Index in Zooplankton communities is mentioned in **Table 43**.

Table 43: 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	7	8	7	6	6	7	8	7
Individuals	10	9	10	9	8	9	10	11
Shannon diversity	1.89	1.93	1.83	1.66	1.56	1.8	2.03	1.93
Simpson (1-D)	0.93	0.97	0.91	0.92	0.93	0.94	0.96	0.91
Species Evenness	0.97	0.93	0.94	0.93	0.87	0.93	0.98	0.99
Margalef	2.61	3.19	2.61	2.28	2.4	2.73	3.04	2.5
Berger-Parker	0.2	0.22	0.3	0.22	0.25	0.22	0.2	0.27
Relative abundance	70	88.89	70	66.67	75	77.78	80	63.64

- **Shannon- Wiener's Index (H)** of zooplankton communities was in the range of **1.56 to 1.93** between selected sampling stations from ME-1 to ME-6 with an average value of **1.77** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of zooplankton communities recorded to be **2.03** at ME-7 and **1.93** at ME-8 with an average

value of **1.98**. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Near SPM (Vadinar).

- **Simpson diversity index (1-D)** of zooplankton communities was ranged between **0.91 to 0.97** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.93** Similarly, for Vadinar Simpson diversity index (1-D) of zooplankton communities was **0.96** at ME-7 and **0.91** at ME-8 with an average of **0.93.**

- **Margalef's diversity index** (Species Richness) of zooplankton communities in Kandla and nearby creeks sampling stations was varying from **2.28 to 3.19** with an average of **2.63** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of zooplankton communities observed **3.04** at ME-7 and **2.50** at ME-8 with an average value of **2.77**.

- **Berger-Parker Index (d)** of zooplankton communities was in the range of **0.20 to 0.30** between selected sampling stations from ME-1 to ME-6 with an average value of **0.23** at Kandla creek and nearby creeks. Berger-Parker Index (d) of zooplankton communities in the sampling stations of Vadinar, was observed **0.20** at ME-7 and **0.27** at ME-8 with an average value of **0.23**. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.87 to 0.97** for all the six-monitoring station of Kandla whereas, for the Vadinar the species evenness was observed **0.98** at ME-7 and **0.99** at ME-8 the locations**,** during the monitoring month.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of 66.67 **to 88.89** between selected sampling stations from ME-1 to ME-6 with an average value of **74.72** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **80** at ME-7 and **63.64** at ME-8 with an average value **71.82**, thus it can be concluded that the studied species is stated as neither highly dominant nor rare.

The details of variation in abundance and diversity in **Benthic organism** is mentioned in **Table 44.**

Table 44: Benthic Fauna variations in abundance and diversity in sub surface sampling

Family/Class	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Thiaridae	-	1	1	-	-	-	-	1
Mollusca	1	-	-	1	1	-	1	-
Odonata	2	2	2	-	-	2	1	1
Lymnidae	1	1	1	-	2	1	-	-
Planorbidae	-	-	-	1	-	-	-	2
Talitridae	-	1	-	1	2	-	1	1
Trochidae	1	-	1	-	-	1	-	-

Family/Class	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Atydae	1		1	2	-	-	1	1
Gammaridae	-	1	-	-	1	2	2	-
Portunidae	1	-	-	2	1	1	1	-
Turbinidae	1	1	-	-	-	-	-	-
Palaemonidae	-	-	-	-	-	-	-	-
Density-Units/l	**8**	**7**	**6**	**7**	**7**	**7**	**7**	**6**
No of Class	**7**	**6**	**5**	**5**	**5**	**6**	**6**	**5**

Few Benthic organisms were observed in the collected sample by using the Van-Veen grabs during the sampling conducted for DPA Kandla and Vadinar. Majority of the species were found under the Macro-benthic organisms during the sampling period were represented by *Odonta,* Lymnidae, etc. The No. of Family of benthic fauna was varying from 6 to 8. The dominating benthic communities at Near Passenger Jetty One were represented Talitridae, Atydae. While lowest number of benthic species was represented by Palaemonidae.

The details of Species richness Index and Diversity Index in Benthic Organisms is mentioned in **Table 45.**

Table 45: Species richness Index and Diversity Index in Benthic Organisms

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	7	6	5	5	5	5	6	5
Individuals	8	7	6	7	7	7	7	6
Shannon diversity	1.91	1.65	1.39	1.47	1.47	1.47	1.65	1.39
Simpson 1-D	0.96	0.95	0.93	0.95	0.9	0.9	0.95	0.93
Species Evenness	0.98	0.92	0.86	0.91	0.91	0.91	0.92	0.86
Margalef	2.89	2.57	2.23	2.06	2.06	2.06	2.57	2.23
Berger-Parker	0.25	0.29	0.33	0.29	0.29	0.29	0.29	0.33
Relative abundance	87.5	85.71	83.33	71.43	71.43	71.43	85.71	83.33

- **Shannon- Wiener's Index (H)** of benthic organism was in the range of **1.39 to 1.91** between selected sampling stations from ME-1 to ME-6 with an average value of **1.56** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of benthic organism recorded to be **1.65** at ME-7 & **1.39** at ME-8 location with an average value of **1.52**. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Vadinar.

- **Simpson diversity index (1-D)** of benthic organism was ranged between **0.90 to 0.96** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.93**. Similarly, for Vadinar Simpson diversity index (1-D) of benthic organism was **0.95** at ME-7 and **0.93** at ME-8 location with an average of **0.94.**

- **Margalef's diversity index** (Species Richness) of benthic organism in Kandla and nearby creeks sampling stations was varying from **2.06 to 2.89** with an average of **2.31** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of

benthic organism observed to be **2.57** at ME-7 and **2.23** at ME-8 location with an average of **2.4**.

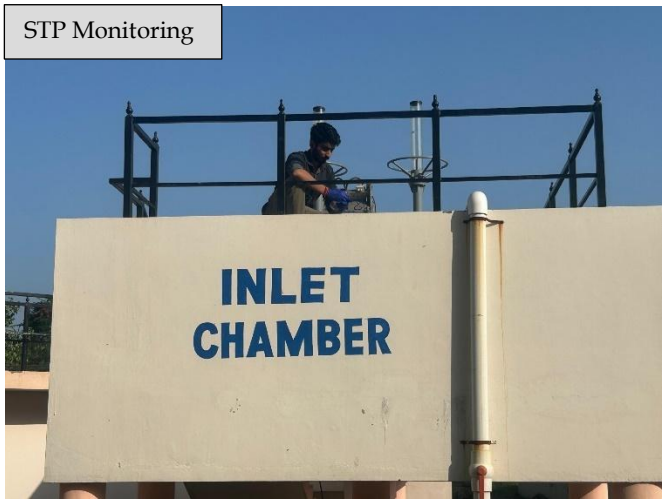
- **Berger-Parker Index (d)** of benthic organism was in the range of 0.25 **to 0.33** between selected sampling stations from ME-1 to ME-6 with an average value of **0.29** at Kandla creek and nearby creeks. Berger-Parker Index (d) of benthic organism in the sampling stations of Vadinar, was observed to be **0.29** at ME-7 and **0.33** at ME-8 location with an average value of **0.31**. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.86 to 0.98** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of **0.86 to 0.92** at both of the location.

- During the sampling period, **Relative Abundance** of Benthic organisms was **71.43 to 87.5** between selected sampling stations from ME-1 to ME-6 with an average value of **78.47** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **85.71** at ME-7 and **83.33** at ME-8 location, with an average value **84.52**, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla

STP Monitoring



Noise Monitoring

Soil Monitoring

Marine Monitoring

Air Monitoring

Drinking Water Monitoring

Annexure 2: Photographs of the Environmental Monitoring conducted at Vadinar

Air Monitoring

Noise Monitoring

STP Monitoring

Drinking water Monitoring

Marine Monitoring

Soil Monitoring

Source: GEMI

Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

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

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"We Provide Environmental Solutions"

Annexure -C

Monsoon Report
(June to September, 2024)

Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continious Monitoring Programme

Submitted to

DEENDAYAL PORT AUTHORITY
ISO 9001:2008 | ISO 14001 | ISPS compliant port

Submitted by

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Abstract

Monsoon (June 2024 to September 2024)

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. (v) EC& CRZ clearance granted by MoEF CC , GOI dated 1/1/2024 augmentation of iquid cargo handling facility specific condition no XXV
2	Deendayal Port letter sanctioning the project	DPA work Order: WK/4751/Part/ (Marine Ecology Monitoring)/72
3	Duration of the project	Three years-from 2024-2027
4	Period of the survey carried	First Year Monsoon season (June 2024 to September 2024)
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	Among the 15 sampling locations, Tuna Creek had the highest mean plant density with 2535 trees/ha, followed by Kharo Creek with 2486 trees/ha. However, in Kharo creek only one station is located. Regarding individual sample locations, the S-6 had the highest tree density (3,673 trees/ha), followed by S-1 (3,522 trees/ha). The S-15 (1,027 trees/Ha) and S-11 (1,221 trees/Ha) had the lowest average tree density.
7b	Mudflats	The highest TOC value (3.1%) was recorded at S-13 followed by S-1 and lowest TOC value was reported at site S-10 dependent on the living life forms and variations in the living object in the mudflats. The bulk density of mangrove soil at

		Deendayal Port Authority coastal region ranged from 1.30 g/cm3 to 1.61 g/cm3. The highest bulk density was recorded at S-13 sites followed by S-14. The lowest bulk density was recorded at S-5 located at Janghi creek.
7c	Phytoplankton	The phytoplankton density varied from 11,200 No/L to 20,480 No/L with the average 15,019 No/L. The highest phytoplankton density was observed at station S-13 (20,480 No/L) followed by S-14 (19,480 No/L), whereas the lowest 11,200 No/L at S-12. *Dictylum ,Nitzschia, Pseudonitzschia, Pleurosigma, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix, Navicula, Gyrosigma* which are distributed at all the stations.
7d	Zooplankton	The zooplankton identified from the 15 stations falls under 7 phyla and 28 genera belonging to the 13groups. Zooplankton population density v during the Monsoon 2024 at the 15 sampling sites ranged from 8,400 No/L to14,420No/L with an overall average of 10,491No/ L . 12 zooplankton genera that exhibited 100% of occurrence.
7e	Intertidal Fauna	The species diversity of the invertebrate phyla showed the maximum for phylum Mollusca (8 species), which is followed by Arthropoda (4species). The overall percentage composition of the three groups of intertidal fauna at the 15 station ie Arthropoda (67.09%), Mollusca (22.11%), and Chordata (10.8%),
7f	Sub-tidal Macrobenthos	macro benthic species of the various groups recorded (Fig.20) & Table 6 from the DPA port environment includes Mollusca (10) and Annelida (4) Arthropoda (2). The percentage composition of the three phyla that occurred during the monsoon. The phylum Mollusca is represented by maximum (65%) share of the subtidal Fauna, followed by Annelida (25.5%), Arthropoda (9.8%)
7g	Seaweeds	NO
7h	Seagrass	NO.
7i	Marine reptiles	NO
7j	Marine mammals	NO
7k	Halophytes	The halophytes sp *Salicornia brachiata* as mesure dominance
7l	Avifauna	A total of 53 species (32 species terrestrial and 21 aquatic bird) representing 9 order, 22 families and 37 genera were recorded during the study period
7m	Physicochemical	This is purely dynamic varies according to tidal current and condition gulf environment and influence to entire creek system.

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1. Introduction

Deendayal Port is located at Kandla in the Kachchh district of Gujarat state, operated by Deendayal Port Authority (DPA) (constituted under the major port Authority Act and the administrative control of ministry of ports shipping & water way GOI)is India's busiest major port in recent years and is gearing to add substantial cargo handling capacity with private participation. DPA being one of the 12 major ports in India is situated at latitude 22°59'4.93N and longitude 70°13'22.59 E on the Kandla creek at the inner end of Gulf of Kachchh (GoK). 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 viz. chemicals, edible oil, crude oil and other petroleum products etc. DPA has handled 132.3 MMTPA during the year 2023-2024. Presently, the Port has total 1-16 dry cargo berths for handling dry cargo, 7 oil jetties, and one barge jetty at Bunder basin, dry bulk terminal at Tuna Tekra, barge jetty at Tuna and two SPMs (2 local & 1 Nayara energy Limited and two product berths-Nayara energy Limited) at Vadinar for handling crude oil & petroleum product. Regular expansion or developmental activities such as the addition of jetties, allied SIPC and ship bunkering facilities oil jetty No 8 and container terminal at Tuna Tekra are underway in order to cope with the increasing the 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 shape 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 (Stage I) with in existing Kandla port – specific condition no. xxiii.

(iii) EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 (1)Setting of oil jetty No7 (2) Setting up barrage jetty at jafarawadi (3) Setting up barrage port at Veera (4) Admirative office building at Tuna Tekra (5) Road connecting from Veera barrage jetty to Tuna gate by M/s DPA -specific condition no. xv.

(iv) EC & CRZ clearance granted by the MoEF &CC, GoI dated 20/11/20 – expansion of port by creation of water front facilities (Oil jetty 8,9,10 and 11) and development of land area 554 acres for associated facilities for storage at old

Kandla , Gandhidham, Kachchh by Ms.Dpa Para VIII Marine Ecology, specific condition iv.

(v)Development of 7 integrated facilities (Stage I) within the existing Kandala port CRZ clearance MoEFcc ,GOI dated 19/12/2016-Specific condition (ii),(iii) and (iv) the project proponent ensure that ,not damage the mangrove patch without disturbing creek water circulation ,there is no blocking of creek or rivers of project area and shoreline also not damaged and it periodically monitored .

(vi) EC& CRZ clearance granted by MoEF CC , GOI dated 1/1/2024 augmentation of liquid cargo handling facility specific condition no XXV.

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 all 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 an 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 faunal 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 and further extended to another 3 years i.e from May 2024 to May 2027 with specific condition XXV for augmentation of liquid cargo handling facility . The study covers all the seasons as specified by specific condition of the Ministry of Environment, Forest and Climate Change (MoEF&CC). The present study is designed considering the scope of 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 & 1.1.2024 with specific

conditions xviii, xxiii, xv, iv and xxv respectively. A detailed holistic approach to different components of 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 the period May 2024 to May 2025 as follows:

- Physico-chemical characteristic of water and sediment will be analysed.
- 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.
- To study the intertidal faunal composition, distribution, diversity, density and other characteristics, other mega faunal components such as mammals, reptiles and amphibians.
- To investigate the species composition, distribution, diversity, density of sub-tidal benthic fauna.
- To estimate the primary productivity selected sampling sites located in around DPT area.
- Investigate the species composition, distribution, density and diversity of phytoplankton and zooplankton.
- To study the distribution of halophytes, sea grasses, seaweeds and other coastal flora, their occurrence, distribution, abundance and diversity.
- To study the Avifaunal Density, diversity, composition, habitat, threatened and endangered species and characters.
- Fishery Resources - Common fishes available, composition, diversity, Catch Per Unit Effort (CPUE) and other socio-economic information.

This study in short attempts the following, to i) developing a strong long term monitoring of the port marine environment from the biological perspective which could be used to monitor changes in the future, and ii) formulating a management plan based on the baseline data in order to ensure long-term ecological health of the port environment. A

better understanding of the marine ecology of the port and its processes has been attempted in this study which will assist in better management and conservation decisions to promote marine environmental health within the port limits.

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 (Table1) .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 (Fig1). 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).

Locations	GPS coordination	
	Latitude	Longitude
S-1	22.9410	70.1358
S-2	22.9616	70.1244
S-3	22.9876	70.2345
S-4	23.0285	70.2331
S-5	23.0804	70.2245
S-6	23 9'19.99	7024'1.47
S-7	22.9771	70.2125
S-8	23.0378	70.4070
S-9	22.9960	70.3932
S-10	23.1007	70.2961
S-11	23.1608	70.4948
S-12	22.9446	70.1062
S-13	23° 6'58.69"	70°21'8.77"
S-14	22.89590	70.07450
S-15	23.0654	70.2172

Table 1 . Sampling locations (2024-2025)

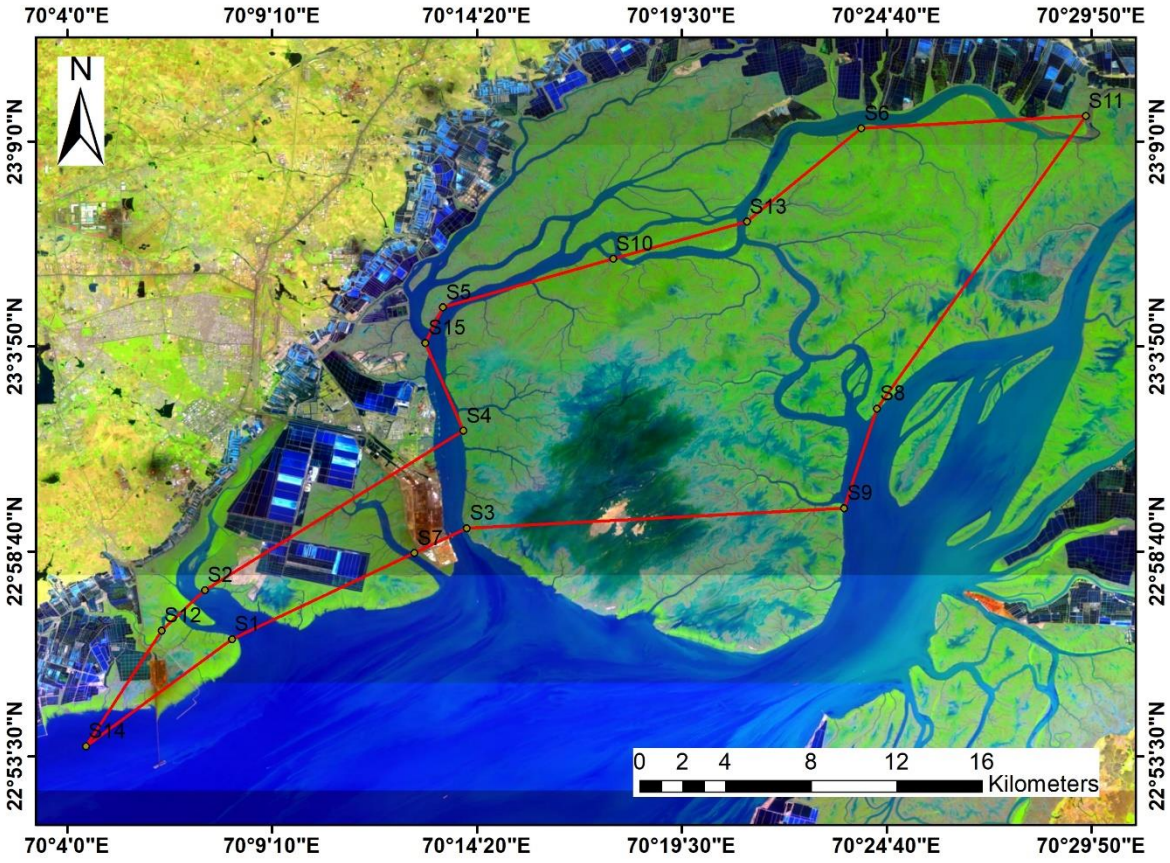


Figure 1. Sampling location of Study area

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.2).

Table 2: Physico-chemical and biological parameters analysed

Parameters	
Water	**Mangrove & Other Flora**
pH	**Mangrove**
Temperature	Vegetation structure, density
Salinity (ppt)	Diversity
Dissolved oxygen	Height
Total Suspended Solids (TSS)	Canopy and other vegetation characteristics
Total Dissolved solids (TDS	**Halophytes:**
Turbidity	Percentage of distribution and cover
Nutrients	Diversity
Nitrate (NO_3)	**Seagrass and Seaweed**
Nitrite (NO_2)	Occurrence, distribution, and diversity
Phosphate	**Intertidal fauna**
Silicate	Composition, distribution, diversity, density and other characteristics
Petroleum Hydrocarbon (PHs)	**Mammals**
Sediment	**Avifauna**
Texture	Density, diversity, composition, habitat,
Bulk density	Threatened and endangered species and characters
Total organic carbon (TOC)	
Biological Parameters	
Phytoplankton- Genera, abundance, diversity and biomass	
Productivity-Chlorophyll a	
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 the 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

Methodology

2.1.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 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).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.

Silicate

The determination of dissolved silicon compounds in natural waters is based on the formation of a yellow silicomolybdic acid when an acid sample is treated with a molybdate solution. It is Spectrophotometrically measured by absorbance (810 nm for maximum absorbance and 660 for about 40% by adopting method of s Grasshoff et.al 1999**.**

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 sampling

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 passed through sieves of different mesh size as per Unified Soil Classification System (USCS). Cumulative weight of the fraction 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).

2.2. 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 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 the 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.

Intertidal Fauna

Intertidal faunal assemblages were studied for their density, abundance and frequency of occurrence during Monsoon 2024 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; 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).

Sub tidal 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. /10cm^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 (2017), Ravinesh *et al*. (2021) and Edward *et al*, (2022) for molluscs. Statistical analyses such as diversity indices and Univariate measures such as Shannon-Wiener diversity index (H'), Margalef's species richness (d), Simpson's dominance (D) were determined using 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

2.3. 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 reflects the 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).

Plate 3. Sediment sample collection at mangrove and mudflat areas

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.

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).

2.4. Mangrove assessment

Mangroves are widely distributed on the Deendayal Port Authority jurisdiction area along the Kandla coast. The 15 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 closeness of the location to the respective creek system. The Point Centered Quadrate Method (PCQM) was used for the collection of data of the mangrove vegetation structure. The data included, measurements of density of plants, height variations, canopy and basal girth 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 to the 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

2.5. 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 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 halophyte

2.6. 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 (Plate 6). For effective sampling, points were fixed at distances within the 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

2.7. 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 Monsoon season (June- September, 2024). 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.

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

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 are presented in Table3.

Temperature (°C) and pH

The water temperature at the sampling sites ranged from 23°C to 30°C.The maximum temperature of seawater was reported at S-7 and the minimum at S-6 in Janghi creek. The pH of seawater ranged from 7.7 to 8.1. The highest pH reported from majority of the stations was 8.0 to 8.1 and the lowest value 7.7 was noticed at S-8 S-11 in Navlaki creek & Janghi . The overall temperature fluctuation minimum which might be due to monsoon water but the pH of the water did not show remarkable variations among the sampling locations.

Salinity (ppt)

Salinity of the water strongly influences the abundance and distribution of marine biota in coastal and marine environments. The salinity ranged from 34 ppt to 42 ppt with the average value of 38 ppt. Minimum salinity was observed at S-3 and maximum at S-8 & S-10 also.

Dissolved oxygen (DO)

Dissolved oxygen is the amount of oxygen dissolved in water and is a fundamental requirement of all biota and chemical processes in the aquatic environment. The concentration varies mainly due to 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). The dissolved oxygen in the coastal waters of Deendayal port authority area ranged from 2.9 mg/L to 8.2 mg/L. The highest DO concentration was observed at station S-4 and lowestvalue reported at S-7.

Suspended Solids (TSS)

The total suspended solids (TSS) concentration at the 15 sampling sites ranged from 205 mg/L to 729 mg/L with the average of 419 mg/L. The highest TSS values was reported at S-6 followed by 658 mg/L in S-3 opposite oil jetty. The minimum TSS value 205 mg/L was recorded at S-13.

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. The TDS of the samples varied from 26,876mg/L 1,39,862mg/L with an average of 84,352 mg/L. The maximum value was reported from S-10.

Turbidity

The turbidity of the water samples from the study sites ranged between 20 NTU and 160 NTU with the average of 59 NTU. The lowest value was noticed at S-8 and the highest value at S-6 followed by S-7 (142 NTU).

Dissolved nutrients (Nitrate, Nitrite, Total Phosphorus and Silicate)

The nutrients influence growth, metabolic activities and reproduction of biotic components in the aquatic environment. The distribution of nutrients mainly depends upon tidal conditions, season and fresh water influx from land. The nitrate concentration ranged from 0.001 mg/L to 0.003 mg/L with an average of 0.002 mg/L.. There was no remarkable variation in the concentration of nitrate among the study stations. Similarly, nitrite values varied between 0.001 mg/L to 0.173 mg/L. The highest concentration was observed at station S-9 and lowest value at station S-14. The Total phosphorus values among the study station ranged from 36 mg/L to 73 mg/L with an average of 54 mg/L. The highest phosphorus concentration was observed at station S-6 near Janghi creek and lowest at station S-3 opposite to oil jetty . During this season the highest concentration over limit might be due to leaching of phosphatic fertilizer while handling in the cargo port area and other cargo discharge . Likewise, the silicate concentration varied from 0.012 mg/L to 0.058 mg/with the average of 0.035 mg/L.The highest concentration of Silicate was observed at S-15 and lowest value at S-14. The variations in the concentration of silicate in correlated with the production of diatoms and siliceous planktonic species which are invoved in the in the export of carbon from surface of open sea towards creek system of Kandla and the particulate matter to the bottom sediment.

Petroleum Hydrocarbons (PHs)

Petroleum Hydrocarbons (PHs) are widely recognized as the most extensively utilized fossil fuels in commercial applications (Kuppusamy et al., 2020). PHs serve as crucial raw materials across various industries and function as primary sources of energy (Varjani, 2017). However, their pervasive use has led to their identification as a major concern in terms of environmental contamination, posing significant threats to ecosystems due to their inherent stability and resilience. The category of PHs encompasses diverse components, including Polycyclic aromatic hydrocarbons (PAHs), alkanes, paraffin, cycloalkanes, organic pollutants, and non-hydrocarbon elements such as phenol, sulfur compounds, thiol, metalloporphyrin, heterocyclic nitrogen, naphthenic acid and asphaltene. The introduction of PHs into an ecological niche or ecosystem promptly alters its composition, leading to a decline in overall functionality and inducing weathering processes. This weathering, in turn, initiates various influences, encompassing chemical reactions (auto-oxidation/photo-oxidation), physical changes (dispersion), physico-chemical alterations (sorption, dissolution, evaporation), and biological transformations (microbial and plant catabolism of hydrocarbons) (Truskewycz et al., 2019).The presence of PHs significantly impacts marine organisms, with bioaccumulation of harmful PHs in the aquatic food chain persisting for extended periods. This, in consequence, affects primary producers, primary consumers, and secondary consumers. Notably, approximately 90% of PH discharges are attributed to anthropogenic activities, particularly oil spills, occurring in both terrestrial and marine environments. Reports indicate an alarming annual discharge of around 8.8 million metric tonnes of oil into aquatic environments (Periathamby and Dadrasnia, 2013).

In the current study, the presence of PHs in water samples collected along all the 15 sampling locations were detected and estimated. The PHs ranged from 1.2 µg/L to 10.1 µg/L.. The highest concentration of the PHs was noticed at S-4 (in front of oil jetty) (10.1 µg/L while the lowest was noted at S-5 (1.2 µg/L) (Phang creek) with average variation of 4.6 2 µg/L among the different station . Overall the PHs in al station little higher which might be due to cargo handling activity.

Table 3: Physico-chemical& Biological characteristics of the waters at the study sites during Monsoon 2024

Parameter	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) (Water)	24	25	25	25	26	23	30	25	25	24	29	24	25	26	23
pH	8.1	8.0	8.1	8.0	8.0	8.1	8.1	7.7	7.9	7.9	7.7	8.0	8.1	8.1	8.0
Salinity (ppt)	36	38	34	39	37	36	41	42	38	42	38	36	40	38	36
Dissolved oxygen (mg/L)	4.3	6.2	5.5	8.2	7.6	7.4	2.9	7.2	6.4	7.0	5.2	5.8	4.1	3.6	5.3
(TSS) (mg/L)	302	599	658	467	346	729	503	329	365	390	346	468	205	259	323
(TDS) (mg/L)	56812	138585	88083	59045	116696	77160	83011	47680	98899	139862	89974	26876	96345	87131	59128
Turbidity (NTU)	58	45	58	74	42	160	142	20	47	60	44	47	31	28	33
Nitrate (NO_3) (mg/L)	0.003	0.002	0.002	0.002	0.002	0.003	0.001	0.002	0.003	0.003	0.002	0.002	0.002	0.002	0.003
Nitrite (NO_2) (mg/L)	0.050	0.038	0.031	0.053	0.050	0.064	0.079	0.061	0.173	0.018	0.062	0.094	0.083	0.001	0.052
Silicate (mg/L)	0.043	0.039	0.030	0.034	0.037	0.028	0.022	0.021	0.053	0.047	0.054	0.027	0.018	0.012	0.058
Total Phosphorus (mg/L)	48.24	61.18	36.18	68.53	62.94	73.24	46.18	51.18	37.06	53.82	42.35	46.18	53.53	67.35	62.94
PHs (µg/L)	7.15	6.35	3.49	10.1	1.2	6.5	2.05	7.85	8.7	2.75	1.75	3.9	3.45	1.4	2.45
TOC	3.12	2.55	2.88	2.715	3.03	2.82	2.91	2.955	2.7	2.43	2.775	2.85	2.67	2.52	2.73
(Biological) Chlorophyll a (mg/L)	0.18	0.27	0.13	0.00	0.04	0.11	0.46	0.89	0.59	0.00	0.21	0.47	0.17	0.20	0.08

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.2.There were noticeable variations in the soil fractions, sand, silt and clay, among the stations. In the present study the highest percentage of clay was reported at S-1 followed by S-4. The highest percentage of sand was observed at S-14 followed by S-11 . As per the observations, the percentage of silt content showed wide fluctuations between stations when compared to the clay and sand The nature of soil texture was characterized by the proportion of clay, sand and silt fractions. The Soil texture revealed the dominance of clay-sandy type while the sandy type substratum was very much dominated as compared to silt. This feature of the bottom sediment might be attributed to the activity of sediment transport in the creek 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.

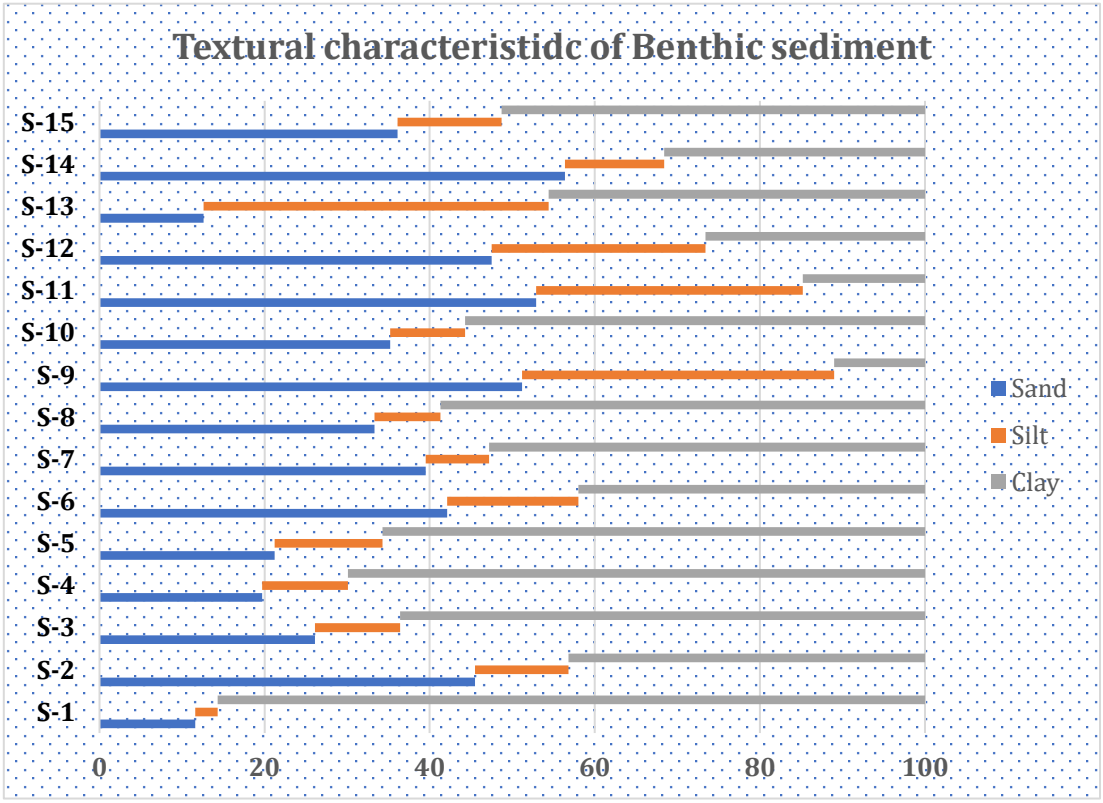


Figure 2: Characteristics of sediment at the study stations in Monsoon 2024

Total Organic Carbon (TOC)

In the present study, the total organic carbon content varied from 2.4% to 3.1% (Fig.3). The highest values of TOC were reported at S-1 followed by S-5 &S-8. The lowest TOC value was recorded at S-10. The distribution of total organic carbon closely followed the distribution of sediment type in general i.e., sediment low in clay content contained relatively low organic carbon. But in the Kandla creek system is associated with Mangroves which holds the organic particles derived from the plants and the fauna undergo decomposition and mixed with the sediment during the the mixing process which would have facilitated the adherence of particulate matter in the soft substratum as most of the stations showed more organic carbon load during monsoon .

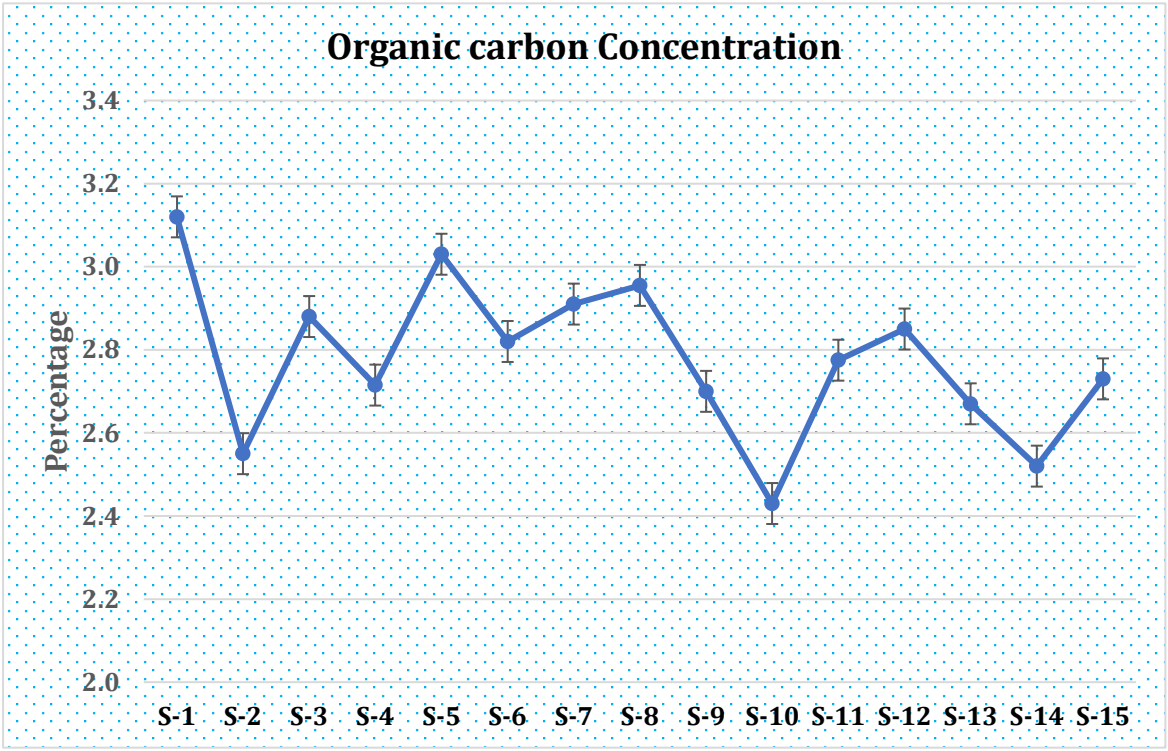


Figure 3: Total Organic Carbon content (%) in the sediment during Monsoon 2024

3.3. Biological characteristics

Primary productivity

Chlorophyll 'a' the photosynthetic pigment which can be used as a proxy for phytoplankton productivity and thus is an essential 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 arbitrated by the activity of microscopic phytoplankton.

At present , the Chlorophyll 'a' concentration ranged from 0.01 mg/L to 0.89 mg/L with average variation among the station was 0.26 mg/L . The highest concentration 0.89 mg/L was reported at S-8 (Fig.4) followed by S-9 (0.59mg/L). The photosynthetic pigment chlorophyll a which is a measure of the population density of phytoplankton during the monsoon period showed minor variations among the sites. The Chlorophyll 'a' content was very low at S-4 (Table 2).

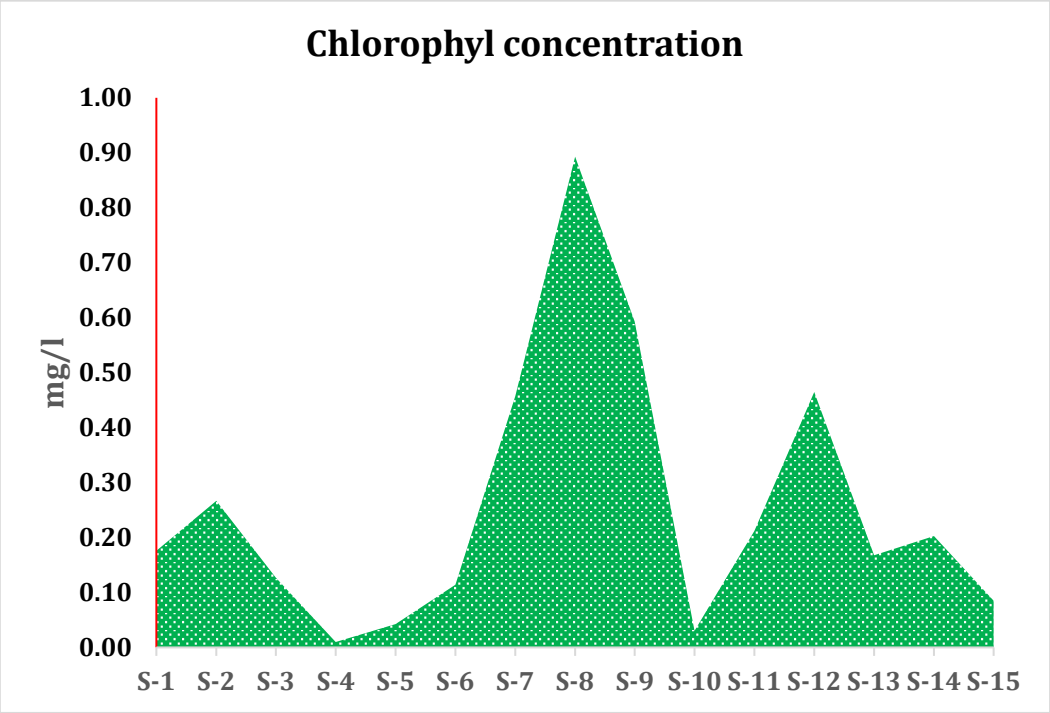


Figure 4: Chlorophyll 'a' concentration at the study stations in Monsoon 2024

3.4. Phytoplankton

Phytoplankton are a key component of the ocean and freshwater ecosystems and provide many ecosystem services including oxygenation through photosynthesis which is estimated to be about half of the Earth's oxygen. Thus, they are important component of the functioning of ecosystems and climate regulation (Jacqueline et al.,2018). The carbon assimilation during photosynthesis by the phytoplankton enables the transfer of atmospheric carbon dioxide into the biomass which is stored in the cells and later pass on to the food chains and being cycled through the food webs. These microscopic producer community has been influenced by the negative impact from human developments and activities, and hence the service provision afforded by them should be accounted for in marine management processes (Jacqueline et al.,2018). Phytoplankton growth depends on the availability of carbon dioxide, sunlight, and nutrients. Phytoplankton, like land plants, require nutrients such as nitrate, phosphate, silicate, and calcium at various levels depending on the species. Some phytoplankton can fix nitrogen and can grow in areas where nitrate concentrations are low. They also require trace amounts of iron which limits phytoplankton growth in large areas of the ocean because iron concentrations are very low. Other factors influence phytoplankton growth rates, including water temperature and salinity, water depth, wind, and what kinds of predators are grazing on them (Lindsey and Scott,2010).

The numerous species of phytoplankton are the primary producers form the basis of marine food-webs, supporting production of higher trophic levels (a provisioning ES), and act as a sink of carbon dioxide. The spatial distributions of phytoplankton and rates of primary productivity are generally subject to bottom-up control, due to the tight coupling between light, temperature and nutrients. understanding of the spatial and temporal variability in phytoplankton parameters are accounted in marine management as these are correlated with physical and chemical factors of the water. The diatoms form the bulk of phytoplankton and the dinoflagellates are scarce. The phyto-plankton in the Gulf of Kachchh shows a primary peak in September and secondary peaks in January or June are instances of local blooms of more than one genus and species of diatoms.The detailed genera and percentage of phytoplankton presented in table -4.

Generic Status

There were four groups of phytoplankton occurred during monsoon along the DPA, Kandla coast and its peripheral creek system which include Diatom (Pennales, Centrales), and Cyanophyceae. The number of genera recorded during the monsoon period was 17 to 22 at the sampling stations with variations in respect to the composition. The maximum number (22) genera were observed at S-13 and the minimum from S-12 representing 17 genera. As far as generic status is concerned the Pennales diatom contributed a smaller number of genera (13) followed by Centrales (9) (Fig.5 & Table 4). Among the 4 groups of phytoplankton, the genera *Pleurosigma , Thalassionema, Coscinodiscus* and *Odontella* was highly dominated.

Percentage composition of phytoplankton

The cumulative percentage composition of the five groups of phytoplankton from all the study sites is presented in Fig.6. The percentage composition varied from 0.14 % to 14.35 % of which the pennales and centrales are the dominant constituting 65% and 34% 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 is constituted by Cyanophyceae (1%) during the monsoon 2024.

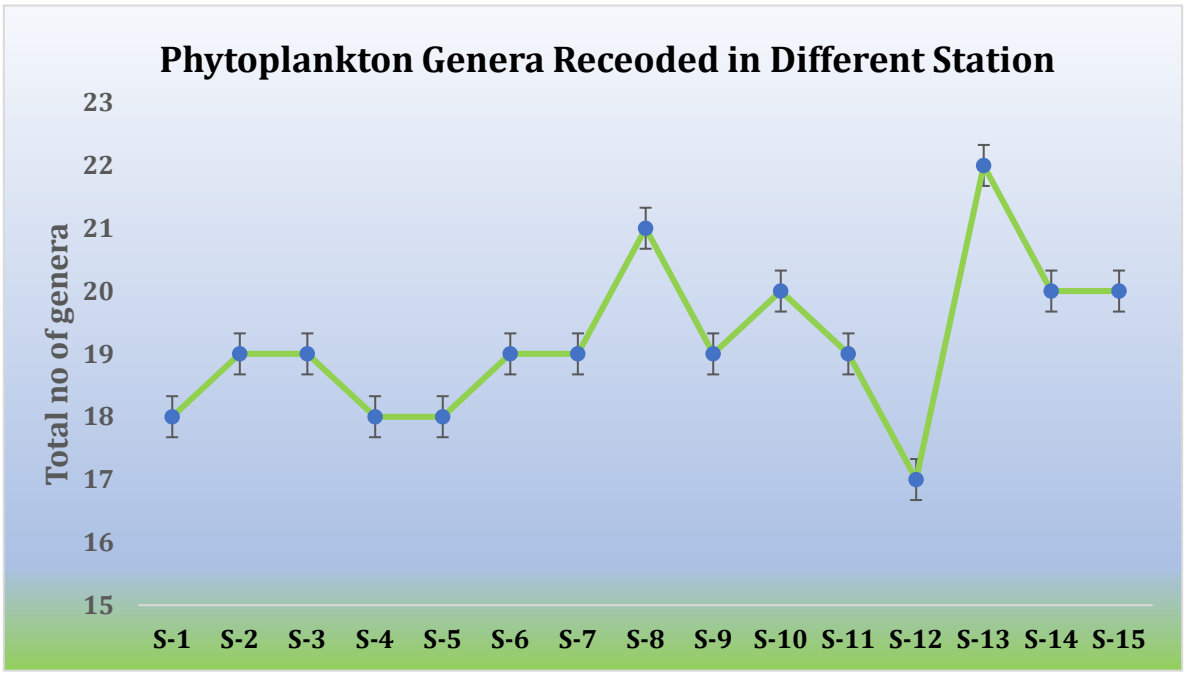


Figure 5: Number of Phytoplankton genera in Monsoon 2024

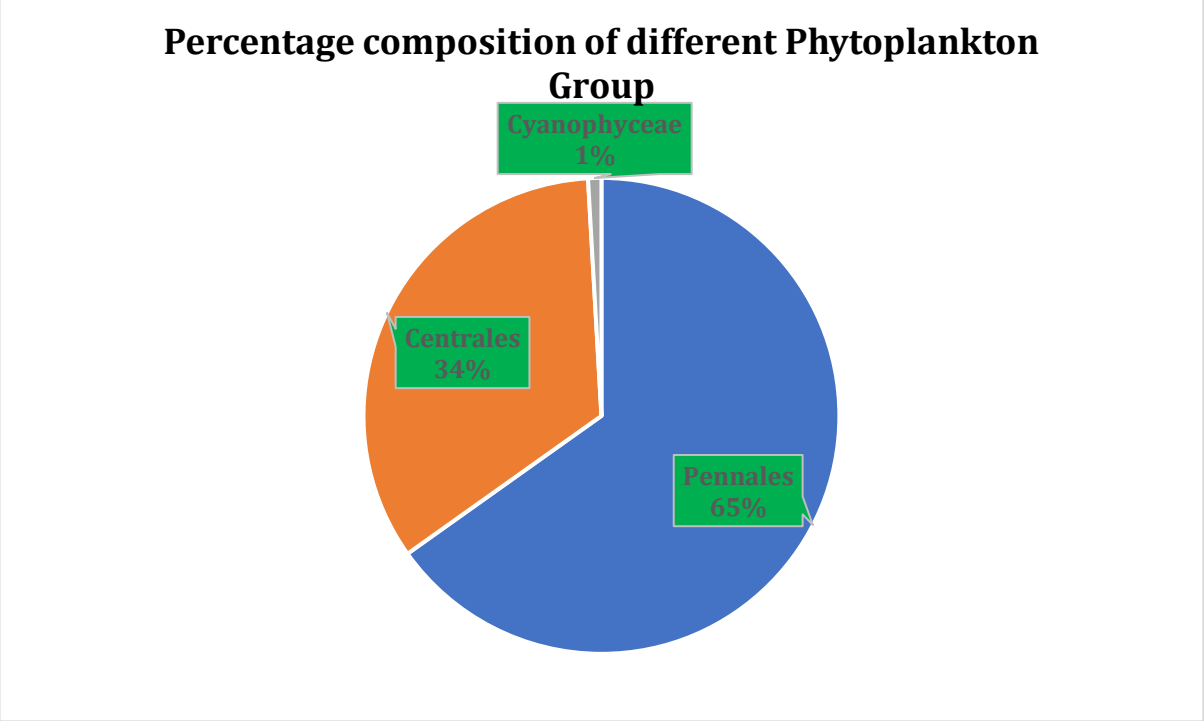


Figure 6: Percentage composition of phytoplankton groups in Monsoon 2024

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 83%. i.e 15 genera of diatoms occurred at all the stations i.e *Dictylum ,Nitzschia, Pseudonitzschia, Pleurosigma, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix, Navicula, Gyrosigma* (fig 7) followed by *Triceratium* and *Noctiluca* (73%) during the monsoon season.

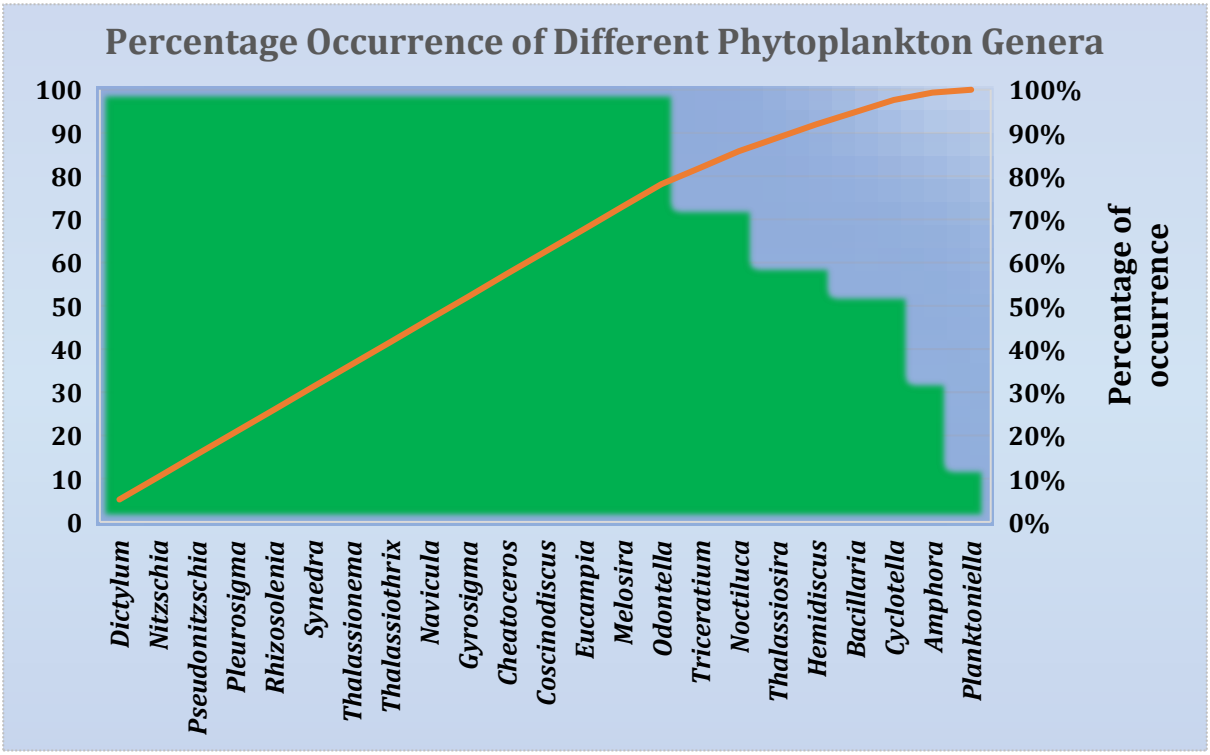


Figure 7: Percentage occurrence of phytoplankton genera in Monsoon 2024

Phytoplankton density and diversity

The density signifies the abundance of plankton which is measured as cell/ individual/L. The phytoplankton density varied from 11,200 No/L to 20,480 No/L with the average 15,019 No/L. The highest phytoplankton density was observed at station S-13 (20,480 No/L) followed by S-14 (19,480 No/L), whereas the lowest 11,200 No/L at S-12 (fig.8). 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 and behavioral factors of biotic communities. Among the different stations, the phytoplankton taxa varied from 17 to 22 (Table-3). During monsoon the Margalef and Menhinik richness indices were maximum as(2.1& 0.2). The Shannon diversity index was maximum 2.7 and minimum 2.5 a. The Simpson index clearly reflexes the species dominance (genera) at all station (fig 9).

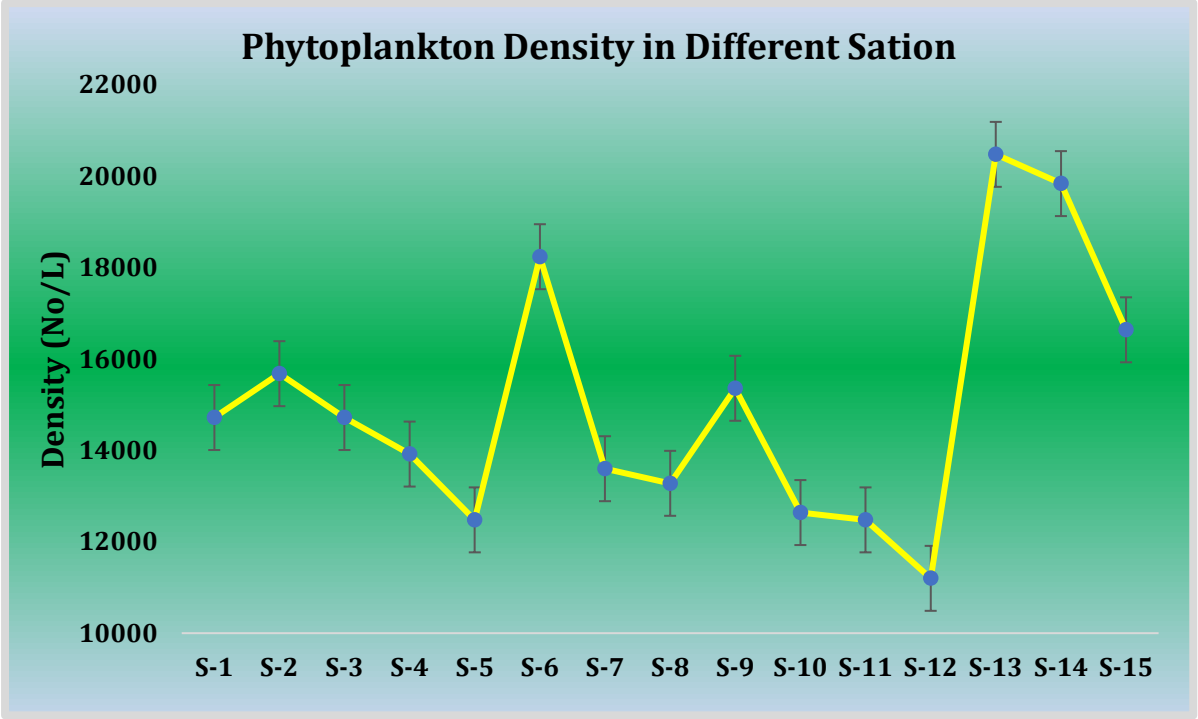


Figure 8: Phytoplankton density in Monsoon 2024

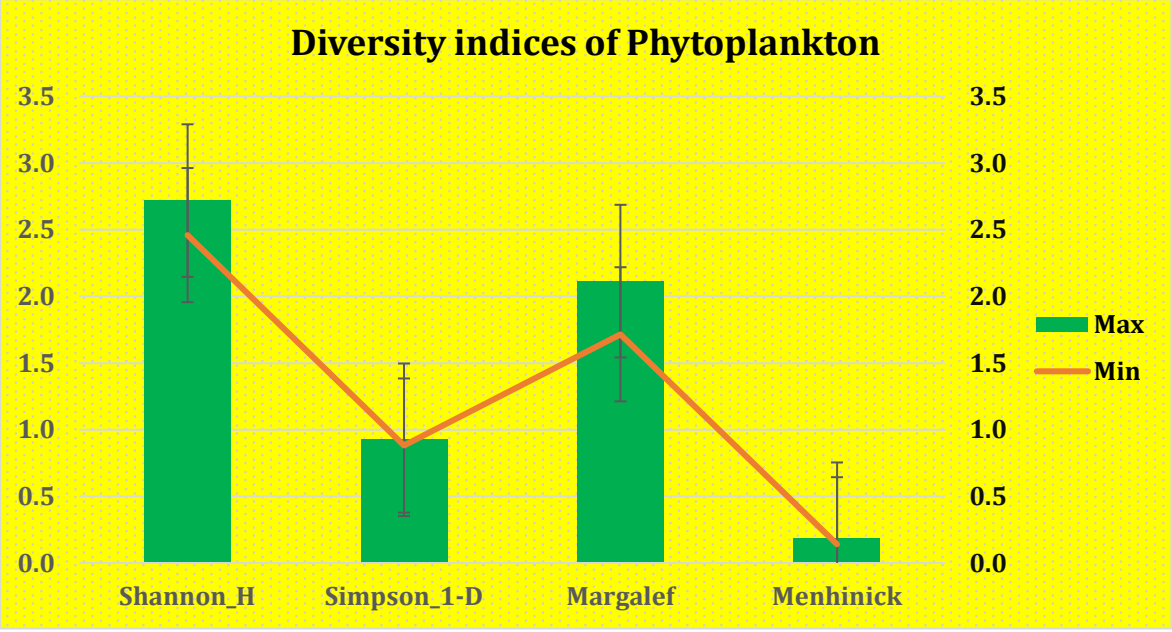


Figure 9: Different diversity indices a. Shannon Index b. Menhinick Index c. Margalef Index d. Simpson Index

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 the cargo movements. Accordingly, species diversity decreases at sites with poor water quality. As presumed from the Shannon diversity index values between 2.60 to 2.93 representing the moderate quality of environmental status dominated by majority of the genera such as *Dictylum ,Nitzschia, Pseudonitzschia, Pleurosigma, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix, Navicula, Gyrosigma* which are distributed at all the stations . A community dominated by relatively few species indicates environmental stress (Plafkin *et al.,* 1989). However, during the monsoon period the many genera appeared and flourish due to the suitable environmental condition in the water. According to Staub *et. al* (1970) species diversity index value between 3.0 to 4.5 represents slightly polluted and the lightly polluted environment shows the index value between 2.0-3.0, and the , 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. Which might be due to the industrial development and salt pan activity along the periphery environment of DPA port authority.

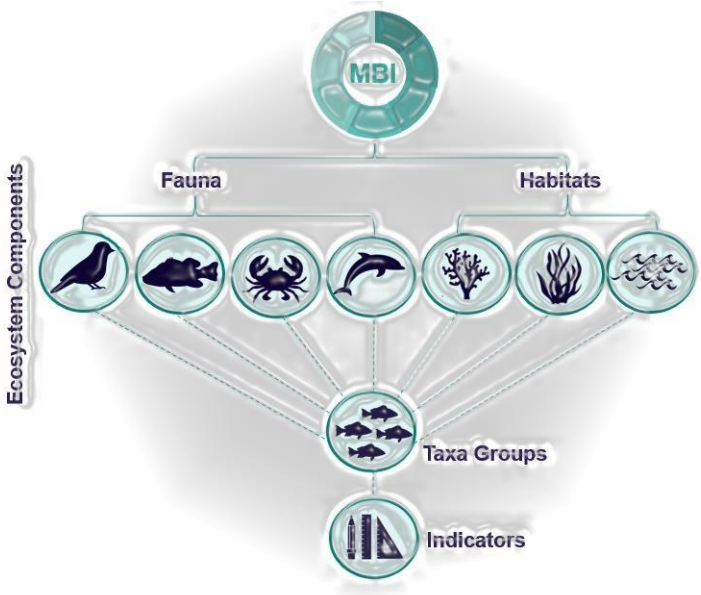


Table 4: Phytoplankton density, percentage composition and occurrence during Monsoon 2024

Group	Genera	Station																
		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*	0	0	0	0	0	160	0	0	160	0	0	160	160	0	160	0.36	33
	Bacillaria	160	0	0	160	0	0	0	160	160	160	0	0	160	160	160	0.57	53
	Dictylum	480	320	160	480	320	320	160	320	480	640	800	480	320	480	960	2.98	100
	Nitzschia	1280	1440	1120	480	960	1440	1280	480	800	480	640	480	640	480	800	5.68	100
	Pseudonitzschia	480	640	800	480	800	480	640	480	800	480	480	320	640	960	480	3.98	100
	Pleurosigma	320	480	640	800	480	1440	1600	1920	1440	480	1280	1440	3360	3040	1760	9.09	100
	Rhizosolenia	1120	480	640	960	480	1280	480	1120	960	480	800	480	1440	1120	1440	5.89	100
	Synedra	1920	2400	2400	1440	1280	1920	320	320	320	480	640	640	2880	1920	480	8.59	100
	Thalassionema	1280	1440	1760	1920	1600	2880	3360	480	2400	2560	1440	1120	2080	4320	3680	14.35	100
	Thalassiothrix	480	1120	1440	480	1120	1440	480	1280	800	960	480	640	480	320	160	5.18	100
	Navicula	800	1280	480	640	800	480	640	1280	1120	960	480	640	800	480	1280	5.40	100
	Gyrosigma	480	320	480	320	160	480	320	320	480	160	160	480	320	160	160	2.13	100
	Thalassiosira	160	160	320	0	320	0	160	160	320	0	0	0	160	320	0	0.92	60
Centrales	*Cheatoceros*	800	640	480	320	480	800	480	640	800	1120	1440	480	800	480	640	4.62	100
	Coscinodiscus	2880	1440	1600	1920	1280	1920	1440	1920	2240	1440	1600	320	2400	3200	640	11.65	100
	Cyclotella	0	0	0	160	0	0	160	160	0	160	320	0	160	160	320	0.71	53
	Eucampia	320	320	480	640	320	480	320	640	480	320	640	320	480	640	800	3.20	100
	Melosira	480	480	320	480	640	800	480	160	320	480	320	640	480	320	800	3.20	100
	Odontella	960	1120	960	1920	960	1280	800	800	1120	640	480	2240	2080	960	1760	8.03	100
	Planktoniella	0	0	0	0	0	160	0	0	0	160	0	0	0	0	0	0.14	13
	Triceratium	320	160	320	160	160	320	320	160	0	0	160	320	160	0	0	1.14	73
	Hemidiscus	0	1280	160	0	0	160	160	320	0	160	160	0	320	160	0	1.28	60
Cyanophyceae	*Noctiluca*	**0**	160	160	160	320	0	0	160	160	320	160	0	160	160	160	0.92	73
Total Density (No/L)		**14720**	**15680**	**14720**	**13920**	**12480**	**18240**	**13600**	**13280**	**15360**	**12640**	**12480**	**11200**	**20480**	**19840**	**16640**		
Total Genera		**18**	**19**	19	18	18	19	**19**	**21**	**19**	**20**	**19**	**17**	**22**	**20**	**20**		

PC: Percentage of Composition

PO: Percentage of Occurrence

3.5. Zooplankton

These are the primary consumers that depends on phytoplankton for their feeding and constitute a second trophic level in food chain of marine ecosystem. The size of the zooplankton members varies greatly from microscopic to macroscopic occupying different depths in the pelagic realm. They constitute the primary food for several higher trophic level organisms which includes fishes, crustaceans and mollusks. Zooplankton provides the required amount of protein to the cultured fishes and crustaceans (Koli and Mule, 2012) as well. The zooplankton species quickly respond to the environmental changes and thus are used as bio-indicators for the assessment of aquatic environments (Sharma et al., 2007). Thus, zooplankton are of great ecological significance as they play important role of transferring organic matter from primary producer to secondary consumers like fishes (Kehayias et al., 2013). Zooplankton in the Gulf of Kachchhis dominated by copepods (Saravanakumar et al.,2017) while the microzooplankton is represented by Cilio-phora and Forminifera (Patel et al., 2017). Ramaiah (1997) stated that studies on zooplankton communities, especially copepods are of key importance in assessing the health of coastal ecosystems. The distribution of living organism is controlled by the variation in salinity of water and its variation caused by dilution and evaporation is most likely to influence the fauna in the coastal ecosystem (Sridhar et al. 2006). The density of zooplankton was found to be high during postmonsoon and premosoon period, bimodal distribution, the primary peak occurring either in October or April and the secondary peak in March or December (Bhaskaran and Gopalakrishnan,2011). Similarly, there occurs gradual increase in number of organisms towards the offshore area with concomitant increase in diversity. The larval forms of echinoderms, cephalopods and brachiopods are usually confined to the offshore (Govindan et al.,1980). The detailed genera and percentage of phytoplankton presented in table- 5

Phylum, group and generic status

The zooplankton identified from the 15 stations falls under 7 phyla and 28 genera belonging to the 13groups (Table 5). The phylum Arthropoda was the predominant, represented with 20 genera including copepods, crabs, shrimps and their larva. The phylum Arthropoda dominated in the samples with major groups Calanoida, Harpacticoida, Cyclopoida, (Copepoda) Decapoda, and the larval forms of crustaceans. There were 9 genera of copepods in the samples. Among copepods, the Calanoida ranked

first in terms of generic representation particularly *Acartia* sp, *Acrocalanus* sp, *Calanopia* sp. and *Calanus* sp. (figure-10).

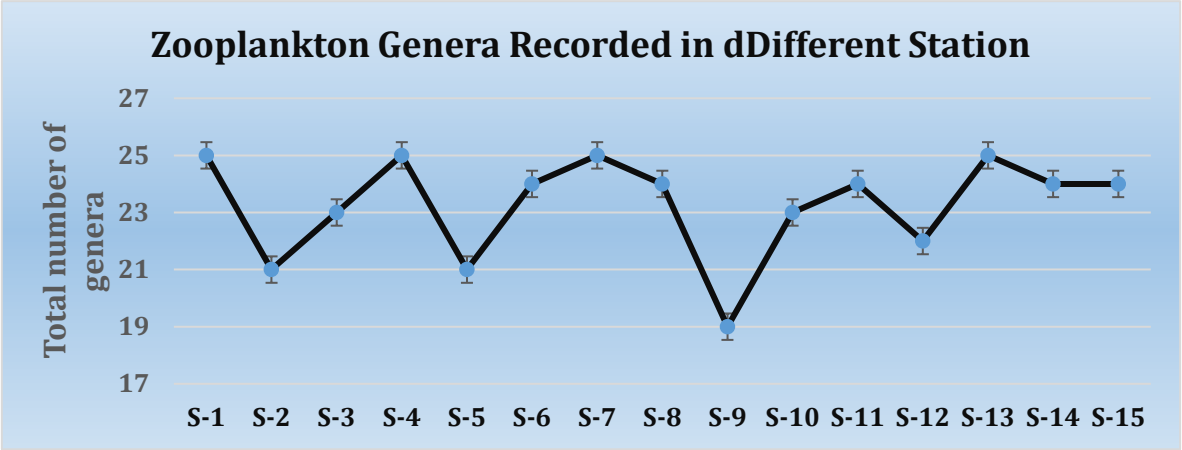


Figure 10: Generic status of zooplankton during Monsoon 2024

Percentage composition

The overall percentage of the various groups of zooplankton varied from 0.4% to 25.8%. The highest percentage was due to the calanoid copepods (25.8%) followed by *Malacostraca* (Brachyuran larvae) (19.9%) and Tintinnida (12.7%). (Fig.11). Among the zooplankton groups calanoid group predominated at all sites.

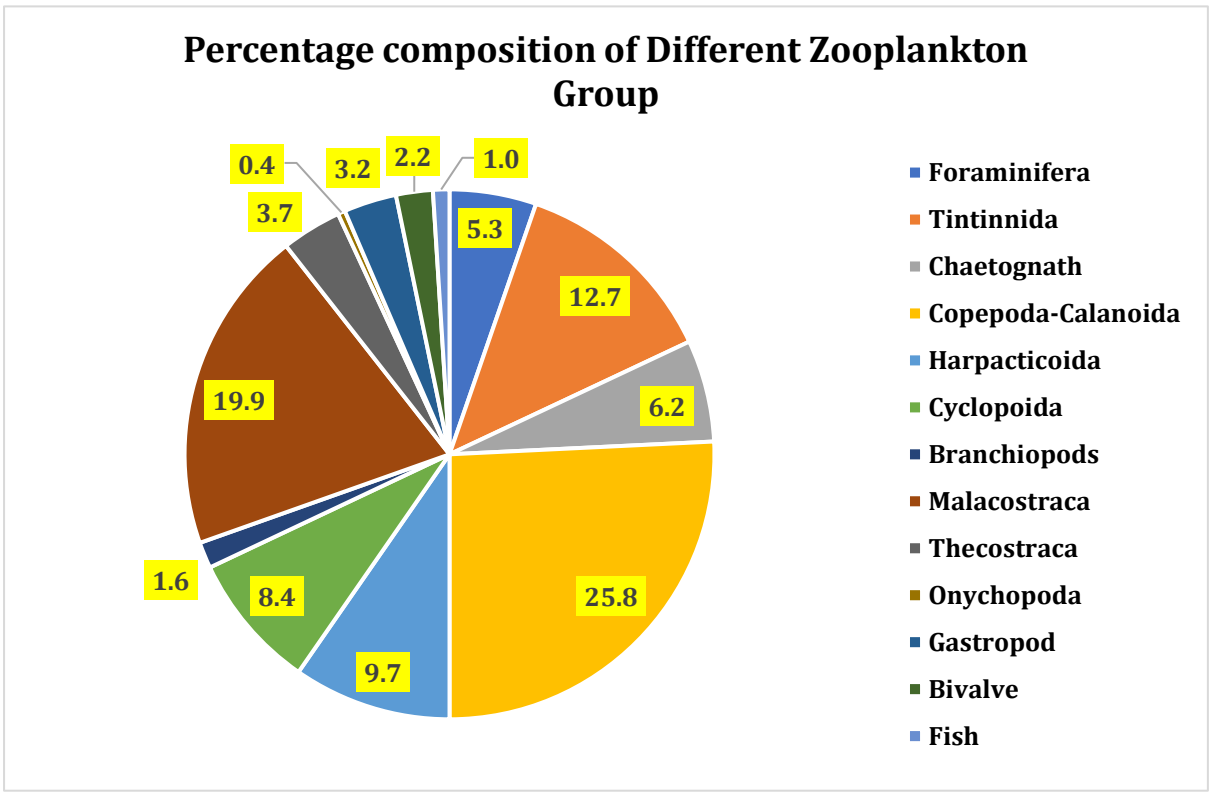


Figure 11: Percentage composition of zooplankton during Monsoon 2024

Percentage occurrence of zooplankton

The percentage occurrence of zooplankton communities(genera) varied from 33% to 100 %. There were 12 zooplankton genera that exhibited 100% of occurrence (Fig.12) followed by the *Euterpina*, *Oithona* and *Oncaea* (93%)and *Calanopia, Nannocalanus* (87%) from the study sites (Table5).

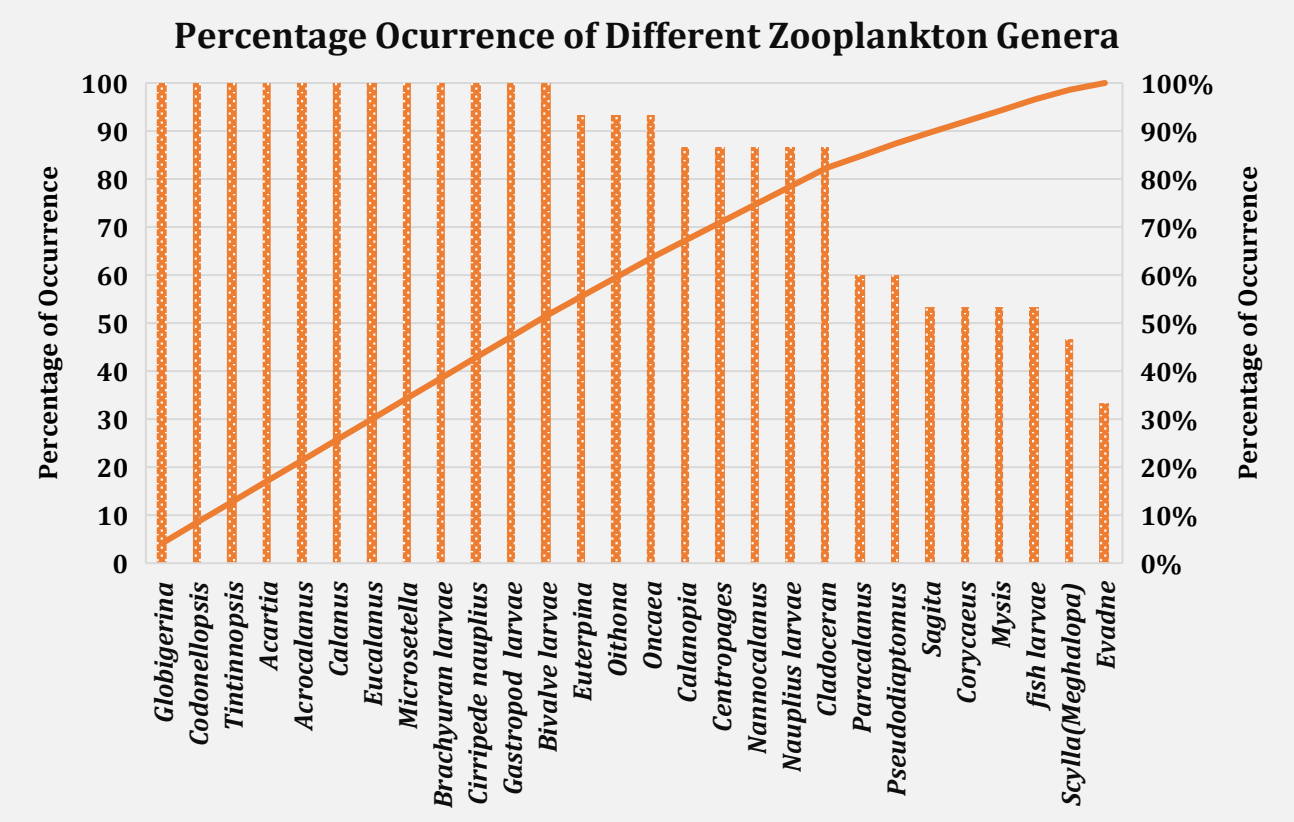


Figure 12: Percentage occurrence of Zooplankton groups during Monsoon 2024

Density of zooplankton

Zooplankton population density v during the Monsoon 2024 at the 15 sampling sites ranged from 8,400 No/L to14,420No/L with an overall average of 10,491No/ L (Table 5). Station-wise, the highest density of 14,420 No/ L was recorded in S-1 followed by S-6 (12,320 No/ L) and lowest density was reported at S-11 (8,400 No/ L) (Figure 13).

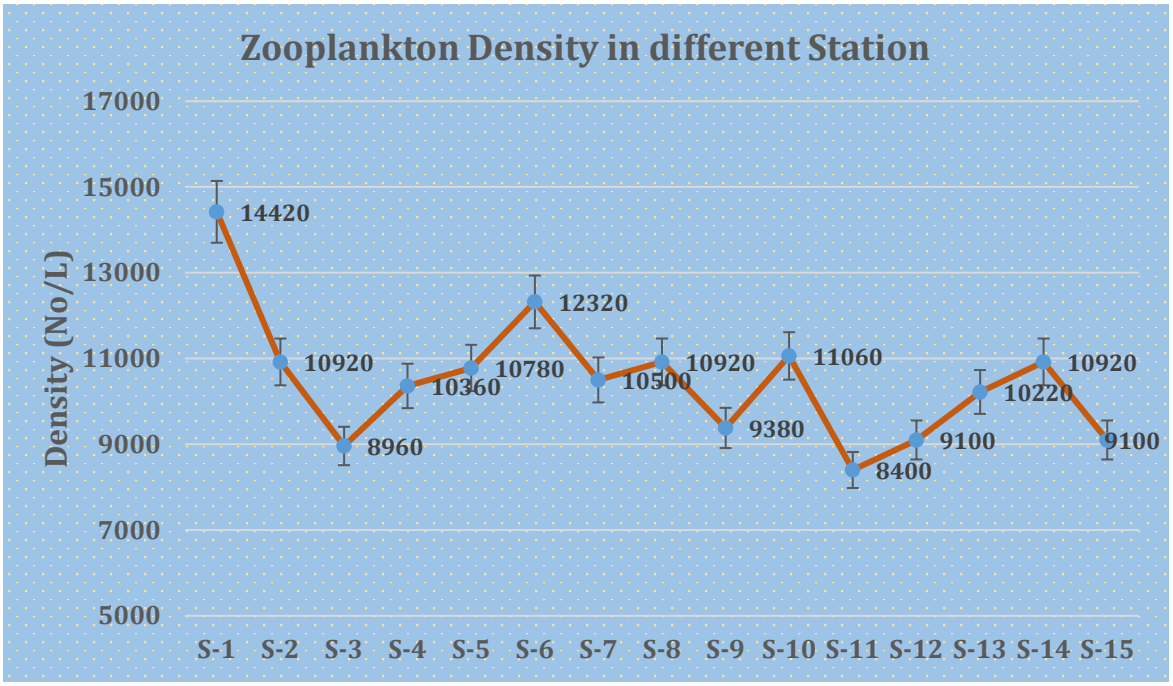


Figure 13: Zooplankton Density in the different stations during Monsoon 2024

Diversity Index

The Shannon diversity index of the zooplankton ranged between 2.44 to 3.01. Similarly, Margalef and Menhinick species richness index also varied from 2.60 to 1.97 and 0.20 to 0.26 respectively representing the moderate quality of the environment. (fig.14).

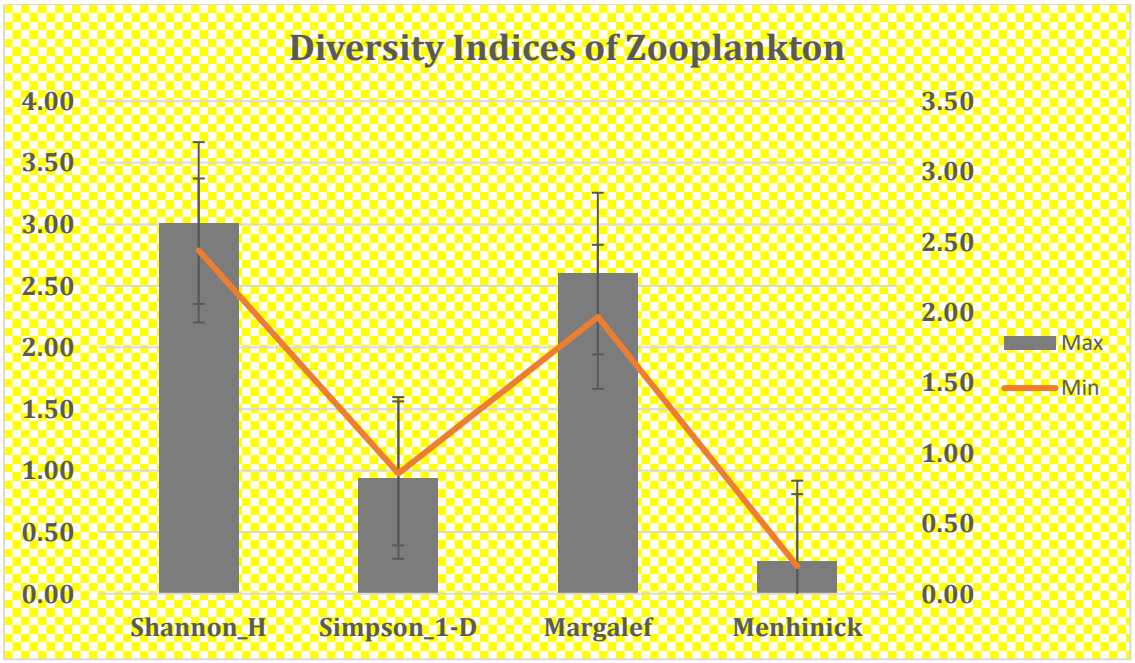


Figure 14: Zooplankton Density indices Monsoon 2024

Table 5: Zooplankton generic status during Monsoon 2024 in Deendayal Port Authority area

Groups	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
Foraminifera	Globigerina	980	1120	280	420	560	800	420	1120	420	700	420	280	420	280	140	5.31	100
Tintinnida	Codonellopsis	420	700	980	420	560	480	280	700	420	280	420	560	980	840	420	5.38	100
	Tintinnopsis	1120	420	700	980	420	800	560	420	1120	420	140	1400	420	1260	980	7.09	100
Chaetognath	Sagita	2800	0	980	1680	2100	1280	700	140	0	0	140	0	0	0	0	6.24	53
Copepoda-Calanoida	Acartia	280	420	140	280	140	640	280	140	140	420	560	280	140	420	560	3.08	100
	Acrocalanus	420	560	280	560	700	480	280	140	420	140	280	560	420	280	140	3.60	100
	Calanopia	420	280	0	280	0	320	140	420	280	420	280	700	980	280	420	3.32	87
	Calanus	700	420	980	420	560	800	420	280	140	420	280	140	420	280	140	4.07	100
	Centropages	420	280	0	140	420	320	420	280	0	140	420	280	560	420	140	2.69	87
	Eucalanus	700	420	280	140	280	960	700	980	420	560	420	280	420	280	560	4.70	100
	Nannocalanus	140	280	560	280	420	160	140	0	0	140	140	280	420	280	140	2.15	87
	Paracalanus	0	140	280	0	0	0	140	140	0	140	280	140	0	140	280	1.07	60
	Pseudodiaptomus	280	140	0	280	0	160	140	0	140	280	0	0	140	0	280	1.17	60
Harpacticoida	Corycaeus	0	0	420	0	0	320	0	420	560	0	0	140	700	280	420	2.07	53
	Euterpina	560	280	420	560	280	480	560	280	420	980	0	140	140	280	420	3.69	93
	Microsetella	840	980	420	420	280	160	420	280	140	280	420	560	280	420	280	3.93	100
Cyclopoida	Oithona	280	0	140	280	420	160	420	700	560	280	420	140	420	280	140	2.95	93
	Oncaea	280	420	140	140	420	320	140	140	0	280	140	140	280	420	140	2.16	93
	Nauplius larvae	140	0	140	280	420	320	140	280	140	0	140	140	280	140	140	1.72	87
	Mysis	140	0	140	0	140	160	140	0	0	0	140	280	140	0	0	0.81	53
	Scylla(Meghalopa	280	140	140	140	0	0	0	140	0	0	140	0	140	0	0	0.71	47
Branchiopods	Cladoceran	280	140	280	140	140	0	280	140	140	280	140	0	280	140	140	1.60	87
Malacostraca	Brachyuran larva	1680	2940	420	1260	1680	1760	2380	2940	3080	3780	1820	1540	1260	2660	2100	19.89	100
Thecostraca	Cirripede naupliu	420	280	560	420	280	480	560	280	420	280	700	420	280	280	140	3.69	100
Onychopoda	Evadne	0	0	0	140	0	0	140	0	0	140	140	0	0	140	0	0.44	33
Gastropod	Gastropod larvae	280	280	140	280	420	320	280	420	280	420	280	420	280	560	420	3.23	100
Bivalve	Bivalve larvae	420	280	140	280	140	320	420	140	140	140	0	280	140	420	280	2.25	100
Fish	fish larvae	140	0	0	140	0	320	0	0	0	140	140	0	280	140	280	1.00	53
Total Density (No/L)		**14420**	**10920**	**8960**	**10360**	**10780**	**12320**	**10500**	**10920**	**9380**	**11060**	**8400**	**9100**	**10220**	**10920**	**9100**		
Total Genera		**25**	**21**	**23**	**25**	**21**	**24**	**25**	**24**	**19**	**23**	**24**	**22**	**25**	**24**	**24**		

PC:

Percentage of Composition PO: Percentage of Occurrence

3.6. Intertidal Fauna

The intertidal zone, the interface between terrestrial and marine environments, represents one of the most dynamic and ecologically multifaceted ecosystems. Globally, the increasing utilization of the littoral zone for several developmental projects and human activities have contributed increasing level of habitat transformation and consequently degradation of this fragile ecosystem. Such degradation is manifested in the rapid loss of biodiversity, which poses a significant threat to the ecosystem's products and services (Liang et al 2024).

The intertidal zone is often referred as the littoral zone is the area where the land is submerged temporarily due to the tidal water inundation, and where the benthic region of the ocean begins and below this zone is the sublittoral (shelf) zone, extending from the low tide mark to the shelf break, is permanently submerged. The Intertidal zone can include rocky ledges, sandy beaches, mudflats, salt marshes, and mangrove swamps and the benthic region has a variety of physical conditions, including depth, light penetration, and pressure. The intertidal zone is a marine habitat that experiences extreme and rapidly changing environmental conditions such as water Temperature, salinity, tidal amplitude, turbidity, along with substratum composition and organic matter and carbon content and the vegetation characteristics which are very much correlated with the fauna population density and distribution along the intertidal zone.

Faunal composition of intertidal macrobenthos

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 (4species). The phylum Chordata was represented by one species (Table 6& Fig.15).Among the station the intertidal genera varied from 4 to 9 number higher number of genera recorded at S-6, S-10 and S-13 (9) and least number of genera recoded at S-15 .

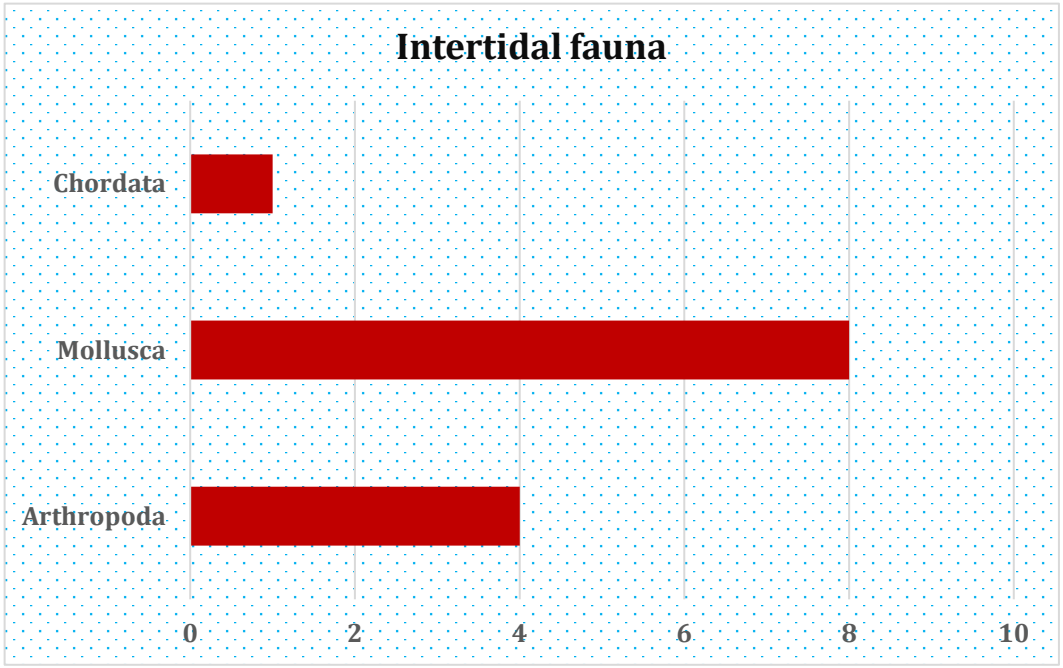


Figure 15: Number of genera of intertidal fauna during in Monsoon 2024

Percentage composition of Intertidal Fauna

The overall percentage composition of the three groups of intertidal fauna at the 15 station ie Arthropoda (67.09%), Mollusca (22.11%), and Chordata (10.8%), as shown in figure 16&17. The cumulative percentage of intertidal fauna varied from 0.1% to 23.5%.

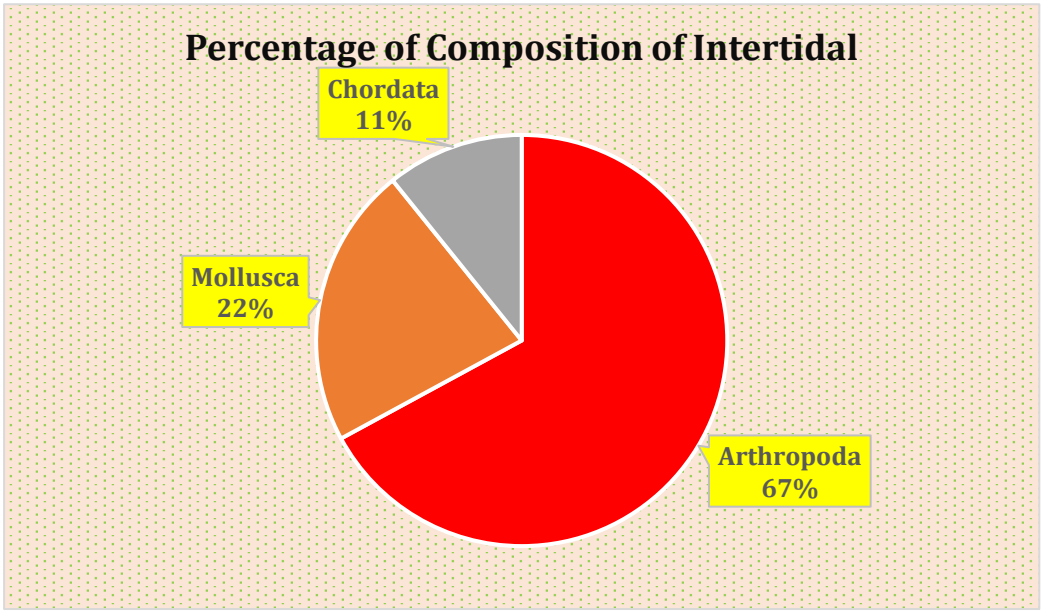


Figure 16: Percentage composition of intertidal fauna during Monsoon 2024

Highest percentage of organism contributed by *Austruca iranica* followed by *Austruca variegata* and least number of organism contributed by *Indothais lacera* , *Optediceros breviculum*.

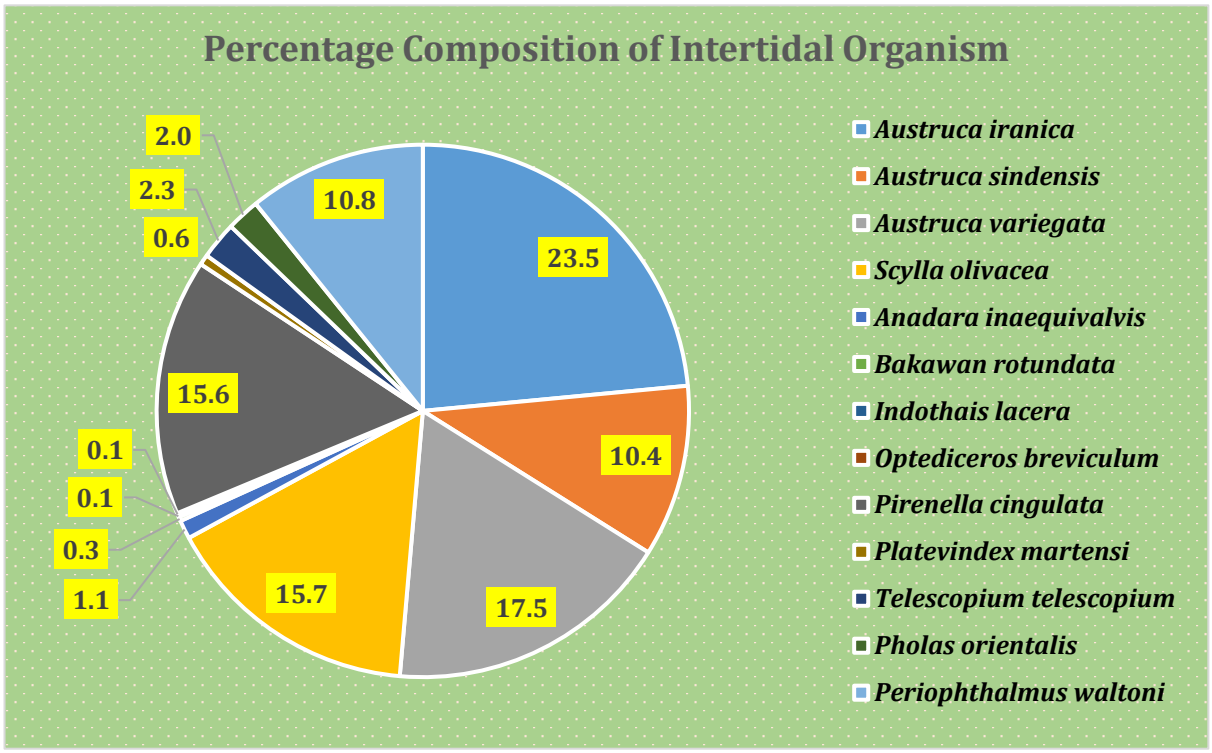


Figure 17: Cumulative % composition of intertidal fauna during Monsoon 2024

Intertidal Fauna density (No/m²)

The number of individuals of the fauna collected from the intertidal zone of the mangroves are presented in Fig 17. It was observed that the faunal density was the highest at S- 2 and the least from S-11.

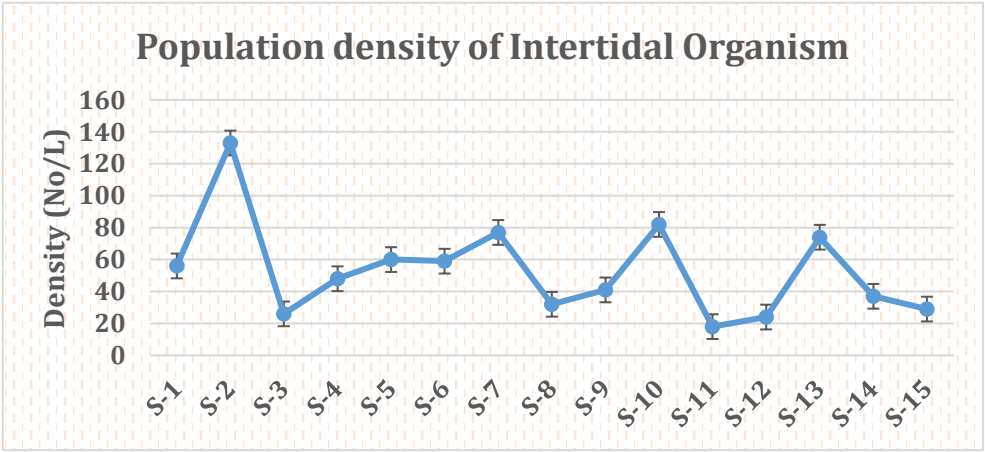


Figure 18: Density of intertidal fauna during Monsoon 2024

The Intertidal faunal diversity documented during the monsoon period of 2024 has shown that the highest number of animals were collected from S-2, and the lowest was from S-11. The most common species are the crustaceans such as *Austruca iranica* and Austruca variegata and among the Mollusca *Pirenella cingulata* (Table.5) and figure 17 represents the various diversity indices calculated for the different fauna recorded from the 15 sites adjoining the DPA port area as presented in figure 19.

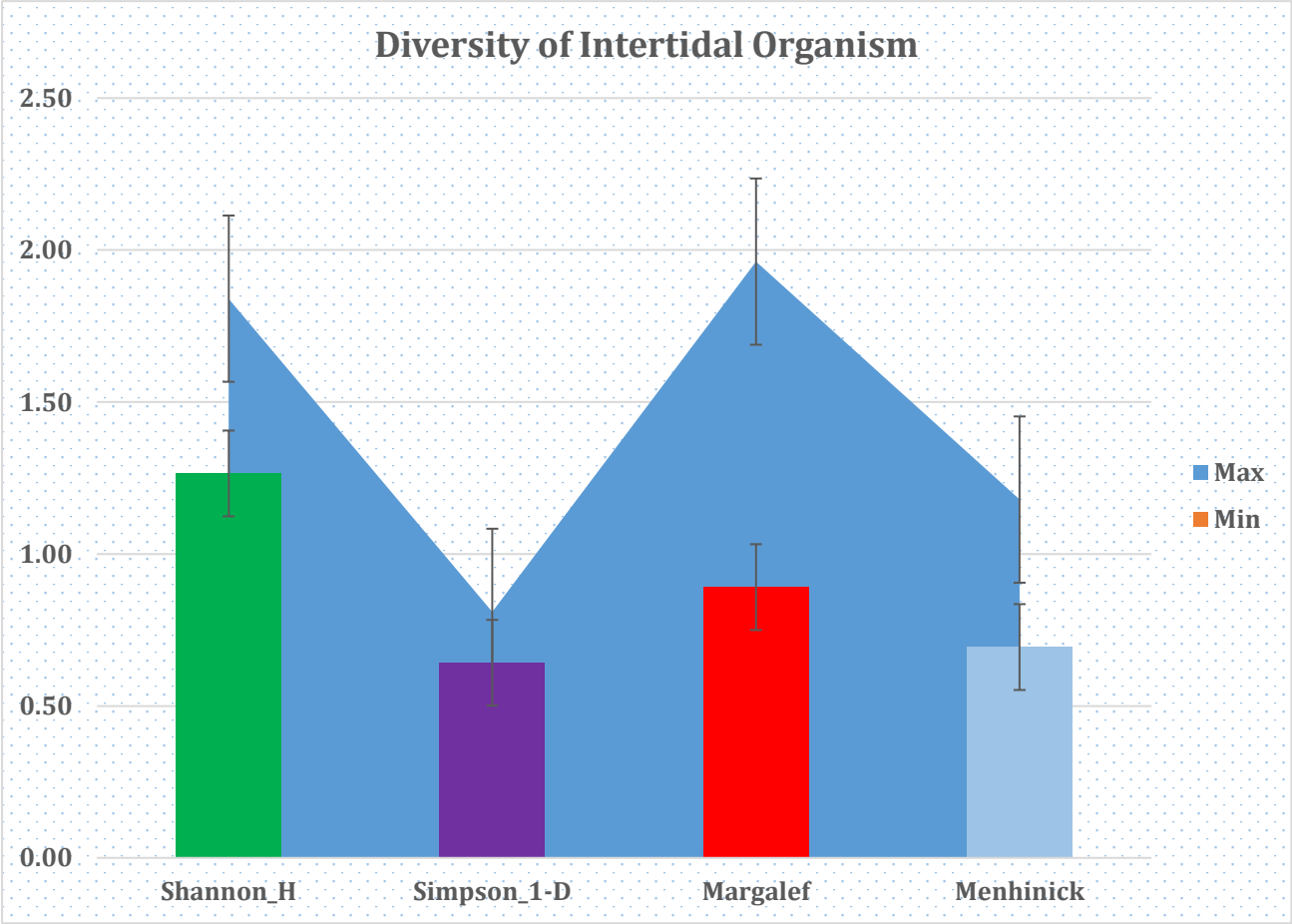


Figure 19. Diversity indices of Intertidal fauna

The maximum and minimum diversity is represent 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). The intertidal diversity of organisn represent in poor conditions.

Table 6: Intertidal faunal distribution along Deendayal Port Authority area during Monsoon 2024

Phyla	Grpup	Station															
		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
Arthropoda	*Austruca iranica*	21	25	14	20	27	18	10	10	12	10	2	6	2	5	5	23.49
	Austruca sindensis	0	3	0	0	3	6	6	5	12	4	10	6	7	17	4	10.43
	Austruca variegata	12	42	2	7	10	12	10	10	10	3	2	2	5	2	10	17.46
	Scylla olivacea	5	25	2	10	5	10	10	3	3	30	2	0	2	8	10	15.70
Mollusca	*Anadara inaequivalvis*	0	0	2	1	0	2	0	0	0	2	0	0	2	0	0	1.13
	Bakawan rotundata	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25
	Indothais lacera	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0.13
	Optediceros breviculum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13
	Pirenella cingulata	15	35	5	0	0	0	29	0	0	0	0	0	40	0	0	15.58
	Platevindex martensi	0	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0.63
	Telescopium telescopium	0	1	0	0	1	1	2	0	0	7	0	0	6	0	0	2.26
	Pholas orientalis	0	1	1	0	4	2	0	2	2	2	0	0	2	0	0	2.01
Chordata	*Periophthalmus waltoni*	0	0	0	10	10	7	10	2	2	20	2	10	8	5	0	10.80
Total Density of population (No/m2)		**56**	**133**	**26**	**48**	**60**	**59**	**77**	**32**	**41**	**82**	**18**	**24**	**74**	**37**	**29**	
Total genera		**5**	**8**	**6**	**5**	**7**	**9**	**7**	**6**	**6**	**9**	**5**	**4**	**9**	**5**	**4**	

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. Benthic fauna is an important component of marine ecosystems, providing key services including secondary production and remineralization. Being sedentary or having only limited mobility, benthic communities are particularly vulnerable to variations in environmental and ecological factors. As a result, they exhibit distinct spatial and temporal distribution patterns on small and large scales. Coastal areas are naturally highly dynamic, with several distinct habitat types coexisting nearby (e.g., estuaries and intertidal habitats) and supporting high biodiversity (Cowie and Woulds,2011) . The abiotic factors structuring benthic communities include salinity, temperature, sediment characteristics, and oxygen availability, however, their relative importance varies among the different habitats. On a fine scale, biotic factors such as competition for food and space, predation, reproductive strategies, and life-history traits influence the distribution and abundance of individual species, in turn determining community structure. Moreover, coastal habitats are also the most impacted by anthropogenic pressures, from climate change-related warming and acidification to habitat degradation and pollution. Benthic fauna, through their diverse feeding modes and lifestyles, not only are affected by conditions in the sediment environment, but also actively influence sediment textural and geochemical properties, the flow regime of bottom waters, and, through exchange of particles and solutes between water and sediments, also regulate properties in overlying waters (Meysman et al., 2006)

All marine sediments are anoxic below a certain depth from the sediment surface and, consequently, sulphidic sediments have a worldwide distribution. Organic sediment enrichment occurs through vertical and advective accumulation of organic carbon from the decomposition of the organic matter . On bottoms where accumulation of organic matter happens and leading to the reduction of oxygen at low concenlration. The oxygen deficiency may very well be the most widespread anthropogenically induced delelerious effect in me marine environment that causes localized mortality of benthic macrofauna. Also there is a complicated interplay between oxygen concentration and sediment geochemistry that regulates the response of organisms to declining dissolved oxygen

concentrations. The physio-biochemical system of estuary is regulated by benthic faunal through burrowing and feeding activities. Benthic communities are the useful tools for biomonitoring and gathering large amount of data in relation to coastal marine health of marine ecosystem. It is important to identify which are the primary causal factors for degradation of coastal ecosystem for design the proper management system at the coastal region..

Distribution and composition of subtidal macrobenthos

The number of macro benthic species of the various groups recorded (Fig.20) & Table 6 from the DPA port environment includes Mollusca (10) and Annelida (4) Arthropoda (2). The percentage composition of the three phyla that occurred during the monsoon is shown in (Fig 20 & table 6) The phylum Mollusca is represented by maximum (65%) share of the subtidal Fauna, followed by Annelida (25.5%), Arthropoda (9.8%) in the total benthic samples collected (Fig.21).

Subtidal Faunal density (No/m^2) variation between the stations

The number of individuals of the animals collected from the different sites are shown in Fig 22. The density of the Fauna was high at S-14 (700/m^2), and the lowest number (175/m^2) was noticed at S-9 during the monsoon 2024.

Diversity index

The figure 22 represent the subtidal microbenthic faunal diversity documented in the monsoon 2024. The highest number of species diversity was documented from stations S-14, S-9, S-3 and S-13. The most common species are *Optediceros breviculum, Glauconome angulata and Pirenella cingulata.* The least diversity was documented for *Solen* sp were found significantly less diversity. The figure 24 represents the various diversity indices calculated for the different fauna recorded from the 15 sites adjoining the DPA port area. Invariabily the minimum and maximum index values of the three indices were observed at S-8&9 and S 14 respectively. Shannon diversity index varied , from 1.00 to 2.00 Simpson index ranged between 0.56 and 0.85 and the Margalef index ranged from 1.03 and 3.30**.**

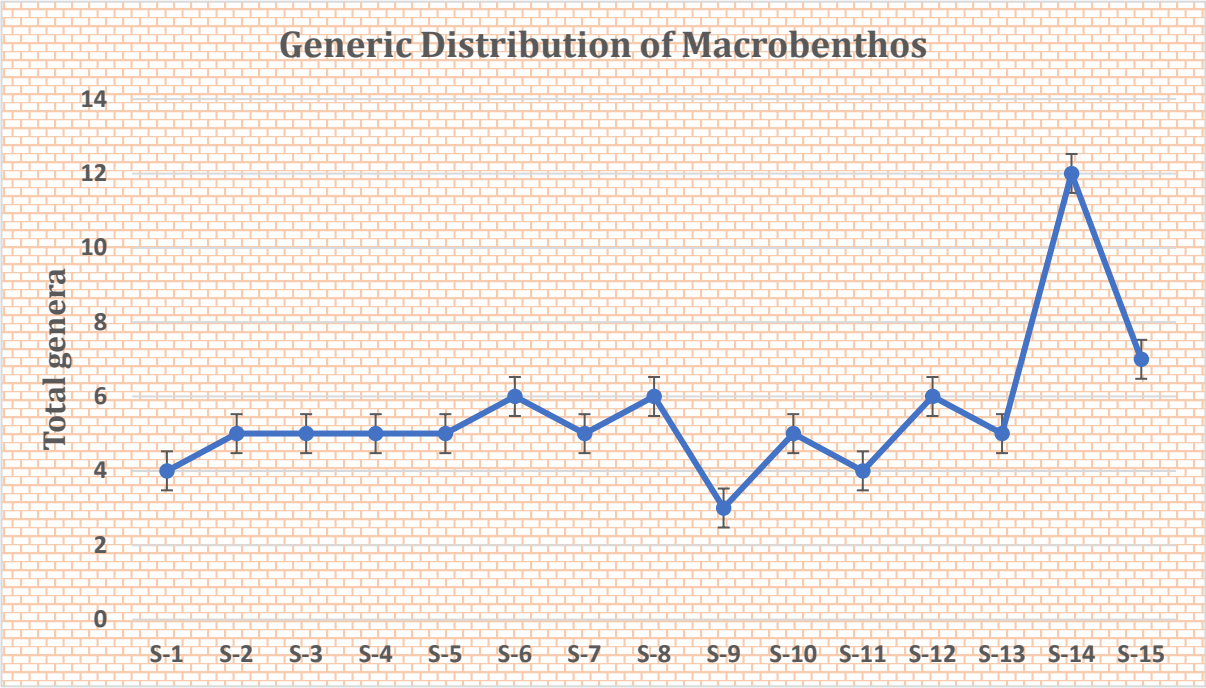


Figure 20. Number of genera of macrobenthos during Monsoon 2024

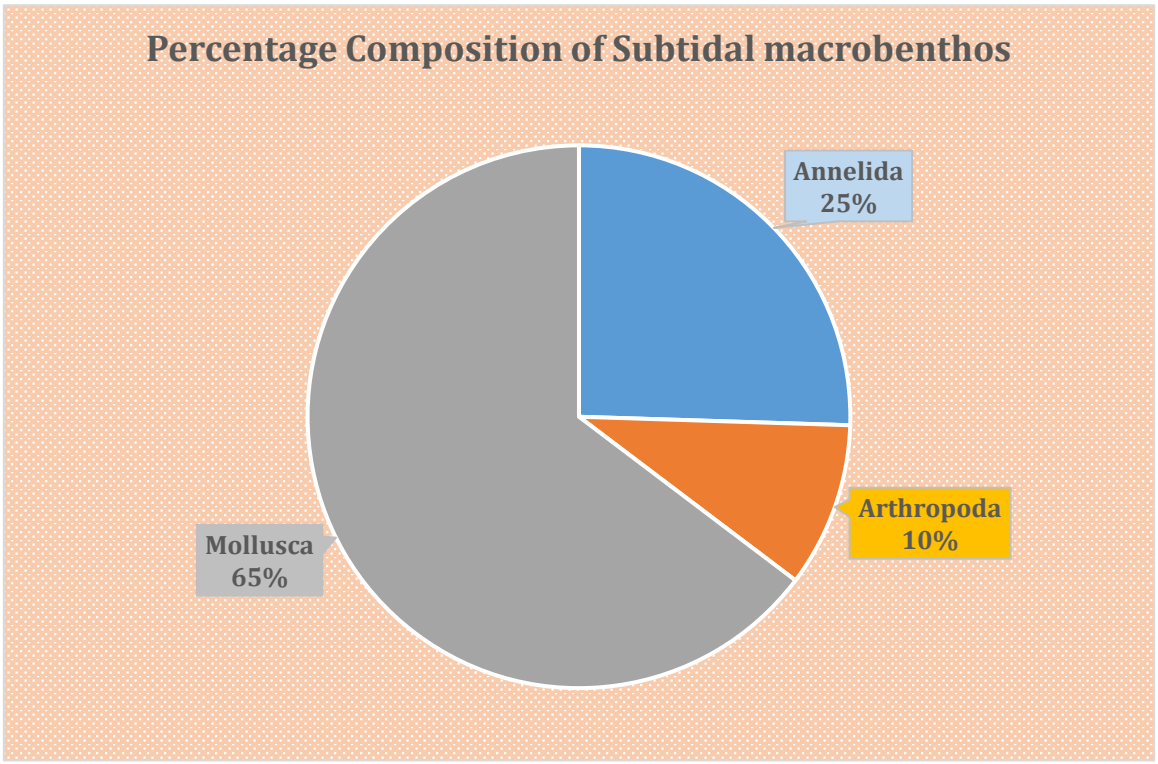


Figure 21. Percentage composition of macrobenthos during Monsoon 2024

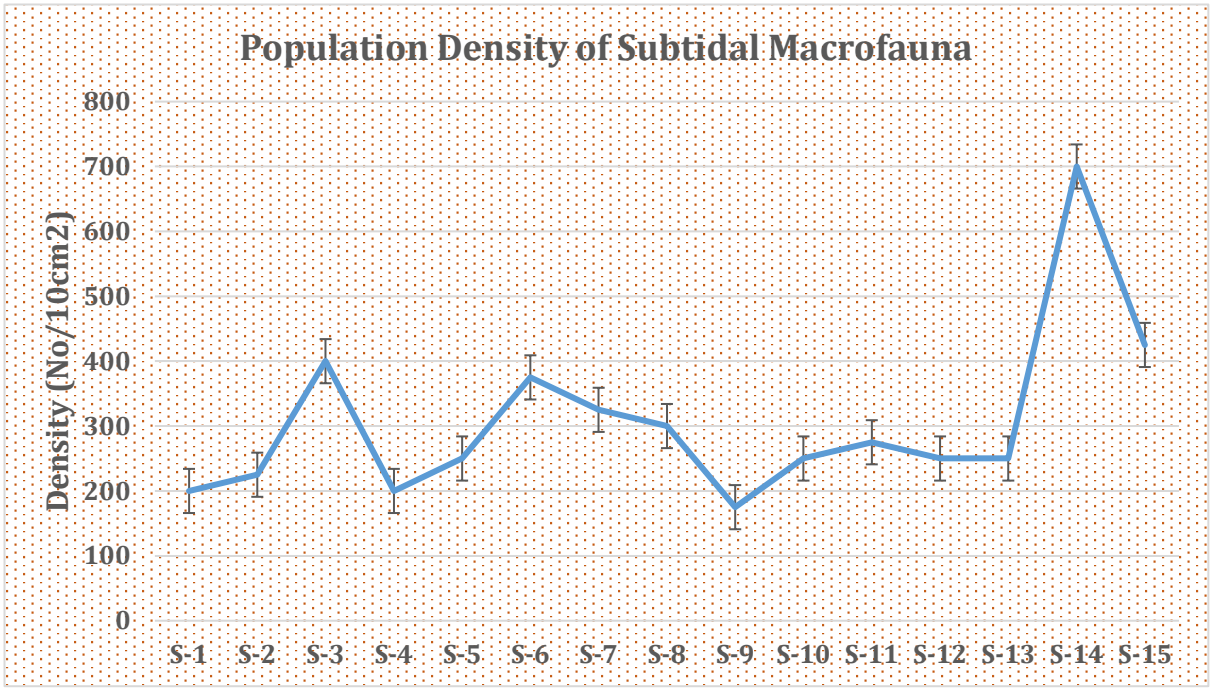


Figure 22. Subtidal fauna density during Monsoon 2024

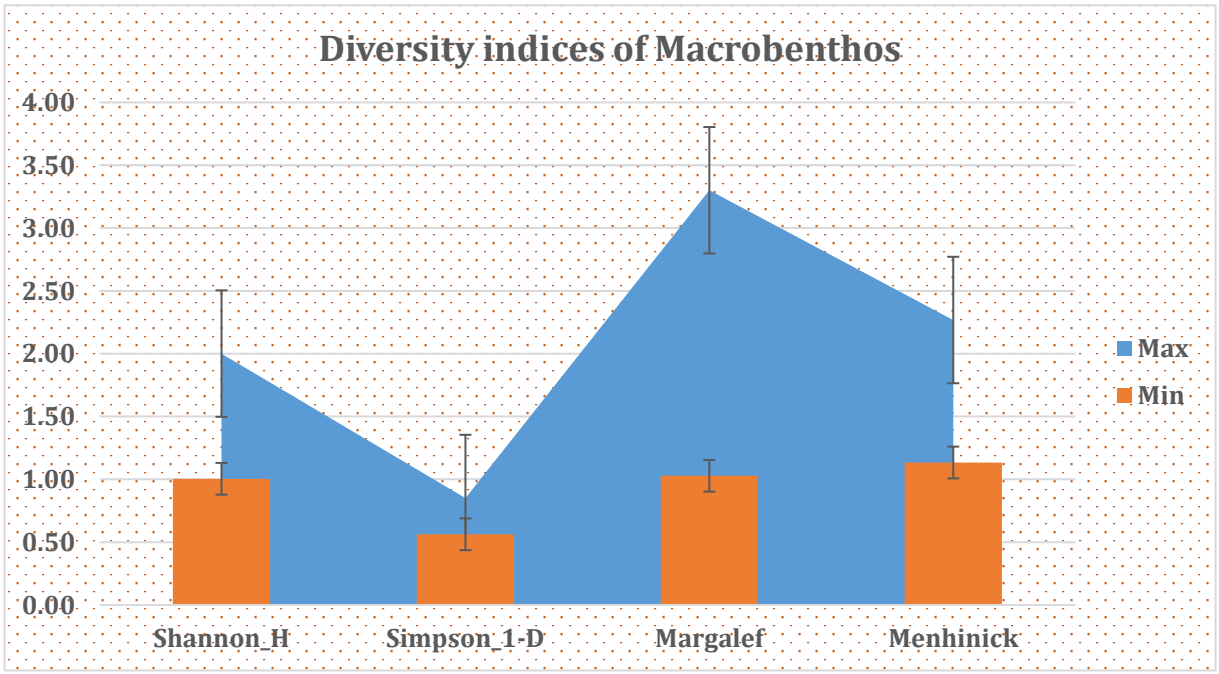


Figure 23. Subtidal macrofaunal diversity indices

Table 7: Macro-benthic faunal distribution during Monsoon 2024 in Deendayal Port Authority

Phyla	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
Annelida	*Capitella sp.*	0	1	0	0	3	0	0	0	1	0	3	1	0	1	0	5.4
	Lumbrineries sp.	1	0	4	0	0	0	1	0	0	2	0	2	2	0	2	7.6
	Nephtys sp.	1	0	2	0	0	0	0	2	3	0	0	0	0	1	0	4.9
	Nereis sp.	0	3	1	0	0	1	0	0	0	1	4	0	1	0	3	7.6
Arthropoda	*Ampithoe sp.*	0	0	0	0	2	0	0	1	0	0	0	2	0	2	0	3.8
	Penaeus sp.	0	2	0	0	1	1	0	0	0	0	2	0	2	0	3	6.0
Mollusca	*Mitrella blanda*	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	1.6
	Natica sp	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1.1
	Optediceros breviculum	1	0	0	2	2	2	3	2	0	0	0	0	0	1	3	8.7
	Pirenella cingulata	5	0	0	0	0	2	1	2	3	1	0	2	3	12	2	17.9
	Turritella sp	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1.1
	Marcia sp.	0	0	0	2	0	1	2	3	0	0	0	1	2	1	2	7.6
	Glauconome angulata	0	2	7	1	2	8	6	2	0	6	0	2	0	0	0	19.6
	Dosinia sp	0	0	2	2	0	0	0	0	0	0	0	0	0	3	0	3.8
	Gafrarium divaricatum	0	1	0	0	0	0	0	0	0	0	0	0	0	2	2	2.7
	Solen sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.5
Total Population		8	9	16	8	10	15	13	12	7	10	11	10	10	28	17	
Density No/m2		**200**	**225**	**400**	**200**	**250**	**375**	**325**	**300**	**175**	**250**	**275**	**250**	**250**	**700**	**425**	
Total genera		4	5	5	5	5	6	5	6	3	5	4	6	5	12	7	

8. Seaweeds

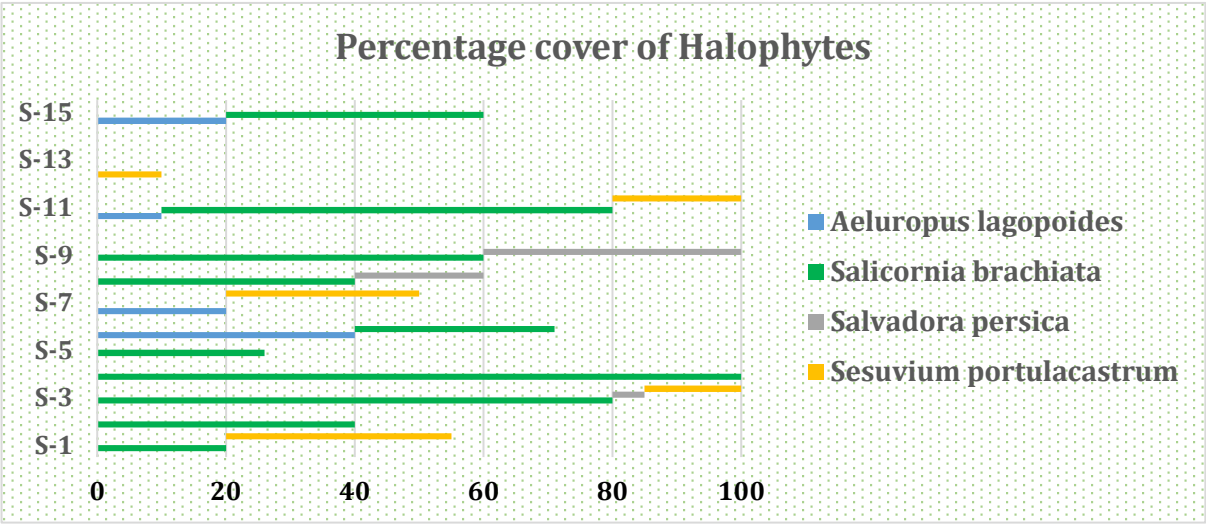
There is no observation of seaweed during the study period

3.9. Seagrass

Similar to seaweed seagrass also not encounter during present observation

3.10. Halophytes

The halophytes are the plants that are adapted to live in coastal estuaries and salt marshes. It is common in arid and desert milieu which often have substantial salt accumulation. Technically these are the plants which have tolerance to moderate to high salt concentration in its growth substrate. Halophytes, that survive and reproduce in environments where the salt concentration is 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, *Salicornia brachiata* (a), *Aeluropus lagopoides* (c), *Salvadora persica* (d) and *Sesuvium portulacastrum*(b) (Plate-7) were recorded along the selected Deendayal Port Authority sites during the monsoon sampling. Among the halophyte species recorded, *Salicornia brachiata* alone was found at ten sampling locations. (Fig.24) and the percentage of cover was found to be the highest at S-4 (100%) and the lowest at S-2 &S-8(40%).



Fifure24.Halophytes diversity of Deendayal Port Authority

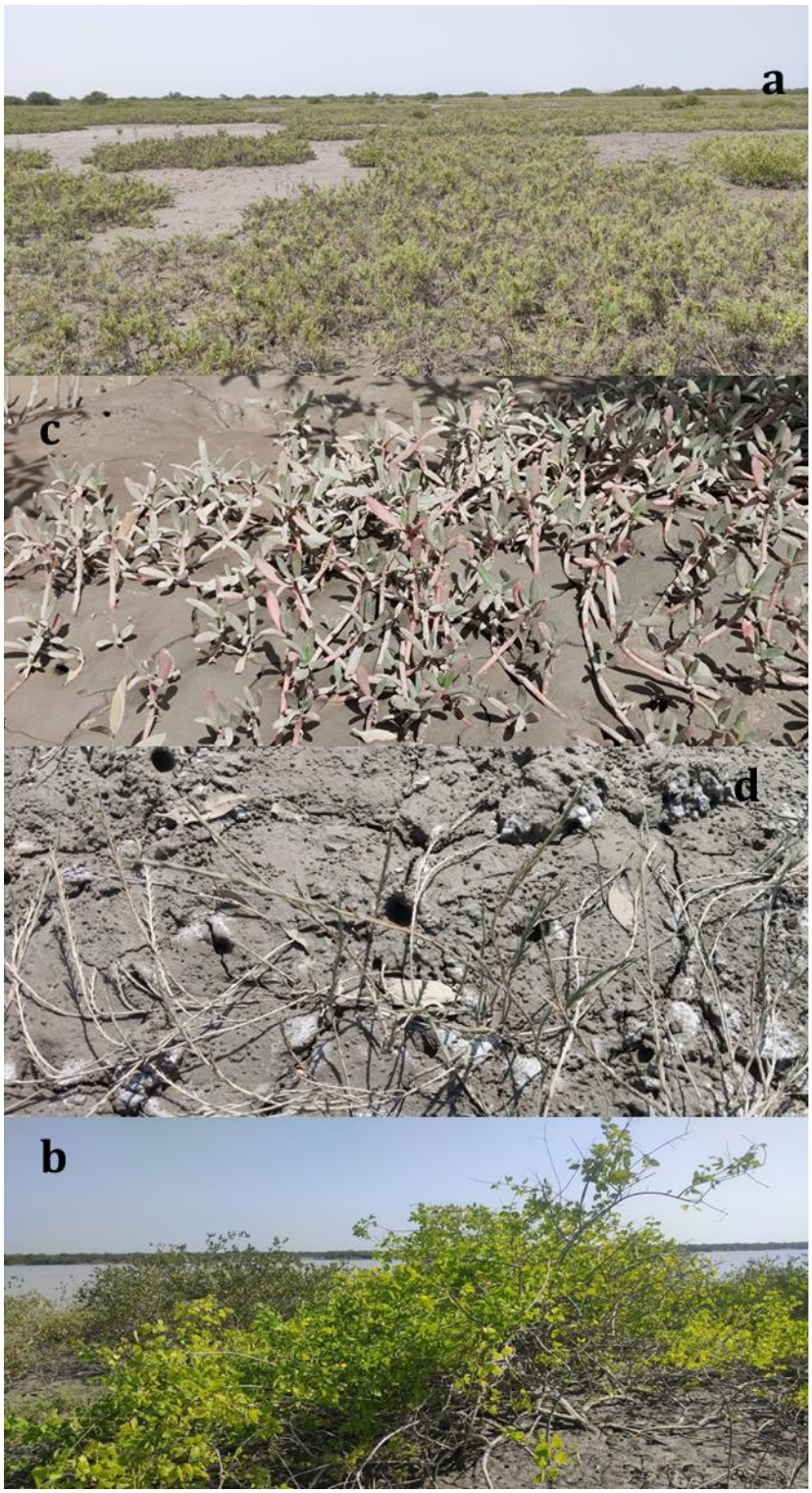


Plate 7. Halophyte species on the intertidal zone of Deendayal Port Authority area

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

3.11. Mangroves

Mangroves in Gujarat are distributed across four main regions: Kachchh, Gulf of Kachchh, Saurashtra, Gulf of Khambhat including South Gujarat. Kachchh and Gulf of Kachchh have the largest mangrove forests, which are meticulously studied and documented by the Gujarat Institute of Desert Ecology (GUIDE). The GUIDE research reveals the unique vegetation characteristics, species composition, ecological importance, and conservation status of these crucial coastal ecosystems. Mangroves serve as critical habitats for a wide variety of marine and terrestrial species, playing a significant role in coastal protection, biodiversity conservation, and local livelihoods. The efforts to study and conserve these ecosystems highlight their importance and the need for sustainable management

Tree Density

During the 2024 monsoon, 15 mangrove sites were selected in and around the Deendayal port Authority to undertake assessment on plant density and growth parameters such as height, girth, and canopy cover. The overall average tree density from the study sites along the DPA, was recorded as 2,189 trees/ha during the monsoon of 2024. However, the area under mangrove cover is shrinking due to increase in the anthropogenic activities such as salt pan formation and other developmental interferences. Among the 15 sampling locations, Tuna Creek had the highest mean plant density with 2535 trees/ha, followed by Kharo Creek with 2486 trees/ha. However, in Kharo creek only one station is located. Regarding individual sample locations, the S-6 had the highest tree density (3,673 trees/ha), followed by S-1 (3,522 trees/ha). The S-15 (1,027 trees/Ha) and S-11 (1,221 trees/Ha) had the lowest average tree density. The varying status of the mangroves across different locations (as illustrated in Fig. 25) reflect the seasonal changes in the local geomorphology as well as the distinct biological and environmental characteristics of each site.

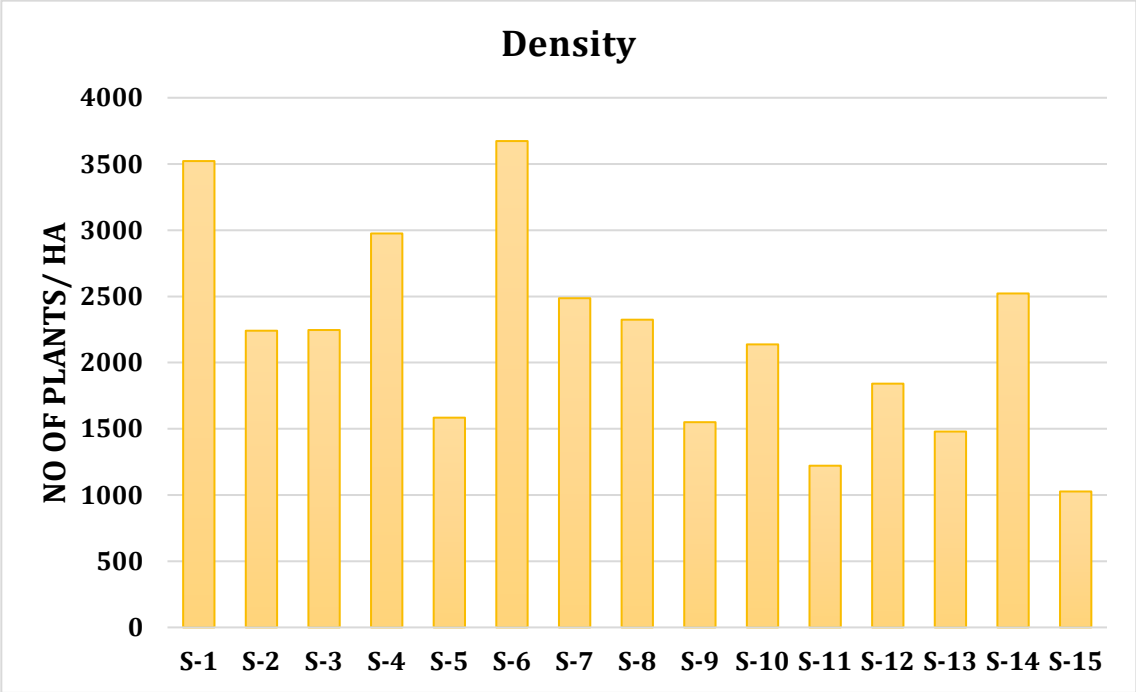


Figure 25. Plant density during monsoon 2024

Height

The overall mean height of the mangroves from the DPA, Kandla environment was 1.8 m during the monsoon of 2024. The highest average tree height was 2 m, recorded at Veera coast area followed by Tuna and Phang creek (1.8 m). In Veera area, only one station (S-14) is located. While considering the sites individually, the average tree height was 2.4 m at S-10 located at Phang creek, followed by site S-12 (2.3 m) located at Tuna creek (Fig.26). During the study, it was observed that the average tree height at several sites varied between 1.3 m and 2.4 m. Height is a crucial factor since it indicates whether trees are developing normally or exhibiting stunted growth. Height also contributes to the complexity of the habitat. Taller mangroves provide better protection against storm surges and high waves. They act as a buffer, reducing the energy of waves before they reach inland areas, thus protecting coastal communities from flooding and erosion. S

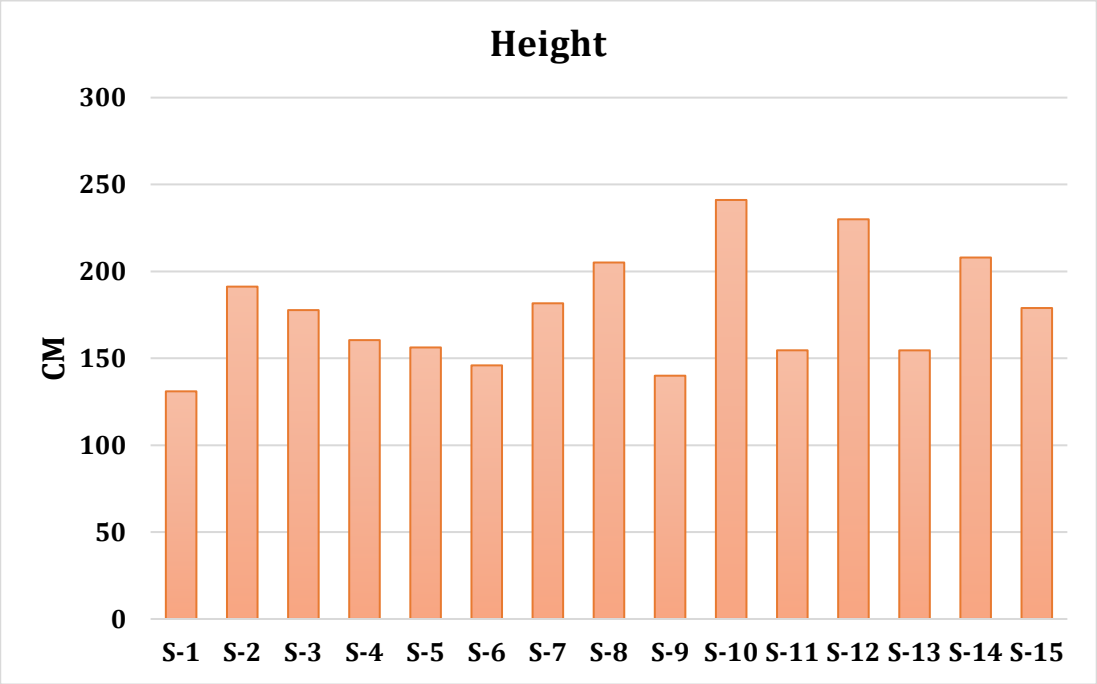


Figure 26. Plant height during monsoon 2024

Canopy Crown Cover

The survey conducted during the 2024 monsoon revealed that the average canopy cover across the mangrove study sites was 3.8 m^2. The figure 27 reflects the overall extent of the mangrove canopy, which plays a vital role in providing habitat for diverse species, stabilizing shorelines, and maintaining ecological balance. The station S-10 at Phang Creek and S-15 at Kandla Creek are noted for having higher average canopy covers compared to other locations. Navlakhi Creek had the highest average canopy cover at 5.2 m^2, followed by Phang Creek at 4.5 m^2, while, S-1 at Tuna Creek, and S-4 at Kandla Creek had comparatively lower average canopy cover. These variations in canopy cover across different sites in the Kandla sample region underscore significant differences influenced by local environmental and biological factors.

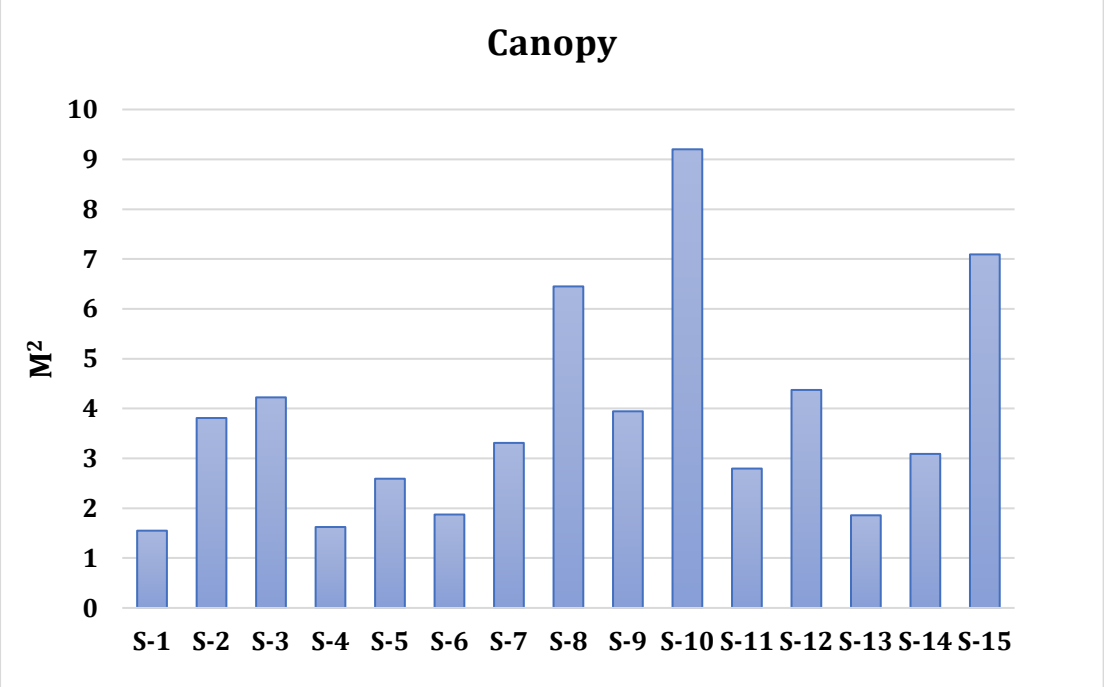


Figure 27. Mangrove canopy cover during monsoon 2024

Basal Girth

The average basal girth of the mangroves at the DPA sampling sites was reported to be 13 cm during the monsoon of 2024. Among the individual sampling sites, the highest average basal girth was recorded at site S-10 (22 cm) and site S-8 (18 cm), located in Phang Creek and Navlakhi Creek respectively (Fig.28). The lowest average basal girth was reported at site S-6 and S-9 (8 cm) in Janghi Creek and Navlakhi Creek, respectively. In the DPA Kandla area, as in other parts of Gujarat and the entire Gulf of Kutch, Avicennia marina is predominant, characterized by its multiple stem pattern. However, some larger trees in a few sites exhibit the higher basal girth measurements

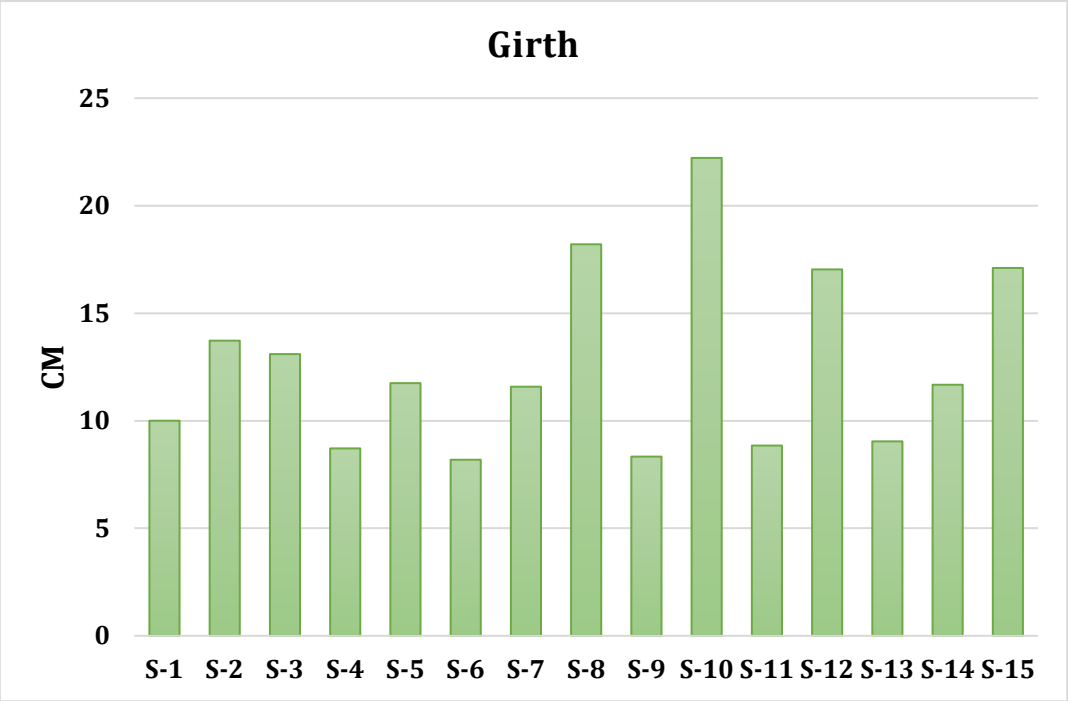


Figure 28. Basal girth of mangrove

Regeneration and recruitment class

The mangrove density and growth parameters were recorded during the survey conducted in the monsoon season of 2024 in the DPA Kandla area. The overall average regeneration class density was recorded as 29,692 plants/ha and the overall average recruitment class density was recorded as 5,308 plants/ha. In site-wise observations, the highest average regeneration class plants were recorded at site S-8 (73,000 plants/ha) which is followed by S-9 (52,000 plants/ha) both located along the Navlakhi creek area, For the recruitment class, the maximum plant density (average) was (11,750 plants/ha) at site S-7 located in the Kharo creek during this survey. Younger class mangroves can assure future availability of matured plants of full-grown trees in the area. Young mangroves help to stabilize soil and trap sediments, preventing coastal degradation and maintaining water quality. As they grow, these young plants will eventually contribute to the various ecosystem services and enhance the coastal protection offered by mature mangroves, shielding shorelines from erosion and storm surges.

Plate 8: Mangrove species recorded along the Deendayal Port area

a. Rhizophora mucronate b. Aegiceras corniculatum c. Ceriops tagal d. Avicennia marina

3.12. Marine Reptiles

The saw-scaled viper *Echis carinatus sochureki* normally encounter in while visit in mangrove survey but during the present observation in all the 15 study location there is no single encounter in study area. The literature describes the species as aggressive and strikes at a lightning speed, the observed specimen was active. In monsoon, the maximum number of this snake was recorded in S-10 located on the northern part of Sat Saida bet in previous record .

3.13. Marine Mammals

Sousa plumbea (Cuvier, 1829) is commonly referred to as the Indian Ocean humpback dolphin. 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). During the field surveys, the Indian Ocean humpback dolphin (Sousa plumbea) was not cited in monsoon season.

3.14. Marine Fishery

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 localitynear the Marine National Park, in Jamnagar, 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*, (Plate 9) the maximum during monsoon. Around 2kg of Mugil was catch in 10 minutes of in 1 km stretch.

Plate 9 Fish catch along the Deendayal Port Authority in monsoon 2024

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 bulk density (or apparent density) is defined as the density of a large volume of porous material powder including the pore spaces within the material particles in the measurement volume. The data on the bulk density of the sediment samples are presented in (Fig.29). The bulk density of mangrove soil at Deendayal Port Authority coastal region ranged from 1.30 g/cm^3 to 1.61 g/cm^3. The highest bulk density was recorded at S-13 sites followed by S-14. The lowest bulk density was recorded at S-5 located at Janghi creek.

Total Organic Carbon (TOC)

The highest TOC value (3.1%) was recorded at S-13 followed by S-1 and lowest TOC value was reported at site S-10 (Fig.30). 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 monsoon samplings revealed that the different sampling sites of Deendayal Port Authority jurisdiction have considerable variations with respect to organic carbon.

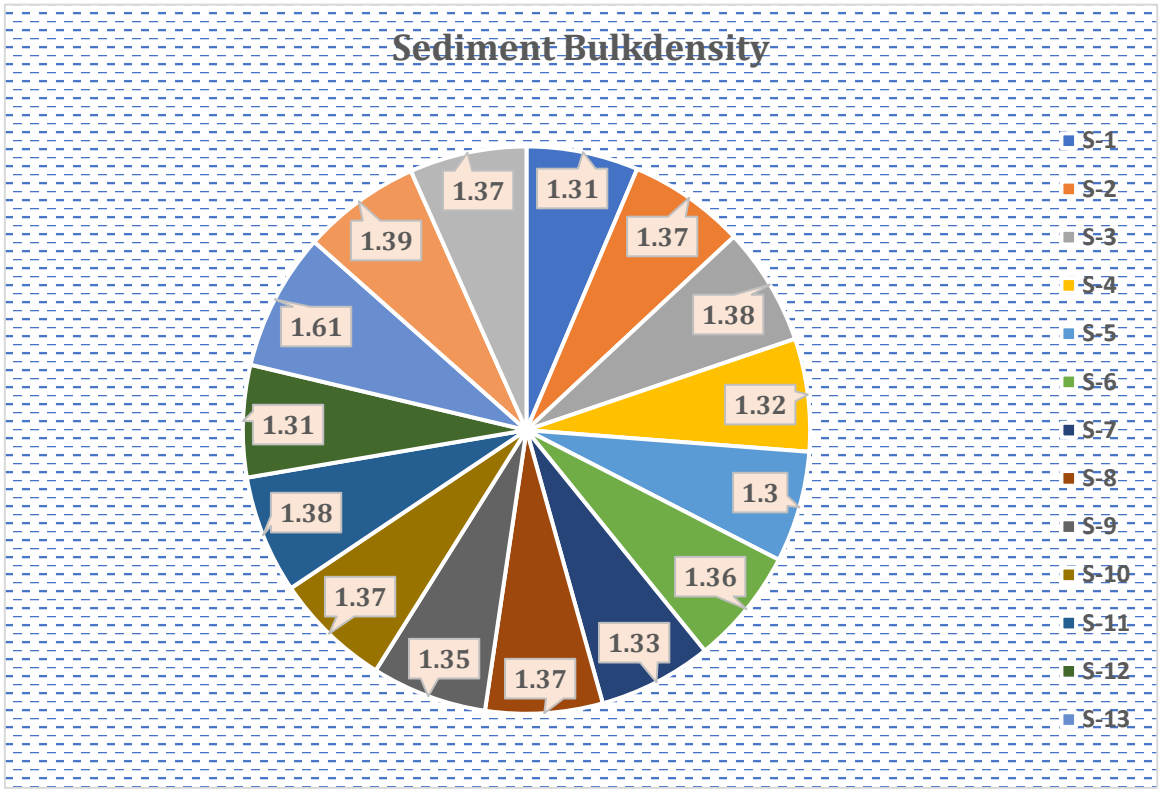


Figure 29: Bulk density of mudflat sediment during Monsoon 2024

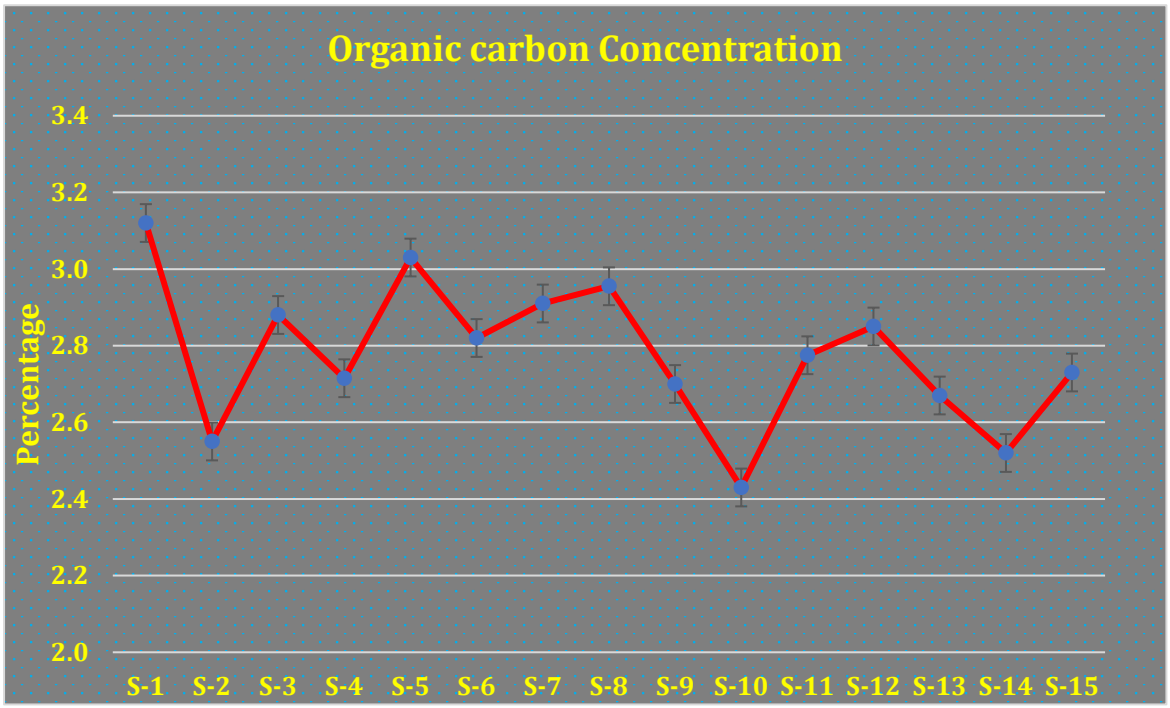


Figure 30: Mudflat sediment Organic Carbon during Monsoon 2024

5. Avifauna

Globally, avifauna has the highest level of diversity. Indian subcontinent comprehends around 1340 species of birds which contribute more than 15% of the world's bird species (Ali and Ripley 1987, Manakadan and Pittie 2001, Grimmett *et al.* 2011, Cox 2010). Thus, understanding the diversity and structure of bird communities to describe the importance of regional or local landscapes for avian conservation and assessment of avian diversity has become an important tool in biodiversity conservation (Safiq *et al.* 1997). The baseline data on diversity, distribution and species composition plays a significant role for identifying priority areas and formulating the species-specific conservation plan (Peterson *et al.* 2000, Colin 2000) and evaluate the habitat quality (Chettri *et al.* 2005, Manjunath and Joshi 2012). While, numerous bird species use their foraging ecology to sustain a trophic level, making birds another key animal group in an ecosystem. Scavenging carcasses, eliminating vermin and insect pests, cycling nutrients, dispersing seeds, pollination, and pest control are some of these services. As scavengers and possible pollinators, they have a functional role in the ecosystem and are appropriately referred to as bio-indicators (Bruford 2002, Gregory *et al.* 2003, Parmar *et al.* 2016, Maznikova *et al.* 2024). The aim of the present study was to understand the occurrence and distribution of avifauna in the coastal areas of the Deendayal Port Authority, Kandla, India (Fig. 31).

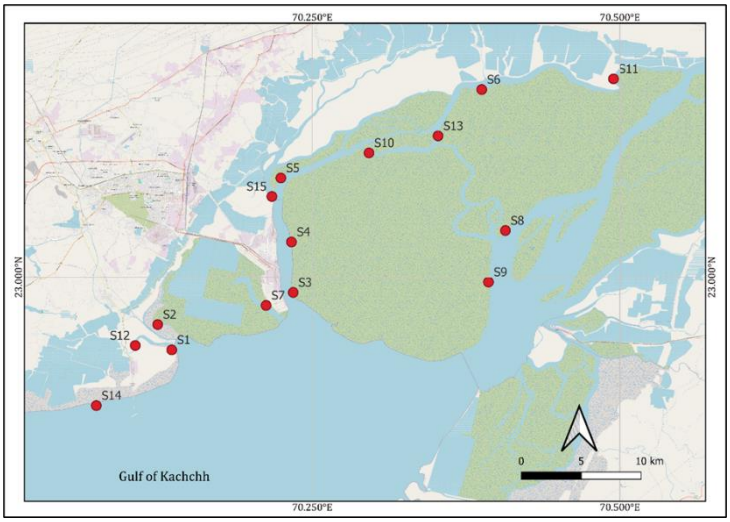


Figure 31. Permanent study sites at Deendayal Port Authority, Kandla, India

Status, Diversity and Distribution of avifauna in different station

The status and diversity of avifauna was studied in coastal areas of Deendayal Port Authority, Kandla, India for the monsoon season. The entire survey was comprehensively carried out by boat survey and walking along the fixed sampling station, for documentation of avifauna. A total of 53 species (32 species terrestrial and 21 aquatic bird) representing 9 order, 22 families and 37 genera were recorded during the study period **(See Annexture 1& Plate 10,11)**. Scolopacidae (nine species) were the most dominant family in terms of species richness followed by Ardeidae (seven species), whereas Columbidae and Laridae (five species), whereas others represent less species (Fig.32)

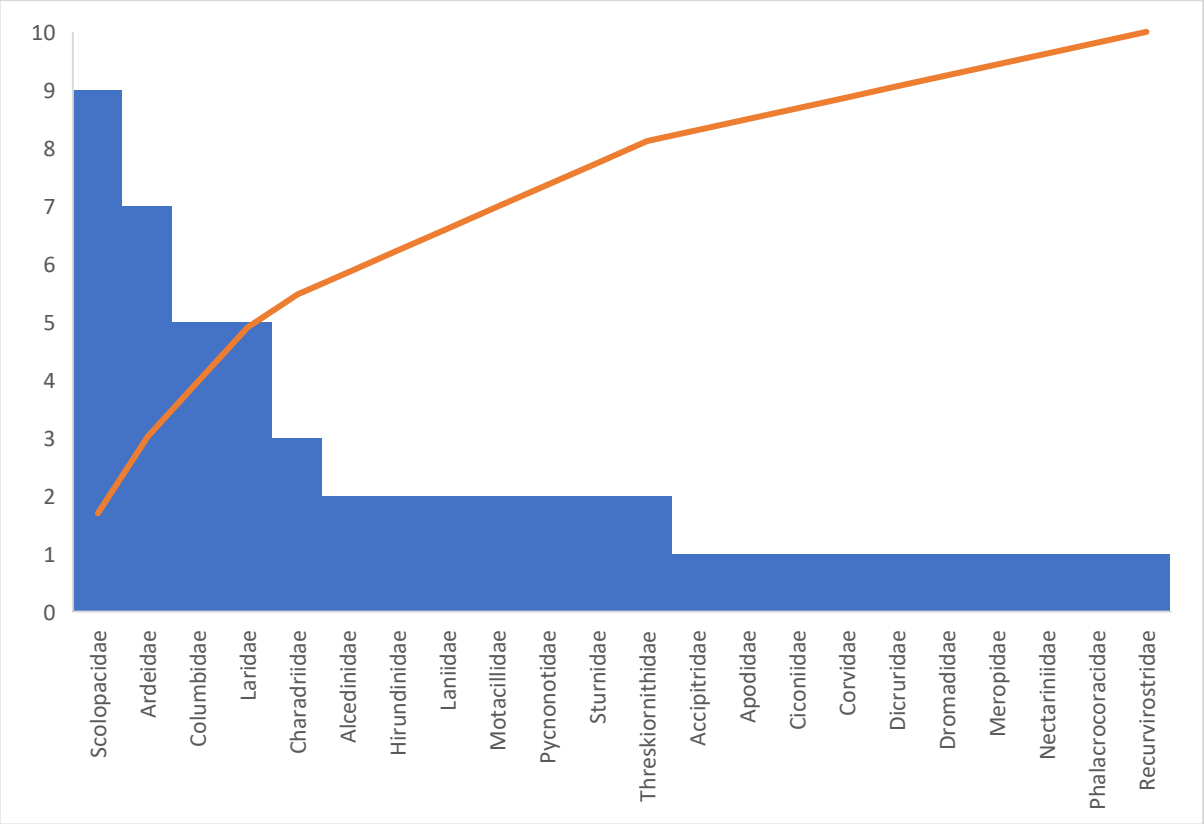


Figure 32 Distribution of families and species at the Deendayal Port Authority

Among the survey station, site 13 (53 species) were the most dominant with 37 genera and 22 families species richness followed by site 5 and 12 (45 species), and site 1 have 44 species and other sites have less species composition **(**Fig. 33).

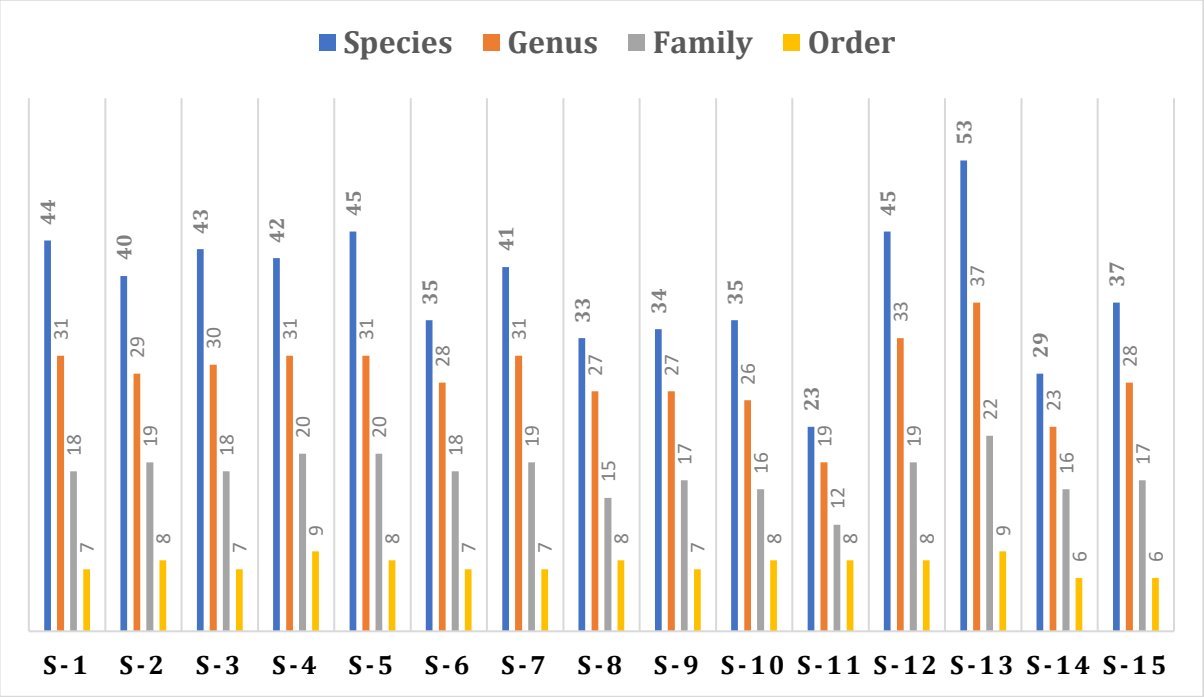


Figure 33 Site wise distribution of Avifauna recorded during monsoon season from the Deendayal Port Authority

The Shannon–Wiener diversity indices shows that site 13 (H=3.738), followed by site 12 (H=3.61), site 5 and 1 (H=3.57), whereas others represent less diversity (Table 7). Based on the movement pattern 36 species (68%) of birds were residence, 14 (26%) are migratory and three (6%) species are regional migratory (Annexure 1, Fig. 34). Considering the abundance of the species during the study period, 32 taxa were recorded from terrestrial, 21 from aquatic habitat. Among 53 species, only five species viz. Painted Stork Mycteria leucocephala (Pennant, 1769), Black-headed Ibis Threskiornis melanocephalus (Latham, 1790), Glossy Ibis Plegadis falcinellus (Linnaeus, 1766), Black-tailed Godwit Limosa limosa (Linnaeus, 1758) and Eurasian curlew Numenius arquata (Linnaeus, 1758) are under the Near Threatened (NT), whereas, River Tern Sterna aurantia (Gray, JE, 1831) is under vulnerable (VU) categories of IUCN Red List of Threatened Species. Moreover, two species (4%) River Tern Sterna aurantia (Gray, JE, 1831) and Common Greenshank Tringa nebularia (Gunnerus, 1767) were under the

Schedule I, and species (96%) were under Schedule II categories of Wild Life (Protection) Act, 1972 **(**Fig 35)

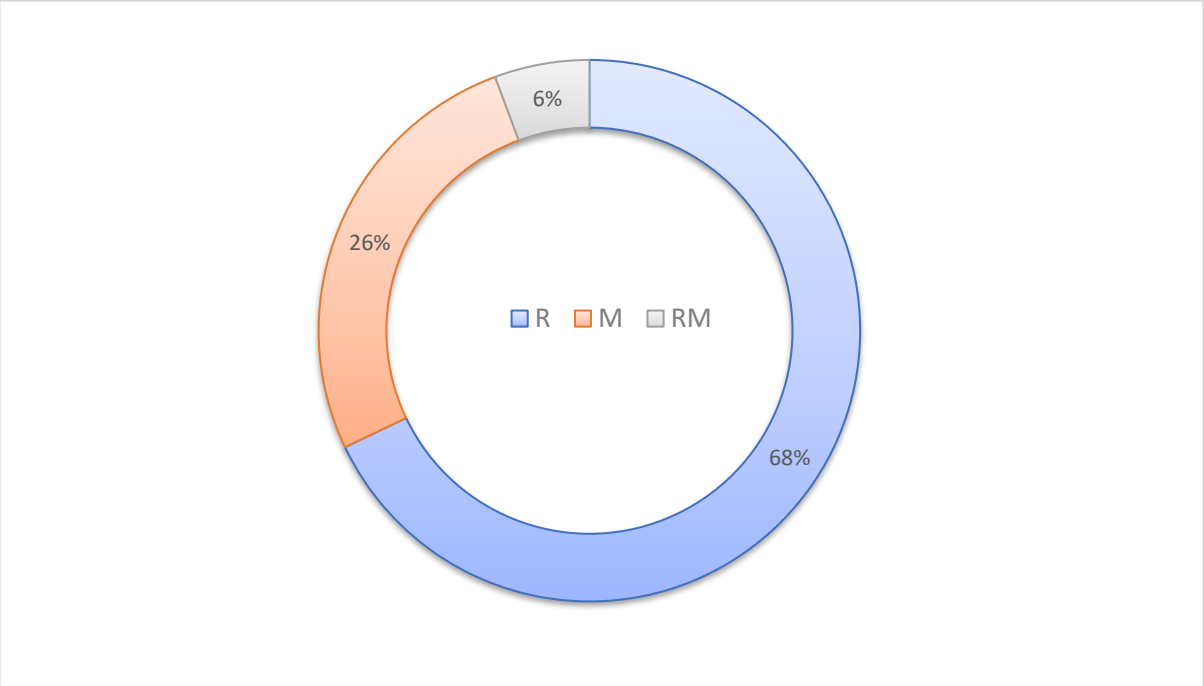


Figure 34 Behavioral status of avifauna from the Deendayal Port Authority,

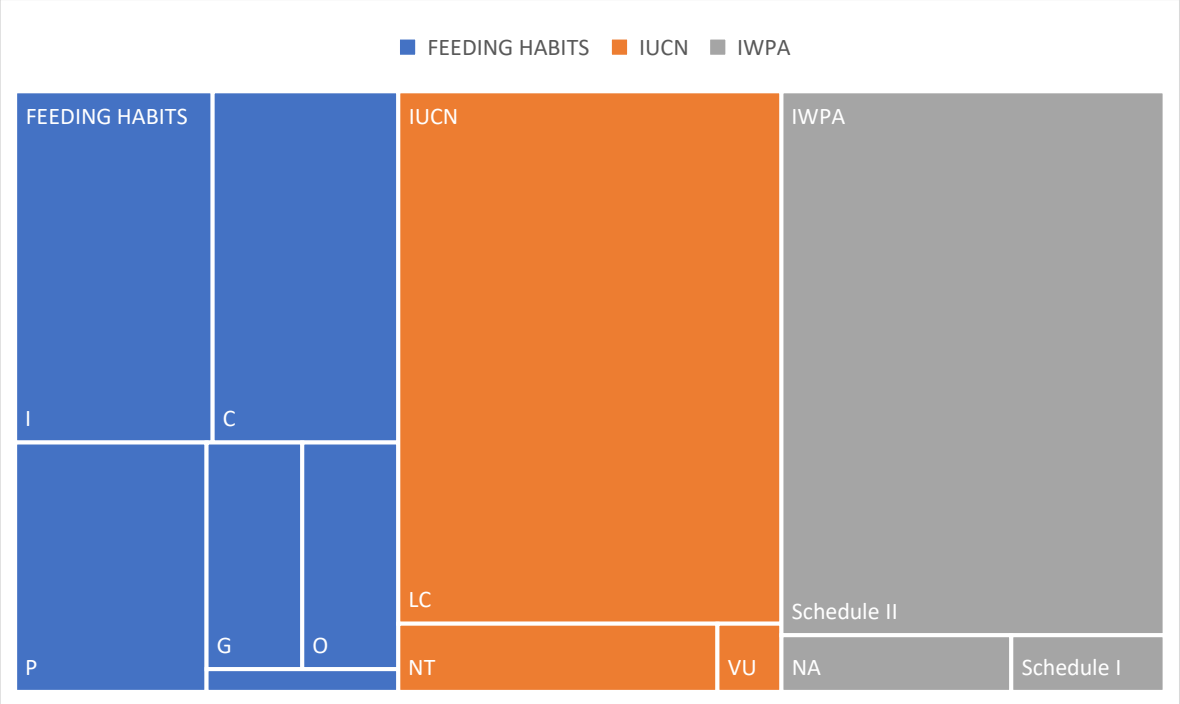


Figure 35 Status of foraging guild and threatened species recorded from Deendayal Port Authority,

Table 8. Site wise diversity indices recorded from DPA in Monsoon 2024

Site	Species	Individuals	Shannon_H	Evenness_e^H/S	Margalef	Equitability_J
S-1	44	115	3.60	0.84	9.06	0.95
S-2	40	126	3.55	0.87	8.06	0.96
S-3	43	170	3.49	0.76	8.18	0.93
S-4	42	185	3.61	0.88	7.85	0.96
S-5	45	172	3.62	0.83	8.55	0.95
S-6	35	105	3.39	0.85	7.31	0.95
S-7	41	159	3.58	0.87	7.89	0.96
S-8	33	95	3.41	0.92	7.03	0.98
S-9	34	91	3.41	0.89	7.32	0.97
S-10	35	136	3.39	0.84	6.92	0.95
S-11	23	62	2.96	0.84	5.33	0.94
S-12	45	171	3.66	0.86	8.56	0.96
S-13	53	218	3.75	0.80	9.66	0.94
S-14	29	74	3.22	0.86	6.51	0.96
S-15	37	96	3.47	0.87	7.89	0.96

Plate 10 Critical Mangroves and Mudflat habitats of birds at Deendayal Port Authority, Kandla (A-F)

Plate 11 . Common and migratory birds from the Deendayal Port Authority, Kandla. (A) Lesser black-backed gull Larus fuscus Linnaeus, 1758 (B) Caspian gull Larus cachinnans Pallas, 1811 (C) Western Reef Heron Egretta gularis (Bosc, 1792) (D) Crab-plover Dromas ardeola Paykull, 1805 (E) Black Headed Ibis Threskiornis melanocephalus (Latham, 1790) (F) Eurasian curlew Numenius arquata (Linnaeus, 1758).

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Annexture 1. Checklist of Avifauna recorded during the monsoon season from the Deendayal Port Authority, Kandla, India.

Sl. No.	Order, Family, Common & Scientific Name	MS	FS	IUCN	IWPA	Habitat
A	**CHARADRIIFORMES**					
1	**Charadriidae**					
1	Little ringed plover *Charadrius dubius* Scopoli, 1786	R	C	LC	Schedule II	A
2	Red-wattled Lapwing *Vanellus indicus* (Boddaert, 1783)	R	I	LC	Schedule II	T
3	Yellow-wattled Lapwing *Vanellus malabaricus* (Boddaert, 1783)	R	I	LC	Schedule II	T
2	**Dromadidae**					
4	Crab-plover *Dromas ardeola* Paykull, 1805	M	C	LC	Schedule II	A
3	**Laridae**					
5	Common tern *Sterna hirundo* Linnaeus, 1758	RM	P	LC	Schedule II	A
6	Little tern *Sternula albifrons* (Pallas, 1764)	R	P	LC	Schedule II	A
7	River Tern *Sterna aurantia* (Gray, JE, 1831)	R	P	V	Schedule I	A
8	Caspian gull *Larus cachinnans* Pallas, 1811	M	P	LC	Schedule II	A
9	Lesser black-backed gull *Larus fuscus* Linnaeus, 1758	M	C	LC	Schedule II	A
4	**Recurvirostridae**					
10	Black Winged Stilt *Himantopus himantopus* (Linnaeus, 1758)	R	C	LC	Schedule II	A
5	**Scolopacidae**					
11	Black-tailed Godwit *Limosa limosa* (Linnaeus, 1758)	M	O	NT	Schedule II	T
12	Common Greenshank *Tringa nebularia* (Gunnerus, 1767)	M	I	LC	Schedule I	T
13	Common Redshank *Tringa tetanus* (Linnaeus, 1758)	M	I	LC	Schedule II	A
14	Common Sandpiper *Actitis hypoleucos* (Linnaeus, 1758)	M	I	LC	Schedule II	A
15	Eurasian curlew *Numenius arquata* (Linnaeus, 1758)	M	C	NT	Schedule II	A
16	Green Sandpiper *Tringa ochropus* Linnaeus, 1758	M	I	LC	Schedule II	T
17	Marsh Sandpiper *Tringa stagnatilis* (Bechstein, 1803)	M	C	LC	Schedule II	T
18	Temminck's stint *Calidris temminckii* (Leisler, 1812)	M	C	LC	Schedule II	T
19	Whimbrel *Numenius phaeopus* (Linnaeus, 1758)	M	P	LC	Schedule II	A
B	**COLUMBIFORMES**					
6	**Columbidae**					

20	Blue Rock Pigeon *Columba livia* (Gmelin, JF, 1789)	R	G	LC	NA	T
21	Spotted Dove *Spilopelia chinensis* (Scopoli, 1786)	R	G	LC	Schedule II	T
22	Eurasian Collared Dove *Streptopelia decaocto* (Frivaldszky, 1838)	R	G	LC	Schedule II	T
23	Laughing Dove *Spilopelia senegalensis* (Linnaeus, 1766)	R	G	LC	Schedule II	T
24	Red Collared Dove *Streptopelia tranquebarica* (Hermann, 1804)	R	G	LC	Schedule II	T
C	**CORACIIFORMES**					
7	**Alcedinidae**					
25	Common Kingfisher *Alcedo atthis* (Linnaeus, 1758)	R	P	LC	Schedule II	A
26	White-throated Kingfisher *Halcyon smyrnensis* (Linnaeus, 1758)	R	C	LC	Schedule II	T
8	**Meropidae**					
27	Green Bee-eater *Merops orientalis* Latham, 1801	R	I	LC	Schedule II	T
D	**PELECANIFORMES**					
9	**Ardeidae**					
28	Cattle Egret *Bubulcus ibis* (Linnaeus, 1758)	R	C	LC	Schedule II	T
29	Great Egret *Ardea alba* (Linnaeus, 1758)	R	P	LC	Schedule II	A
30	Indian Pond Heron *Ardeola grayii* (Sykes, 1832)	R	C	LC	Schedule II	A
31	Intermediate Egret *Ardea intermedia* (Wagler, 1829)	R	P	LC	Schedule II	A
32	Little Egret *Egretta garzetta* (Linnaeus, 1766)	R	C	LC	Schedule II	A
33	Grey Heron *Ardea cinerea* Linnaeus, 1758	R	P	LC	Schedule II	T
34	Western Reef Heron *Egretta gularis* (Bosc, 1792)	RM	P	LC	Schedule II	A
10	**Threskiornithidae**					
35	Black Headed Ibis *Threskiornis melanocephalus* (Latham, 1790)	R	C	NT	Schedule II	A
36	Glossy Ibis *Plegadis falcinellus* (Linnaeus, 1766)	R	C	NT	Schedule II	T
E	**CICONIIFORMES**					
11	**Ciconiidae**					
37	Painted Stork *Mycteria leucocephala* (Pennant, 1769)	R	C	NT	Schedule II	A
F	**PASSERIFORMES**					
12	**Corvidae**					
38	House Crow *Corvus splendens* (Vieillot, 1817)	R	O	LC	NA	T

13	**Dicruridae**					
39	Black Drongo *Dicrurus macrocercus* Vieillot, 1817	R	I	LC	Schedule II	T
14	**Hirundinidae**					
40	Barn Swallow *Hirundo rustica* (Linnaeus, 1758)	RM	I	LC	Schedule II	T
41	Wire-tailed Swallow *Hirundo smithii* Leach, 1818	R	I	LC	Schedule II	T
15	**Laniidae**					
42	Bay-backed Shrike *Lanius vittatus* Valenciennes, 1826	R	I	LC	Schedule II	T
43	Brown shrike *Lanius cristatus* Linnaeus, 1758	R	I	LC	Schedule II	T
16	**Motacillidae**					
44	White Wagtail *Motacilla alba* Linnaeus, 1758	M	I	LC	Schedule II	T
45	Yellow Wagtail *Motacilla flava* Linnaeus, 1758	M	I	LC	Schedule II	T
17	**Nectariniidae**					
46	Purple Sunbird *Cinnyris asiaticus* (Latham, 1790)	R	N	LC	Schedule II	T
18	**Pycnonotidae**					
47	White Eared Bulbul *Pycnonotus leucotis* (Gould, 1836)	R	O	LC	Schedule II	T
48	Red-vented Bulbul *Pycnonotus cafer* (Linnaeus, 1766)	R	O	LC	Schedule II	T
19	**Sturnidae**					
49	Common Myna *Acridotheres tristis* (Linnaeus, 1766)	R	O	LC	Schedule II	T
50	Brahminy Starling *Sturnia pagodarum* (Gmelin, JF, 1789)	R	I	LC	Schedule II	T
G	**SULIFORMES**					
20	**Phalacrocoracidae**					
51	Little Cormorant *Microcarbo niger* (Vieillot, 1817)	R	P	LC	Schedule II	A
H	**Apodiformes**					
21	**Apodidae**					
52	House Swift *Apus nipalensis* (Hodgson, 1837)	R	I	LC	Schedule II	
I	**ACCIPITRIFORMES**					
22	**Accipitridae**					
53	Black Kite *Milvus migrans* (Boddaert, 1783)	R	C	LC	Schedule II	T

Gujarat Institute of Desert Ecology
Mundra Road, Bhuj 370 001, Kachchh, Gujarat
E-mail: desert_ecology@yahoo.com
www.gujaratdesertecology.com

Annexure -D

List of CSR Works for the Oct 2024 to Till March-2025		
Sr.No	**Name of work**	**Approved cost (Rs in Lakhs)**
1	Request for construction of relocatable of sports arena at Gandhidham Military Station,HQ 98 Artillery Brigade Military Station Gandhidham	₹ 28.00
2	Proposal for construction of Police Community Hall at Police Headquarters Shinay.Office of the Superintendent of Police, East – Kutch Gandhidham.	₹ 100.00
3	Proposal for providing AWG system at their check posts located in the Runn of Kutch,Commandant BSF Station Gandhidham	₹ 82.70
4	Proposal for providing 4000 pieces of Tripal/Tarpaulin,Matri Sena Charitable Trust	₹ 32.00
5	Proposal for Upgrading Satellite Eye Hospital at Bhuj.1.Request for financial support for the addition of cornea and retina outpatient departments (OPD), a spectacle dispensing unit, and a medicine counter as part of our OPD activities, & equipment purchase.	₹ 35.08
6	Proposal for financial assistance for purchase of C Arm and OT table to start Orthopedic at St. Joseph's Hospital Gandhidham,ST. Joseph's Hospital Trust, Gandhidham.	₹ 28.78
7	Proposed to establish a women empowerment center, through Ujjas Mahila Sangh,Gandhidham	₹ 119.48
8	CSR fund for extension of building of pre- primary unit of S.H.N. Academy School being managed by Indian Institute of Sindhology at Adipur	₹ 71.55
9	CSR Grant for 'Strengthening of School Ecosystem at Primary School Level in Kachchh District,Ladies Environment Action Foundation (LEAF), Gandhinagar	₹ 50.00
Total Amount		₹ 547.59

Annexure -E

दीनदयाल पोर्ट प्राधिकरण
DEENDAYAL PORT AUTHORITY

Office of the Dy. Chief Engineer
(EMC & I/c), Ground Floor,
Administrative Office Building
Post Box No. 50, Gandhidham–Kachchh
Email: seplkpt@gmail.com,
www.deendayalport.gov.in

****

No: EG/WK/4783/VII/ 143 **Date: 04/10/2024**

To,
M/s. Precitech Laboratories Pvt. Ltd.
1st floor, Bhanujyot Complex,
Plot no. C5/27, B/h. Pachratna Complex,
Near GIDC Char Rasta,
VAPI-396195
Mail – vapi@precitechlab.com

WORK ORDER

Sub: "Strengthening of Existing Environmental Management Cell of Deendayal Port Authority: Appointment of Environment Expert for two years and further extendable for one years."

Ref: 1) Tender dated 28/12/20223 submitted by M/s Precitech Laboratories Pvt. Ltd., Vapi.
2) LOA No. EG/WK/5375/171 dated 19/09/2024.
3) Performance Guarantee submitted by M/s. Precitech Laboratories Pvt Ltd in the form of Bank Guarantee of Rs. 9,45,000.00 vide Bank Guarantee no. 1102924BG0B00238 dated 30.09.2024 issued by State Bank India, Commercial Branch, Vapi.

Sir,

Kindly refer above cited Letter of Acceptance dated 19/09/2024.

1) You shall have to provide Key Experts as per tender requirement during the entire contract period. Accordingly, you shall have to submit the qualification and experience certificates of the Key experts to be appointed at DPT, as per tender conditions for verification & approval.
2) Please submit the agreement of contract as per Tender Conditions.
3) Kindly commence the work on or before 07/10/2024.

Please note that the time period for providing Consultancy service for the subject work will be Initially for Two years and further extendable for one year on mutual consent as per tender condition.

Accordingly, a copy of Form-III is enclosed herewith for information and necessary action please.

Encl: Form – III

04/10/24
Dy. Chief Engineer (PL) & EMC (I/c),
Deendayal Port Authority

CC: 1. TPA to CE - For kind information to Chief Engineer, please.
2. RAO, DPA
3. Sr. DD (EDP) with a request to hoist this work order in website of DPA.

4. A.M.(W/A)

दीनदयाल पोर्ट प्राधिकरण
DEENDAYAL PORT AUTHORITY

Office of the Dy. Chief Engineer
(EMC & I/c), Ground Floor,
Administrative Office Building
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No: EG/WK/4783/VII/ **Date: 4/09/2024**
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FORM – III

(Under rule 21(2) of the Contract Labour (Regulation and Abolition) Central Rules,1970; and Rules 7(3) of the Inter-State Migrant Workmen (Regulation of Employment and Conditions of Service) Central Rules, 1980)

CERTIFICATE BY PRINCIPAL EMPLOYER FOR OBTAINING LICENCE FROM ASSISTANT LABOUR COMMISSIONER (C), GOPALPURI.

Certified that:

I have engaged the applicant "Precitech Laboratories Pvt Ltd. 177, 1st floor, Bhanujyot Complex, Plot no. C5/27, B/h. Pachratna Complex,Near GIDC Char Rasta,VAPI-396195. as a contractor in my establishment for the work **"Strengthening of Existing Environmental Management Cell of Deendayal Port Authority: Appointment of Environment Expert for two years and further extendable for one years."** to be carried out for **24 months** (as per tender) and the work will be commenced on or before **07/10/2024**.

1) I undertake to be bound by all the provisions of the Contract Labour (Regulations and Abolition) Act, 1970 (37 of 1970) and the Contract Labour (Regulations and Abolition) Central Rules, 1971 The inter-State Migrant Workman (Regulation of Employment and Conditions of Service) Act, 1979 (30 of 1979) and the Inter State Migrant Workmen (Regulation of Employment and Conditions of Service) Central Rules, 1980* in so far as the provisions are applicable to me in respect of the employment of Contract Labour/inter-state migrant workmen by the applicant in my establishment.

2) The engagement of contract labour in the said work is not prohibited under sub-section (1) of section 10 of the Contract Labour (Regulation and Abolition) Act, 1970 (37 of 1970) or an award or a settlement.

04/09/24

Dy. Chief Engineer (PL) & EMC (I/c),
Deendayal Port Authority