Deendayal Port Authority
(Erstwhile :Deendayal Port Trust)

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Office of the Dy.CE & EMC (i/c),
ANNEX, Administrative Office
Gandhidham - Kutch
Pin – 370 201.

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EG/WK/4751/Part (Revamping – EC onwards)/ 134 **Dated24/12/2025**

To,
The Deputy Director General of Forests (C),
Ministry of Environment, Forest & Climate Change,
Integrated Regional Office,
Gandhinagar, A wing-407 & 409,
Aranya Bhavan Near CH-3 Circle,
Sector 10 A, Gandhinagar -382010.

Sub: "Augmentation of Liquid Cargo Handling Capacity from 8 MMTPA to 23.8 MMTPA Through Modernisation of Existing Pipeline Network at Oil Jetty Area, Deendayal Port Trust, Kandla – **Pointwise Compliance of the conditions stipulated in the EC & CRZ Clearance and Monitoring Report in Datasheet req.**
(EC Identification No. EC24A033GJ192347 and Proposal No. IA/GJ/NCP/280634/2018)

Ref.: **1)** EC & CRZ Clearance accorded by the SEIAA, Gujarat vide letter no. 10-26/2018-IA.III dated 01/01/2024.
2) DPA letter no. EG/WK/4751/Part (Revamping – EC onwards)/100 dated 29/07/2024 – Compliance Report submitted in PARIVESH 2 PORTAL (Period up to May,2024).
3) DPA letter no. EG/WK/4751/Part (Revamping – EC onwards)/21 dated 03/02/2025
4) DPA letter no. EG/WK/4751/Part (Revamping – EC onwards)/09 dated 02/06/2025

Sir,

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

In this connection, it is to state that, MoEF&CC, GOI had accorded EC&CRZ Clearance dated 01/01/2024 to the subject project of the DPA. In the said clearance letter, in the Para B STANDARD CONDITIONS, No. XI Miscellaneous (sub para no. iv), the MoEF&CC, GOI has stipulated the condition that, ***"The project proponent shall submit six-monthly reports on the status of the compliance of the stipulated environmental conditions on the website of the Ministry of Environment, Forest and Climate Change at environment clearance portal"***.

Accordingly, we are submitting herewith compliance report of the stipulated conditions mentioned in the EC & CRZ clearance granted by the MoEF&CC, GoI dated 01/01/2024 (period April 2025 to September 2025) in the Parivesh Portal of the MoEF&CC, GOI Further, we are also submitting herewith monitoring report in data sheet

This is for kind information and record, please.

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

Yours faithfully,

XEN (EMC)
Deendayal Port Authority

Annexure –I

Half Yearly Compliance Report
2025
01 Dec(01 Apr - 30 Sep)

Acknowledgement

Proposal Name	Augmentation of Liquid Cargo Handling Capacity from 8 MMTPA to 23.8 MMTPA Through Modernization of Existing Pipeline Network at Oil Jetty Area, Deendayal Port Trust, Kandla
Name of Entity / Corporate Office	Deendayal Port Authority
Village(s)	Kandla (CT)
District	KACHCHH

Proposal No.	IA/GJ/NCP/280634/2018
Plot / Survey / Khasra No.	
State	GUJARAT
MoEF File No.	10-26/2018-IA.III

Category	INFRA-1
Sub-District	Gandhidham
Entity's PAN	*****EQUIRED
Entity name as per PAN	Deendayal Port Authority

Compliance Reporting Details

Reporting Year 2025

Remarks (if any)

Reporting Period 01 Dec(01 Apr - 30 Sep)

Details of Production and Project Area

Name of Entity / Corporate Office Deendayal Port Authority

	Project Area as per EC Granted	**Actual Project Area in Possession**
Private	0	0
Revenue Land	0	0
Forest	0	0
Others	23	23
Total	23	23

Production Capacity

Sr. no	Product Name	units	Valid Upto	Capacity	Production last year	Capacity as per CTO

Conditions

Specific Conditions

Sr.No.	**Condition Type**	**Condition Details**
1	Statutory compliance	Construction activity shall be carried out strictly according to the

		provisions of the CRZ Notification, 2011. No construction work other than those permitted in Coastal Regulation Zone Notification shall be carried out in Coastal Regulation Zone area

PPs Submission: Being Complied Construction activity is being carried out as per the EC and CRZ Clearance accorded by the MoEFCC, GoI vide F. No. 10-26/2018-IA-III dated 1/1/2024.	Date: 18/12/2025

2	Statutory compliance	All the recommendations and conditions specified by the Gujarat State Coastal Zone Management Authority (GCZMA) vide letter No ENV-10-2021-41-T dated 25th August, 2022 shall be complied with

PPs Submission: Being Complied Compliance Report of GCZMA Recommendation dated 25/8/2022 is attached herewith as Annexure A	Date: 29/12/2025

3	Statutory compliance	Consent to Establish/Operate for the project shall be obtained from the State Pollution Control Board as required under the Air (Prevention and Control of Pollution) Act, 1981 and the Water (Prevention and Control of Pollution) Act, 1974

PPs Submission: Complied The Consent to Establish (CTE) from the GPCB had already been obtained vide CTE amendment (CTE 115467) granted by the GPCB vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/609592 dated 23/12/2021 with a validity period 11/2/2026. A copy of same had already been submitted along with compliance report submitted on 29/07/2024.	Date: 18/12/2025

4	Marine/Coastal	PP shall ensue while scrapping of 125 old pipeline and laying of 84 new process shall not cause any spillage/leakage.

PPs Submission: Being Complied Due care is being taken while scrapping of 125 old pipeline and laying of 84 new pipeline process to avoid spillage/leakages.	Date: 18/12/2025

5	Marine/Coastal	As proposed by PP Steel scrap will be temporarily stored in designated area before being auctioned off. The storage of steel scrap and any other scrapped material shall be stored temporarily outside the CRZ area

PPs Submission: Being Complied The steel scrap is being stored temporarily in designated area, as per the stipulated condition.	Date: 18/12/2025

6	WASTE MANAGEMENT	Wastes discharged from ships will be handed over to the port licensed waste disposal contractors

PPs Submission: Being Complied DPA already issued Grant of License/Permission to carry out the work of collection and disposal of Hazardous Waste/Sludge/ Waste Oil from Vessels calling at Deendayal Port through DPA contractors to the GPCB authorized recyclers.	Date: 18/12/2025

7	Marine/Coastal	No new berths will be constructed nor there any proposal to increase the size of the ships presently being handled at the oil jetties. Hence no dredging shall be carried out

PPs Submission: Agreed to Comply Point noted. No dredging is envisaged in the subject project.	Date: 18/12/2025

8	AIR QUALITY MONITORING AND	The project proponent shall install system carryout to Ambient Air Quality monitoring for common/criterion parameters relevant to the

	PRESERVATION	main pollutants released (e.g. PM10 and PM2.5 in reference to PM emission, and SO2 and NOx in reference to SO2 and NOx emissions) within and outside the port area at least at four locations (one within and three outside the port area at an angle of 120 degree each), covering upwind and downwind directions

PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area including Air Quality Monitoring vide work order dated 15/02/2023. Latest monitoring report is attached herewith as Annexure B Further, DPA has accorded GUIDE, Bhuj, for Continuous Ambient Air Quality Monitoring (CAAQMS) on a nomination basis, vide Work Order dated 24/06/2025. The work order is attached herewith as Annexure C	Date: 29/12/2025

9	AIR QUALITY MONITORING AND PRESERVATION	Appropriate Air Pollution Control (APC) system shall be provided for all the dust generating points including fugitive dust from all vulnerable sources, so as to comply prescribed fugitive emission standards

PPs Submission: Complied There is no point for of the generation of dust at the project site. The entire project area is located within the Customs Bonded Area of Deendayal Port Authority, Kandla (Oil Jetty Complex). The project involves replacement and revamping of existing Pipeline network at Oil Jetty area (Scrapping of 125 old existing pipelines and laying of 84 new pipelines)	Date: 18/12/2025

10	AIR QUALITY MONITORING AND PRESERVATION	The project proponent shall submit monthly summary report of continuous stack emission and air quality monitoring and results of manual stack monitoring and manual monitoring of air quality /fugitive emissions to Regional Office of MoEFandCC, Zonal office of CPCB and Regional Office of SPCB along with six-monthly monitoring report.

PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area including Air Quality Monitoring vide work order dated 15/02/2023. Latest monitoring report is attached herewith as Annexure B	Date: 29/12/2025

11	AIR QUALITY MONITORING AND PRESERVATION	Effective safeguard measures, such as regular water sprinkling shall be carried out in critical areas prone to air pollution and having high level of particulate matter such as around loading and unloading point and all transfer points. Extensive water sprinkling shall be carried out on haul roads. It should be ensured that the Ambient Air Quality parameters conform to the norms prescribed by the Central Pollution Control Board in this regard

PPs Submission: Complied There is no point for of the generation of dust at the project site. The entire project area is located within the Customs Bonded Area of Deendayal Port Authority, Kandla (Oil Jetty Complex). The project involves replacement and revamping of existing Pipeline network at Oil Jetty area (Scrapping of 125 old existing pipelines and laying of 84 new pipelines).	Date: 18/12/2025

12	Risk Mitigation and Disaster Management	Risk assessment for spill scenarios and Disaster Management Plan as prepared shall be in place in the environment Management cell of Deendayal Port Authority with all SOP for various scenarios.

PPs Submission: Complied DPA is already having Disaster Management Plan including the spill scenarios. A copy communicated along with compliance report submitted on 03/02/2025.	Date: 18/12/2025

13	Marine/Coastal	Spillage of fuel/engine oil and lubricants from the construction site

		are a source of organic pollution which impacts marine life, particularly benthos. This shall be prevented by suitable precautions and also by providing necessary mechanisms to trap the spillage.

PPs Submission: Complied DPA is already having oil spillage contingency plan in place for the whole port area A copy communicated along with compliance report submitted on 03/02/2025.	Date: 18/12/2025

14	WASTE MANAGEMENT	Oil spillage prevention and mitigation scheme shall be prepared. In case of oil spillage/contamination, action plan shall be prepared to clean the site by adopting proven technology. The recyclable waste (oily sludge) and spent oil shall be disposed of to the authorized recyclers

PPs Submission: Complied DPA is already having oil spillage contingency plan in place for the whole port area. DPA already issued Grant of License/Permission to carry out the work of collection and disposal of Hazardous Waste/Sludge/ Waste Oil from Vessels calling at Deendayal Port through DPA contractors to the GPCB authorized recyclers	Date: 18/12/2025

15	WASTE MANAGEMENT	Construction spoils, including bituminous material and other hazardous materials, must not be allowed to contaminate watercourses and the dump sites for such material must be secured so that they should not leach into the ground water.

PPs Submission: Complied There is no point for of the generation of dust at the project site. The entire project area is located within the Customs Bonded Area of Deendayal Port Authority, Kandla (Oil Jetty Complex). The project involves replacement and revamping of existing Pipeline network at Oil Jetty area (Scrapping of 125 old existing pipelines and laying of 84 new pipelines).	Date: 18/12/2025

16	Risk Mitigation and Disaster Management	The proponent shall put in place the detailed on site and off site Emergency Management Plan as per the Manufacture, Storage and Import of Hazardous Chemical Rules, 1989, as amended to date which may cover the natural disasters also

PPs Submission: Complied DPA is already having Disaster management plan in place.	Date: 18/12/2025

17	Risk Mitigation and Disaster Management	The company shall develop a contingency plan for H2S release including all necessary aspects from evacuation to resumption of normal operations. The workers shall be provided with personal H2S detectors in locations of high risk of exposure along with self containing breathing apparatus

PPs Submission: Complied 03 Nos. of Multi Gas Detectors and 16 Nos. of Self Contained Breathing Apparatus Sets are presently available at Fire Brigade Section. Also the liquid terminal operators brings the Multi gas detectors whenever their vessel berths at oil jetties. Further the updating in Risk assessment and Disaster Management Plan is completed in consultation with M/s IR CLASS by Marine Department. A copy communicated along with compliance report submitted on 03/02/2025.	Date: 18/12/2025

18	Risk Mitigation and Disaster Management	Emergency Response Plan (ERP) shall be based on the guidelines prepared by OISD, DGMS and Govt. of India

PPs Submission: Complied DPA is already having Disaster management plan in place.	Date: 18/12/2025

19	Marine/Coastal	Sediment analysis of harbor at identified locations shall be analyzed

		and records for past and present period shall be maintained

PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area including Air Quality Monitoring vide work order dated 15/02/2023. Latest monitoring report is attached herewith as Annexure B.	Date: 29/12/2025

20	Marine/Coastal	The Project proponent shall ensure that no creeks or rivers are blocked due to any activities at the project site and free flow of water is maintained

PPs Submission: Agreed to Comply Point noted. The entire project area is located within the Customs Bonded Area of Deendayal Port Authority, Kandla (Oil Jetty Complex). The project involves replacement and revamping of existing Pipeline network at Oil Jetty area (Scrapping of 125 old existing pipelines and laying of 84 new pipelines) located on existing Pipeline trestle.	Date: 18/12/2025

21	Marine/Coastal	No underwater blasting is permitted.

PPs Submission: Agreed to Comply Not applicable. No underwater blasting is envisaged.	Date: 18/12/2025

22	Statutory compliance	Necessary approvals be taken during implementation and commissioning from statutory bodies concerned

PPs Submission: Agreed to Comply Point noted for compliance	Date: 18/12/2025

23	Marine/Coastal	A site specific biodiversity conservation plan including mitigation measures to be developed from competent nationally/internationally recognized institute with appropriate financial allocation for its implementation

PPs Submission: Complied DPA had appointed GUIDE, Bhuj for the preparation of Marine Biodiversity Management plan vide work order dated 03/05/2021. A copy of the Final Report (prepared by GUIDE, Bhuj) had already been submitted along with compliance report submitted on 29/07/2024.	Date: 18/12/2025

24	Marine/Coastal	Shoreline should not be disturbed due to dumping. Periodical study on shore line changes shall be conducted and mitigation carried out, if necessary. The details shall be submitted along with the six monthly monitoring report

PPs Submission: Complied Point noted for compliance Earlier, w.r.t. compliance of stipulated conditions of some other EC and CRZ Clearances, DPA had assigned the work Shoreline Change Study for Deendayal Port Authority (Erstwhile Deendayal Port Authority), Kandla, Kachchh District, Gujarat, to Study the Effect of Dumping, if any vide their work order dated 12/10/2021 to NCSCM, Chennai. The work has been completed and final report has already been submitted by DPA to the concerned authorities in compliance reports submitted. A copy of same had already been submitted along with compliance report submitted on 29/07/2024.	Date: 18/12/2025

25	Marine/Coastal	A continuous monitoring programme covering all the seasons on various aspects of the coastal and marine environsneed to be undertaken by a competent organization available in the State or by entrusting to the National Institutes/renowned Universities/accredited Consultant with rich experiences in marine science aspects. Monitoring should include sea weeds, sea grasses, mudflats, sand dunes, fisheries, mangroves and other marine biodiversity

		components as part of the management plan

PPs Submission: Being Complied DPA issued work order to Gujarat Institute of desert Ecology, Bhuj (expert agency in the field) vide letter no. EG/WK/ 4751 /Part (Marine Ecology Monitoring) / 72 dated 10/06/2024 for Regular Monitoring of Marine Ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme covering all seasons on various aspects of the Coastal Environs covering Physico-chemical parameters of marine water and marine sediment samples coupled with biological indices (for three years 2024-2027) reg. A copy of final report is attached herewith as Annexure D.	Date: 29/12/2025

26	WASTE MANAGEMENT	Necessary arrangements for the treatment of the effluents and solid wastes/ facilitation of reception facilities under MARPOL must be made and it must be ensured that they conform to the standards laid down by the competent authorities including the Central or State Pollution Control Board and under the Environment (Protection) Act, 1986. The provisions of Solid Waste Management Rules, 2016. E-Waste Management Rules, 2016, and Plastic Waste Management Rules, 2016 shall be complied with.

PPs Submission: Complied DPA already issued Grant of License/Permission to carry out the work of collection and disposal of Hazardous Waste/Sludge/ Waste Oil from Vessels calling at Deendayal Port through DPA contractors to GPCB authorized recycler. Further, it is to state that, all ships are required to follow DG Shipping circulars regarding the reception facilities at Swachch Sagar portal DPA has appointed GEMI, Gandhinagar for the Preparation of Plan for management of Plastic waste, Solid Waste including C and D wastes, E-waste, hazardous waste including biomedical waste and Non-hazardous waste in DPA vide work order dated 24/01/2023. The work is completed final report is communicated along with compliance report submitted on 03/02/2025.	Date: 18/12/2025

27	PUBLIC HEARING	All the commitments made to the public during public hearing/public consultation meeting shall be satisfactorily implemented and adequate budget provision shall be made accordingly

PPs Submission: Complied DPA has assigned the work of Planning and monitoring of the of the activities to be undertaken under Environment Management Plan under EIA and EC to GEMI, Gandhinagar vide work order dated 25/10/2023. The work is completed final report is communicated along with compliance report submitted on 02/06/2025.	Date: 18/12/2025

28	Risk Mitigation and Disaster Management	All the recommendations mentioned in the risk assessment report, disaster management plan and safety guidelines shall be implemented

PPs Submission: Complied Point noted for the compliance	Date: 18/12/2025

29	Corporate Environmental Responsibility	As per the Ministrys Office Memorandum F. No. 22-65/2017-IA.III dated 30th September, 2020, the project proponent shall abide by all the commitments made by them to address the concerns raised during the public consultation. The project proponent shall initiate the activities proposed by them, based on the commitment made in the public hearing, and incorporate in the Environmental Management Plan and submit to the Ministry. All other activities including pollution control, environmental protection and conservation, R and R, wildlife and forest conservation/protection measures including the NPV, Compensatory Afforestation, either proposed by the project proponent based on the social impact assessment and R and R action plan carried out during the preparation of EIA report or prescribed by EAC, shall also be implemented and become part of EMP

PPs Submission: Complied DPA has assigned the work of Planning and monitoring of the of the activities to be undertaken under Environment Management Plan under EIA and EC. To GEMI, Gandhinagar vide work order dated 25/10/2023. The work is completed final report is communicated along with compliance report submitted on 02/06/2025.	Date: 18/12/2025

General Conditions

Sr.No.	Condition Type	Condition Details
1	Statutory compliance	The project proponent shall prepare a Site-Specific Conservation Plan and Wildlife Management Plan and approved by the Chief Wildlife Warden. The recommendations of the approved Site-Specific Conservation Plan / Wildlife Management Plan shall be implemented in consultation with the State Forest Department. The implementation report shall be furnished along with the six-monthly compliance report (incase of the presence of schedule I species in the study area).
PPs Submission: Agreed to Comply DPA has assigned the work of Preparation of Site-Specific Conservation Plan and Wildlife Management Plan for the implementation of the stipulated conditions of EC and CRZ Clearance for Kandla to Mecon Limited, Ranchi, vide Work Order dated 24/06/2025. The work is in progress, and a copy of the Work Order is attached herewith as Annexure E.		Date: 29/12/2025
2	Statutory compliance	The project proponent shall obtain the necessary permission from the Central Ground Water Authority, in case of drawl of ground water / from the competent authority concerned in case of drawl of surface water required for the project.
PPs Submission: Agreed to Comply DPA is not using ground water for any of its activities. The Water requirement is being met through GWSSB (Narmada Pipeline) and through private tankers		Date: 18/12/2025
3	Statutory compliance	All excavation related dewatering shall be as duly authorized by the CGWA. A NOC from the CGWA shall be obtained for all dewatering and ground water abstraction.
PPs Submission: Agreed to Comply DPA is not using ground water for any of its activities. The Water requirement is being met through GWSSB (Narmada Pipeline) and through private tankers		Date: 18/12/2025
4	Statutory compliance	A certificate of adequacy of available power from the agency supplying power to the project along with the load allowed for the project should be obtained.
PPs Submission: Complied Power requirement for the proposed activity will not change from the existing requirement. Power is supplied by Paschim Gujarat Vij Company Limited a Govt. of Gujarat organization		Date: 18/12/2025
5	Statutory compliance	All other statutory clearances such as the approvals for storage of diesel from Chief Controller of Explosives, Fire Department, Coast Guard, Civil Aviation Department shall be obtained, as applicable by project proponents from the respective competent authorities.
PPs Submission: Agreed to Comply Point noted for compliance		Date: 18/12/2025

6	AIR QUALITY MONITORING AND PRESERVATION	The project proponent shall install system to carryout Ambient Air Quality monitoring for common/criterion parameters relevant to the main pollutants released (e.g. PM10 and PM2.5 in reference to PM emission, and SO2 and NOx in reference to SO2 and NOx emissions) within and outside the project area at least at four locations, covering upwind and downwind directions
PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area including Air Quality Monitoring vide work order dated 15/02/2023. Latest monitoring report is attached herewith as Annexure B Further, DPA has accorded GUIDE, Bhuj, for Continuous Ambient Air Quality Monitoring (CAAQMS) on a nomination basis, vide Work Order dated 24/06/2025. The work order is attached herewith as Annexure C.		Date: 29/12/2025
7	AIR QUALITY MONITORING AND PRESERVATION	Appropriate Air Pollution Control (APC) system shall be provided for all the dust generating points including fugitive dust from all vulnerable sources, so as to comply prescribed emission standards
PPs Submission: Complied There is no point for of the generation of dust at the project site. The entire project area is located within the Customs Bonded Area of Deendayal Port Authority, Kandla (Oil Jetty Complex). The project involves replacement and revamping of existing Pipeline network at Oil Jetty area (Scrapping of 125 old existing pipelines and laying of 84 new pipelines)		Date: 18/12/2025
8	AIR QUALITY MONITORING AND PRESERVATION	Shrouding shall be carried out in the work site enclosing the dock/proposed facility area. This will act as dust curtain as well achieving zero dust discharge from the site. These curtain or shroud will be immensely effective in restricting disturbance from wind in affecting the dry dock operations, preventing waste dispersion, improving working conditions through provision of shade for the workers.
PPs Submission: Complied There is no point for of the generation of dust at the project site. The entire project area is located within the Customs Bonded Area of Deendayal Port Authority, Kandla (Oil Jetty Complex). The project involves replacement and revamping of existing Pipeline network at Oil Jetty area (Scrapping of 125 old existing pipelines and laying of 84 new pipelines)		Date: 18/12/2025
9	AIR QUALITY MONITORING AND PRESERVATION	Dust collectors shall be deployed in all areas where blasting (surface cleaning) and painting operations are to be carried out, supplemented by stacks for effective dispersion
PPs Submission: Complied There is no point for of the generation of dust at the project site. The entire project area is located within the Customs Bonded Area of Deendayal Port Authority, Kandla (Oil Jetty Complex). The project involves replacement and revamping of existing Pipeline network at Oil Jetty area (Scrapping of 125 old existing pipelines and laying of 84 new pipelines)		Date: 18/12/2025
10	AIR QUALITY MONITORING AND PRESERVATION	Diesel power generating sets proposed as source of backup power should be of enclosed type and conform to rules made under the Environment (Protection) Act, 1986. The height of stack of DG sets should be equal to the height needed for the combined capacity of all proposed DG sets. Use of low sulphur diesel. The location of the DG sets may be decided with in consultation with State Pollution Control Board
PPs Submission: Complied Available D.G sets are enclosed type and conforms to rules made under the Environment (Protection) Act, 1986		Date: 18/12/2025

11	AIR QUALITY MONITORING AND PRESERVATION	A detailed traffic management and traffic decongestion plan shall be drawn up to ensure that the current level of service of the roads within a 05 kms radius of the project is maintained and improved upon after the implementation of the project. This plan should be based on cumulative impact of all development and increased habitation being carried out or proposed to be carried out by the project or other agencies in this 05 Kms radius of the site in different scenarios of space and time and the traffic management plan shall be duly validated and certified by the State Urban Development department and the P.W.D./ competent authority for road augmentation and shall also have their consent to the implementation of components of the plan which involve the participation of these departments

PPs Submission: Complied DPA is already having traffic management plant. A Copy of same had already been submitted along with the compliance report submitted on 29/07/2024	Date: 18/12/2025

12	WATER QUALITY MONITORING AND PRESERVATION	Total fresh water use shall not exceed the proposed requirement as provided in the project details. Prior permission from competent authority shall be obtained for use of fresh water

PPs Submission: Agreed to Comply Looking at the small quantity of Waste water generated it will be treated in the Septic tanks/Soak pits	Date: 18/12/2025

13	WATER QUALITY MONITORING AND PRESERVATION	Sewage Treatment Plant shall be provided to treat the wastewater generated from the project. Treated water shall be reused for horticulture, flushing, backwash, HVAC purposes and dust suppression

PPs Submission: Agreed to Comply Looking at the small quantity of Waste water generated it will be treated in the Septic tanks/Soak pits	Date: 18/12/2025

14	WATER QUALITY MONITORING AND PRESERVATION	A certificate from the competent authority for discharging treated effluent/ untreated effluents into the Public sewer/ disposal/drainage systems along with the final disposal point should be obtained

PPs Submission: Agreed to Comply Looking at the small quantity of Waste water generated it will be treated in the Septic tanks/Soak pits	Date: 18/12/2025

15	WATER QUALITY MONITORING AND PRESERVATION	No diversion of the natural course of the river shall be made without prior permission from the Ministry of Water resources

PPs Submission: Agreed to Comply It is assured that, no diversion of the natural course of the river is made.	Date: 18/12/2025

16	Noise Monitoring & Prevention	Noise level survey shall be carried as per the prescribed guidelines and report in this regard shall be submitted to Regional Officer of the Ministry as a part of six-monthly compliance report

PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area including Noise parameter vide work order dated 15/02/2023. A copy of latest monitoring report is attached herewith as Annexure B.	Date: 29/12/2025

17	Noise Monitoring & Prevention	Noise from vehicles, power machinery and equipment on-site should not exceed the prescribed limit. Equipment should be regularly serviced. Attention should also be given to muffler maintenance and enclosure of noisy equipments.

PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area including Noise parameter vide work order dated 15/02/2023. A copy of latest monitoring report is attached herewith as Annexure B.	Date: 29/12/2025

18	Noise Monitoring & Prevention	Acoustic enclosures for DG sets, noise barriers for ground-run bays, ear plugs for operating personnel shall be implemented as mitigation measures for noise impact due to ground sources

PPs Submission: Being Complied Available D.G set is provided with the acoustic enclosures, noise barriers for ground-run bays, ear plugs are provided for operating personnel	Date: 18/12/2025

19	Noise Monitoring & Prevention	The ambient noise levels should conform to the standards prescribed under E(P)A Rules, 1986 viz. 75 dB(A) during day time and 70 dB(A) during night time.

PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area including Noise parameter vide work order dated 15/02/2023. A copy of latest monitoring report is attached herewith as Annexure B.	Date: 29/12/2025

20	ENERGY PRESERVATION MEASURES	Provide solar power generation on roof tops of buildings, for solar light system for all common areas, street lights, parking around project area and maintain the same regularly;

PPs Submission: Being Complied DPA has installed solar rooftop systems under the CSR scheme at various organizations, namely: Arya Samaj Charitable Trust, Gandhidham (30 kW); Blind Peoples Association (India), Bhuj (8 kW); Karunavihar Kanya Sadan, Adipur (8 kW); Manav Seva Trust, Gandhidham (20 kW); Mata Laxmi Rotary Charitable Society, Adipur (20 kW); Shree Anjar Education Society, Anjar (68 kW); Shri Hari Aarso Trust, Adipur (8 kW); Shri Navchetan Mandal, Madhapar (Opposite Kutch Dairy) (33 kW); Shri Navchetan Mandal, Madhapar (Chanchal Hanuman Road) (22 kW); Shri Navchetan Mandal, Madhapar (Near GEB Office) (10 kW); Shri Ramakrishna Sharda Sevashram, Anjar (10 kW); and Shri Ramakrishna Seva Kendra (Centre), Adipur (14 kW).	Date: 18/12/2025

21	ENERGY PRESERVATION MEASURES	Provide LED lights in their offices and residential areas

PPs Submission: Complied All the conventional HPSV lights have been replaced by Energy efficient LED lights	Date: 18/12/2025

22	WASTE MANAGEMENT	Necessary arrangements for the treatment of the effluents and solid wastes must be made and it must be ensured that they conform to the standards laid down by the competent authorities including the Central or State Pollution Control Board and under the Environment (Protection) Act, 1986.

PPs Submission: Complied Looking at the small quantity of Waste water generated it will be treated in the Septic tanks/Soak pits	Date: 18/12/2025

23	WASTE MANAGEMENT	The solid wastes shall be managed and disposed as per the norms of the Solid Waste Management Rules, 2016.
PPs Submission: Complied Companies authorized by Central Pollution Control Board(CPCB) and State Pollution Control Board (SPCB) have been awarded the work of Grant of Permission / License for removal of Dry Solid Waste(Non-Hazardous) from Vessels calling at Deendayal Port for collection, transporting and disposal of solid waste by the Deendayal Port Trust		Date: 18/12/2025
24	WASTE MANAGEMENT	Any wastes from construction and demolition activities related thereto shall be managed so as to strictly conform to the Construction and Demolition Waste Management Rules, 2016.
PPs Submission: Agreed to Comply Demolition of any building or masonry structure is not envisaged in the present project		Date: 18/12/2025
25	WASTE MANAGEMENT	A certificate from the competent authority handling municipal solid wastes should be obtained, indicating the existing civic capacities of handling and their adequacy to cater to the M.S.W. generated from project
PPs Submission: Complied A MoU has been signed for the Municipal solid waste management along with the Gandhidham Municipal Corporation		Date: 18/12/2025
26	WASTE MANAGEMENT	Used CFLs and TFLs should be properly collected and disposed off/sent for recycling as per the prevailing guidelines/ rules of the regulatory authority to avoid mercury contamination
PPs Submission: Complied DPA has entered in agreement with MSTC Ltd. Vadodara for selling / auction of all scrap items including e-waste		Date: 18/12/2025
27	GREENBELT	An overall green area of at-least 33 percentage of the Industrial Area should be developed with native species. The green area shall be 40 percentage in case of critically polluted area. The project proponent of the Industrial Area shall comply with the additional commitment made by them in the EIA report regarding the development of green belt
PPs Submission: Complied DPA entrusted the work for Greenbelt development to the Forest Department, GoG for plantation in an area of 32.5 Ha. The work is completed. DPA has appointed Gujarat Institute of Desert Ecology (GUIDE) for Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l) vide Work Order No.EG/WK/4757/Part Greenbelt GUIDE, dated 31st May, 2022. The work completed (5000 saplings). Further, DPA has accorded the work of Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The work is completed and final report The work is completed and final report is submitted along with compliance report submitted on 03/02/2025. Further DPA has accorded the work of Green belt development in DPA and its surrounding area (Phase III) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 5000 saplings at DPA and 200 saplings at Gopalpuri colony. The inception report is attached herewith as Annexure F.		Date: 29/12/2025
28	GREENBELT	The Industrial Areas are directed to accordingly allocate the area to be developed as green cover to respective individual industrial units so as to achieve the above mentioned condition.
PPs Submission: Complied		Date:

DPA not covers under the Industrial Unit. However, DPA entrusted the work for Greenbelt development to the Forest Department, GoG for plantation in an area of 32.5 Ha. The work is completed. DPA has appointed Gujarat Institute of Desert Ecology (GUIDE) for Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l) vide Work Order No.EG/WK/4757/Part Greenbelt GUIDE, dated 31st May, 2022. The work completed (5000 saplings). Further, DPA has accorded the work of Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The work is completed and final report is submitted along with compliance report submitted on 03/02/2025 Further DPA has accorded the work of Green belt development in DPA and its surrounding area (Phase III) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 5000 saplings at DPA and 200 saplings at Gopalpuri colony. The inception report is attached herewith as Annexure F.	29/12/2025

29	GREENBELT	The individual industrial unit, at the time of obtaining EC, shall bring a letter from the Industrial Area for the area allocated to them to be developed as green cover as a part of obligation from the Industrial Area.

PPs Submission: Agreed to Comply DPA not covers under the Industrial Unit	Date: 18/12/2025

30	GREENBELT	Wherever possible, plantations around the periphery of the Industrial Area, in the downwind direction and along the road sides shall be provided for containment of pollution and for formation of a screen between the industrial area and the outer civil area. The choice of plants should include shrubs of height 1 to 1.5 m and tree of 3 to 5 m height. The intermixing of trees and shrubs should be such that the foliage area density in vertical is almost uniform.

PPs Submission: Complied DPA entrusted the work for Greenbelt development to the Forest Department, GoG for plantation in an area of 32.5 Ha. The work is completed. DPA has appointed Gujarat Institute of Desert Ecology (GUIDE) for Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l) vide Work Order No.EG/WK/4757/Part Greenbelt GUIDE, dated 31st May, 2022. The work completed (5000 saplings). Further, DPA has accorded the work of Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The work is completed and final report is submitted along with compliance report submitted on 03/02/2025. Further DPA has accorded the work of Green belt development in DPA and its surrounding area (Phase III) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 5000 saplings at DPA and 200 saplings at Gopalpuri colony. The inception report is attached herewith as Annexure F.	Date: 29/12/2025

31	GREENBELT	The parameters like selection of plant species, procedure for plantation, density of tree plantation etc shall be as per the CPCB guidelines

PPs Submission: Complied Selection of plant species procedure for plantation, density of tree plantation etc done as per the CPCB guidelines for the plantation activities carried out.	Date: 18/12/2025

32	Human Health Environment	Workers shall be strictly enforced to wear personal protective equipments like dust mask, ear muffs or ear plugs, whenever and wherever necessary/ required. Special visco-elastic gloves will be used by labour exposed to hazards from vibration.

PPs Submission: Being Complied Personal protective equipments like dust mask, ear muffs or ear plugs are being provided to the workers wherever required	Date: 18/12/2025

33	Human Health Environment	Safety training shall be given to all workers specific to their work area and every worker and employee will be engaged in fire hazard awareness training and mock drills which will be conducted regularly. All standard safety and occupational hazard measures shall be implemented and monitored by the concerned officials to prevent the occurrence of untoward incidents/ accident
PPs Submission: Being Complied Regular safety trainings are being given to the workers.		Date: 18/12/2025
34	Human Health Environment	Emergency preparedness plan based on the Hazard identification and Risk Assessment (HIRA) and Disaster Management Plan shall be implemented
PPs Submission: Complied DPA is already having Disaster Management Plan including the spill scenarios. A copy of same had already been submitted along with the compliance report submitted on 03/02/2025.		Date: 18/12/2025
35	Human Health Environment	Provision shall be made for the housing of construction labour within the site with all necessary infrastructure and facilities such as fuel for cooking, mobile toilets, mobile STP, safe drinking water, medical health care, creche etc. The housing may be in the form of temporary structures to be removed after the completion of the project.
PPs Submission: Complied Provision is made for the housing of construction labour within the site with all necessary infrastructure and facilities such as fuel for cooking, mobile toilets, mobile STP, safe drinking water, medical health care, creche etc. are provided		Date: 18/12/2025
36	Human Health Environment	Occupational health surveillance of the workers shall be done on a regular basis.
PPs Submission: Complied Occupational health surveillance of the workers is being carried out		Date: 18/12/2025
37	Corporate Environmental Responsibility	The company shall have a well laid down environmental policy duly approved by the Board of Directors. The environmental policy should prescribe for standard operating procedures to have proper checks and balances and to bring into focus any infringements/deviation/violation of the environmental / forest /wildlife norms/ conditions. The company shall have defined system of reporting infringements / deviation / violation of the environmental / forest / wildlife norms / conditions and / or shareholders / stake holders. The copy of the board resolution in this regard shall be submitted to the MoEFandCC as a part of six-monthly report
PPs Submission: Complied DPA is already having Environmental Policy duly signed by Chairperson of the DPA		Date: 18/12/2025
38	Corporate Environmental Responsibility	A separate Environmental Cell both at the project and company head quarter level, with qualified personnel shall be set up under the control of senior Executive, who will directly report to the head of the organization
PPs Submission: Complied DPA is already having Environment Management cell. Further, DPA has also appointed expert agency for providing Environmental Experts from time to time. DPA appointed M/s Precitech		Date: 29/12/2025

Laboratories, Vapi for providing Environmental Experts vide work order dated 4/10/2024 (Copy of work order is attached herewith as Annexure G. In addition, it is relevant to submit here that, DPA has appointed a Chief Manager (Environment and Safety) and two Managers (Environment and Safety) on contractual basis for the period of 3 years and further extendable to 2 years (Copy of duty report is attached herewith as Annexure H.		
39	Corporate Environmental Responsibility	Action plan for implementing EMP and environmental conditions along with responsibility matrix of the company shall be prepared and shall be duly approved by competent authority. The year wise funds earmarked for environmental protection measures shall be kept in separate account and not to be diverted for any other purpose. Year wise progress of implementation of action plan shall be reported to the Ministry/Regional Office along with the Six Monthly Compliance Report
PPs Submission: Complied DPA has assigned the work of Planning and monitoring of the of the activities to be undertaken under Environment Management Plan under EIA and EC to GEMI, Gandhinagar vide work order dated 25/10/2023. The work is completed final report is communicated along with compliance report submitted on 02/06/2025.	Date: 18/12/2025	
40	Corporate Environmental Responsibility	Self environmental audit shall be conducted annually. Every three years third party environmental audit shall be carried out.
PPs Submission: Complied DPA has appointed GUIDE, Bhuj for the work of To carry out Environment Audit of the DPA with work order dated 15/07/2023. The work is completed final report communicated along with compliance submitted on 03/02/2025.	Date: 18/12/2025	
41	MISCELLANEOUS	The project proponent shall make public the environmental clearance granted for their project along with the environmental conditions and safeguards at their cost by prominently advertising it at least in two local newspapers of the District or State, of which one shall be in the vernacular language within seven days and in addition this shall also be displayed in the project proponents website permanently.
PPs Submission: Complied DPA has already displayed the EC copies in their website www.deendayalport.gov.in DPA has given advertisement in the local newspaper regarding Environmental Clearance granted by the MoEF and CC, GoI for the subject project as under dated 10/01/2024. A copy of same submitted along with the compliance report submitted on 29/07/2024	Date: 18/12/2025	
42	MISCELLANEOUS	The copies of the environmental clearance shall be submitted by the project proponents to the Heads of local bodies, Panchayats and Municipal Bodies in addition to the relevant offices of the Government who in turn has to display the same for 30 days from the date of receipt
PPs Submission: Complied DPA vide letter dated 04/01/2024 has already been communicated copy of EC and CRZ Clearance accorded by the MoEF and CC, GoI dated 01/01/2024 to the Heads of Local bodies, Panchayats and Municipal Bodies etc. A copy of same submitted along with the compliance report submitted on 29/07/2024	Date: 18/12/2025	
43	MISCELLANEOUS	The project proponent shall upload the status of compliance of the stipulated environment clearance conditions, including results of monitored data on their website and update the same on half-yearly basis.

PPs Submission: Complied DPA has already submitted the six-monthly compliance reports of the stipulated environment clearances including results of monitored data to MoEF and CC vide its letter dated 29/07/2024. The same is also uploaded on the official website of Deendayal Port Authority (www.deendayalport.gov.in).	Date: 18/12/2025

44	MISCELLANEOUS	The project proponent shall submit six-monthly reports on the status of the compliance of the stipulated environmental conditions on the website of the ministry of Environment, Forest and Climate Change at environment clearance portal.

PPs Submission: Being Complied DPA has already submitted the six-monthly compliance reports of the stipulated environment clearances including results of monitored data to MoEF and CC vide its letter dated 02/06/2025.	Date: 18/12/2025

45	MISCELLANEOUS	The project proponent shall submit the environmental statement for each financial year in Form-V to the concerned State Pollution Control Board as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently and put on the website of the company.

PPs Submission: Being Complied DPA has regularly submitting environmental statement for each financial year in Form-V to the concerned State Pollution Control Board	Date: 18/12/2025

46	MISCELLANEOUS	The criteria pollutant levels namely; PM2.5, PM10, SO2, NOx (ambient levels) or critical sectoral parameters, indicated for the project shall be monitored and displayed at a convenient location near the main gate of the company in the public domain

PPs Submission: Being Complied DPA has appointed Gujarat Environment Management Institute (GEMI), Gandhinagar for regular monitoring of environmental parameters for the whole port area vide work order dated 15/02/2023. A copy of latest monitoring report is attached herewith as Annexure B	Date: 29/12/2025

47	MISCELLANEOUS	The project proponent shall inform the Regional Office as well as the Ministry, the date of financial closure and final approval of the project by the concerned authorities, commencing the land development work and start of production operation by the project

PPs Submission: Complied DPA board approved the project at cost of Rs 211.61 Crores.	Date: 18/12/2025

48	MISCELLANEOUS	The project authorities must strictly adhere to the stipulations made by the State Pollution Control Board and the State Government.

PPs Submission: Agreed to Comply Point noted	Date: 18/12/2025

49	MISCELLANEOUS	The project proponent shall abide by all the commitments and recommendations made in the EIA/EMP report, commitment made during Public Hearing and also that during their presentation to the Expert Appraisal Committee.

PPs Submission: Agreed to Comply Point noted	Date: 18/12/2025

50	MISCELLANEOUS	No further expansion or modifications in the Industrial Area shall

		be carried out without prior approval of the Ministry of Environment, Forests and Climate Change (MoEFandCC).
PPs Submission: Agreed to Comply Point noted		Date: 18/12/2025
51	MISCELLANEOUS	Concealing factual data or submission of false/fabricated data may result in revocation of this environmental clearance and attract action under the provisions of Environment (Protection) Act, 1986
PPs Submission: Agreed to Comply Point noted		Date: 18/12/2025
52	MISCELLANEOUS	The Ministry may revoke or suspend the clearance, if implementation of any of the above conditions is not satisfactory.
PPs Submission: Agreed to Comply Point noted		Date: 18/12/2025
53	MISCELLANEOUS	The Ministry reserves the right to stipulate additional conditions if found necessary. The Company in a time bound manner shall implement these conditions.
PPs Submission: Agreed to Comply Point noted		Date: 18/12/2025
54	MISCELLANEOUS	The Regional Office of this Ministry shall monitor compliance of the stipulated conditions. The project authorities should extend full cooperation to the officer (s) of the Regional Office by furnishing the requisite data / information/monitoring reports.
PPs Submission: Agreed to Comply Point noted		Date: 18/12/2025
55	MISCELLANEOUS	The above conditions shall be enforced, inter-alia under the provisions of the Water (Prevention and Control of Pollution) Act, 1974, the Air (Prevention and Control of Pollution) Act, 1981, the Environment (Protection) Act, 1986, Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016 and the Public Liability Insurance Act, 1991 along with their amendments and Rules and any other orders passed by the Honble Supreme Court of India / High Courts and any other Court of Law relating to the subject matter.
PPs Submission: Agreed to Comply Point noted		Date: 18/12/2025
56	MISCELLANEOUS	Any appeal against this EC shall lie with the National Green Tribunal, if preferred, within a period of 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.
PPs Submission: Agreed to Comply -----------		Date: 18/12/2025

Visit Remarks

Last Site Visit Report Date:	14/11/2022
Additional Remarks:	

Note: This acknowledgement is as per the details submitted by project proponent. In no way is this document to be considered as conclusion on any action on the compliance of the project. This is strictly for the project proponent's reference purpose.

Annexure–A

COMPLIANCE REPORT (for the period up to September 2025)

Subject: Status of Compliance with the conditions stipulated by Gujarat State Coastal Zone Management Authority, Gandhinagar, in CRZ Recommendation Letter granted for "**Augmentation of liquid handling capacity from 8 MMTPA to 23.8 MMTPA through modernization of existing pipeline network at oil jetty area of Deendayal Port Trust**".

CRZ Recommendations: Letter No. ENV-I0-2021-41-T dated 25 August 2022, of Director (Environment) & Member Secretary, GCZMA, Forest & Environment Department, GoG.

**Note: Based on the recommendation of* the GCZMA, MoEF&CC, GoI *had accorded Environmental & CRZ Clearance vide letter dated 01/01/2024*

Sr. No.	Conditions in CRZ Recommendation Letter	Compliance
	Specific Conditions	
1	Project proponent unit shall scrap of existing 125 pipelines and remaining 42 pipelines may be maintain while 84 new pipeline will be laid.	It is assured that due care is being taken while scrapping of existing 125 pipelines.
2	Project proponent shall carry out proposed activities, replacement & revamping of existing pipeline network at oil jetty area and no new land shall be use.	Activities of replacement & revamping is being carried out at the existing oil jetty area and no new land is used.
3	Project proponent shall obtain consent to establish for their proposed expansion from 8 MMTPA to 23.08 MMTPA from GPCB.	The Consent to Establish (CTE) from the GPCB had already been obtained vide CTE amendment (CTE 115467) granted by the GPCB vide letter no. PC/CCA-KUTCH-812(5)/GPCB ID 28494/609592 dated 23/12/2021 with a validity period 11/2/2026 A copy of same had already been submitted along with compliance report submitted on 29/07/2024.
4	Project proponent shall not carry out any construction activities or any activities till obtaining CRZ Clearance from MoEF&CC, new Delhi	DPA has already received CRZ recommendation from GCZMA vide letter no. ENV-10-2021-41-T cell dated 25/08/2022. Additionally, DPA has also received EC and CRZ clearance from MoEF&CC vide file no. letter F. No. 10-26/2018-IA-III dated 01/01/2024.
5	Project Proponent shall adhere to all recommendation given by MECON Ltd. Ranchi, Jharkhand.	It is assured that, recommendation given by MECON Ltd. Ranchi, Jharkhand is being adhered to
6	Project Proponent shall adhere to undertaking dated 25.01.202	It is assured that, undertaking dated 25/01/202 being adhered to.
7	Project Proponent shall carry out Mangrove Plantation in 50 Ha area with consultant of concern District Forest Office of District and Gujarat Ecology commission. Necessary report in this regard may be submitted periodically to this office.	DPA has assigned the work for the "Mangrove Plantation in an area of 50 Ha for the Deendayal Port Authority to GUIDE, Bhuj vide work order dated 10/06/2024. The work is completed copy of final report is attached herewith as **Annexure A** Additionally, 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
8	Project Proponent shall strictly adhere to all conditions of Terms of Reference issued by MoEF&CC, GOI vide F.No. 10-26/2018-IA-III dated 14/06/2018.	DPA has already received the EC and CRZ clearance from MoEF&CC vide file no. letter F. No. 10-26/2018-IA-III dated 01/01/2024. A copy of same had already been submitted along with compliance report submitted on 29/07/2024
9	Project Proponent shall strictly adhere to all conditions of Amendment Terms of Reference issued by MoEF&CC, GOI vide F.No. 10-26/2018-IA-III dated 11/06/2020.	

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: August - September 2025)

Document Ref No.: GEMI/DPA/782(2)(6)/2025/50

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 Report (EMR) for the period 15th August to 14th September 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 (August – September 2025)"* is prepared.

- **Name of the Report:** *Environment Monitoring Report (August-September 2025)*
- **Date of Issue:** 12/11/2025
- **Version:** 1.0
- **Report Ref.:** GEMI/DPA/782(2)(6)/2025/50

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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 16th August -15th September 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:

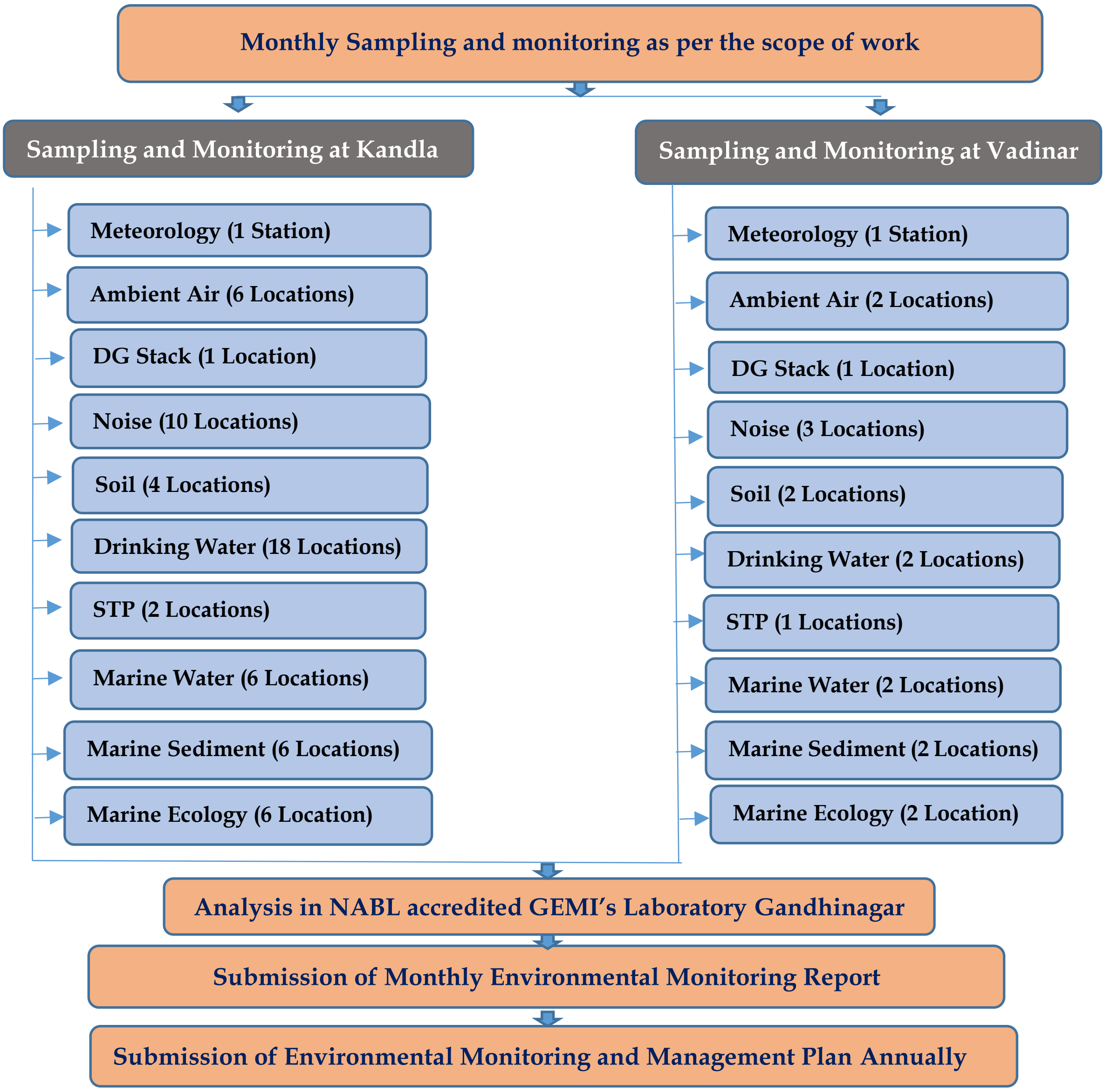


Figure 1: Methodology flow chart

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	°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.

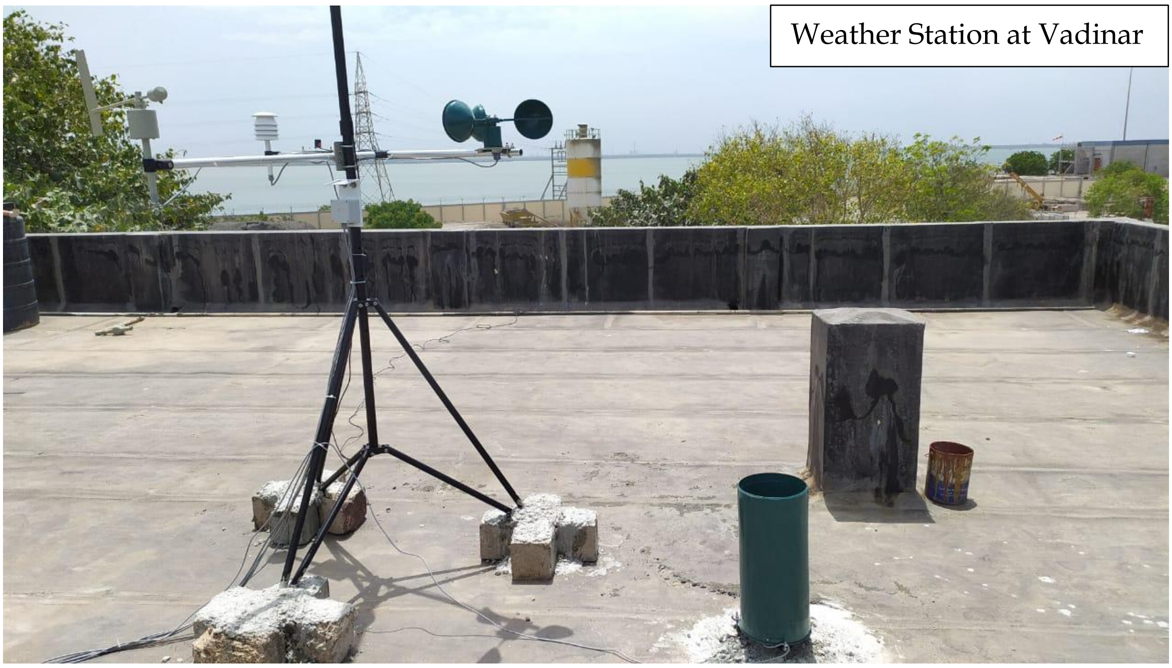


Figure 2: Photographs of Automatic Weather Monitoring Station at Kandla and Vadinar

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			
August-September 2025	4.35	64	0.6	30.21	37.9	24.7	74.56	90.4	49.8	66.17	North	0.33
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			
August-September 2025	3.62	28	0.6	27	36.3	22.2	79.72	91.5	56.8	67.58	SSW	0.16

3.3 Data Interpretation and Conclusion

- **Temperature**

a. **Kandla:** The ambient temperature for the monitoring period varies between the range of 24.7– 37.9°C for Kandla, with average temperature of 30.21°C.

b. **Vadinar:** The ambient temperature for the monitoring period varies between the range of 22.2-36.3°C for Vadinar, with average temperature of 27°C.

- **Relative Humidity**

a. **Kandla**: The Relative Humidity recorded between the range of 49.8–90.4, with average Humidity of 74.56%.

b. **Vadinar:** During the study period, the Relative Humidity varies between 56.8-91.5%, with average Humidity of 79.72%.

- **Rainfall**

a. **Kandla:** 0.33 mm/hr rainfall was observed at Kandla.

b. **Vadinar:** 0.16 mm/hr 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 0.6–64 Km/hr.

b. **Vadinar:** During the monitoring period, the Wind speed recorded ranges between 0.6-28 Km/hr.

- **Solar Radiation:**

a. **Kandla:** The average Solar Radiation for the monitoring period was recorded as 66.17 W/m^2.

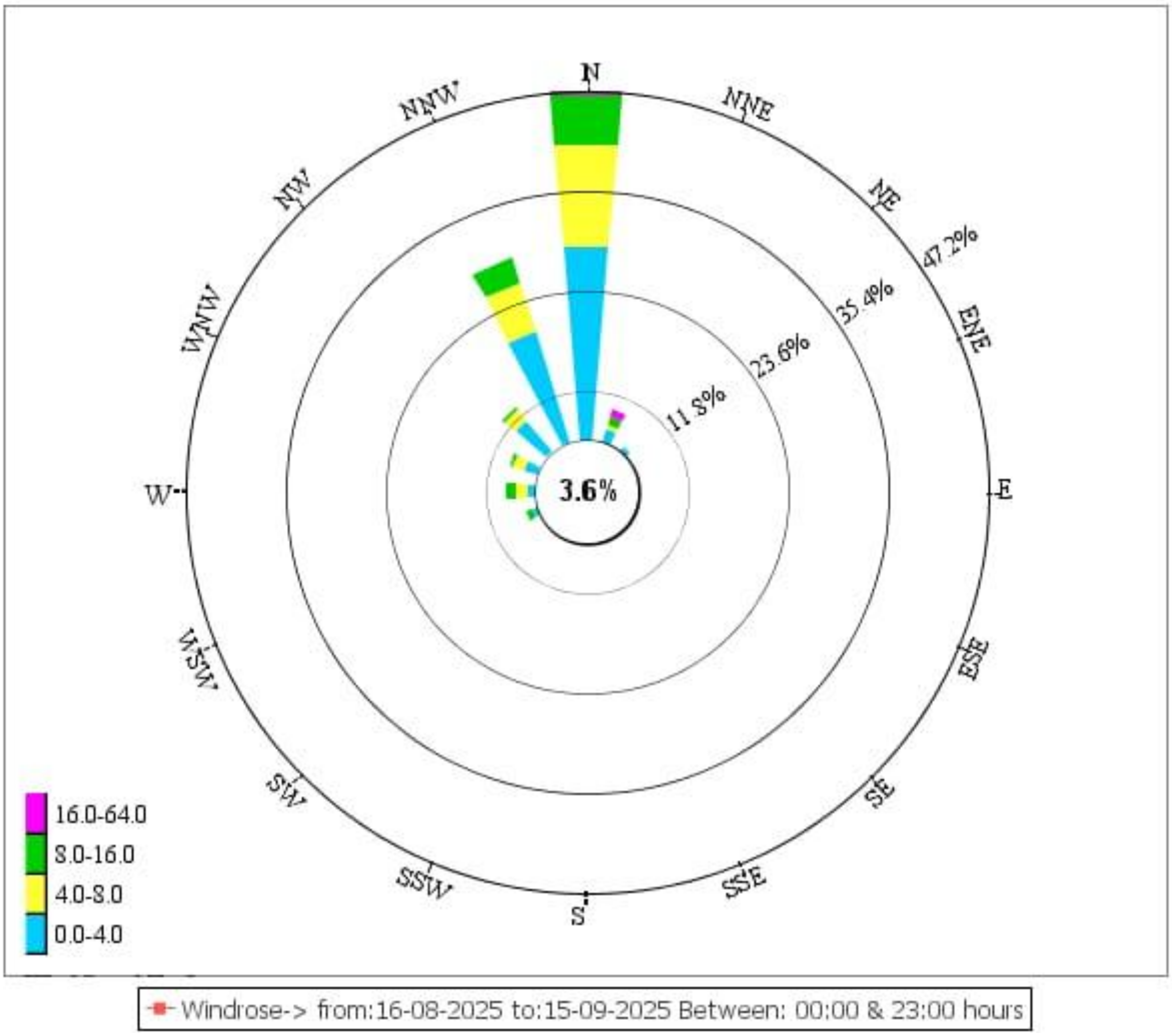
b. **Vadinar:** The average Solar Radiation was recorded as 67.58 W/m^2.

- **Wind rose diagram -**

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

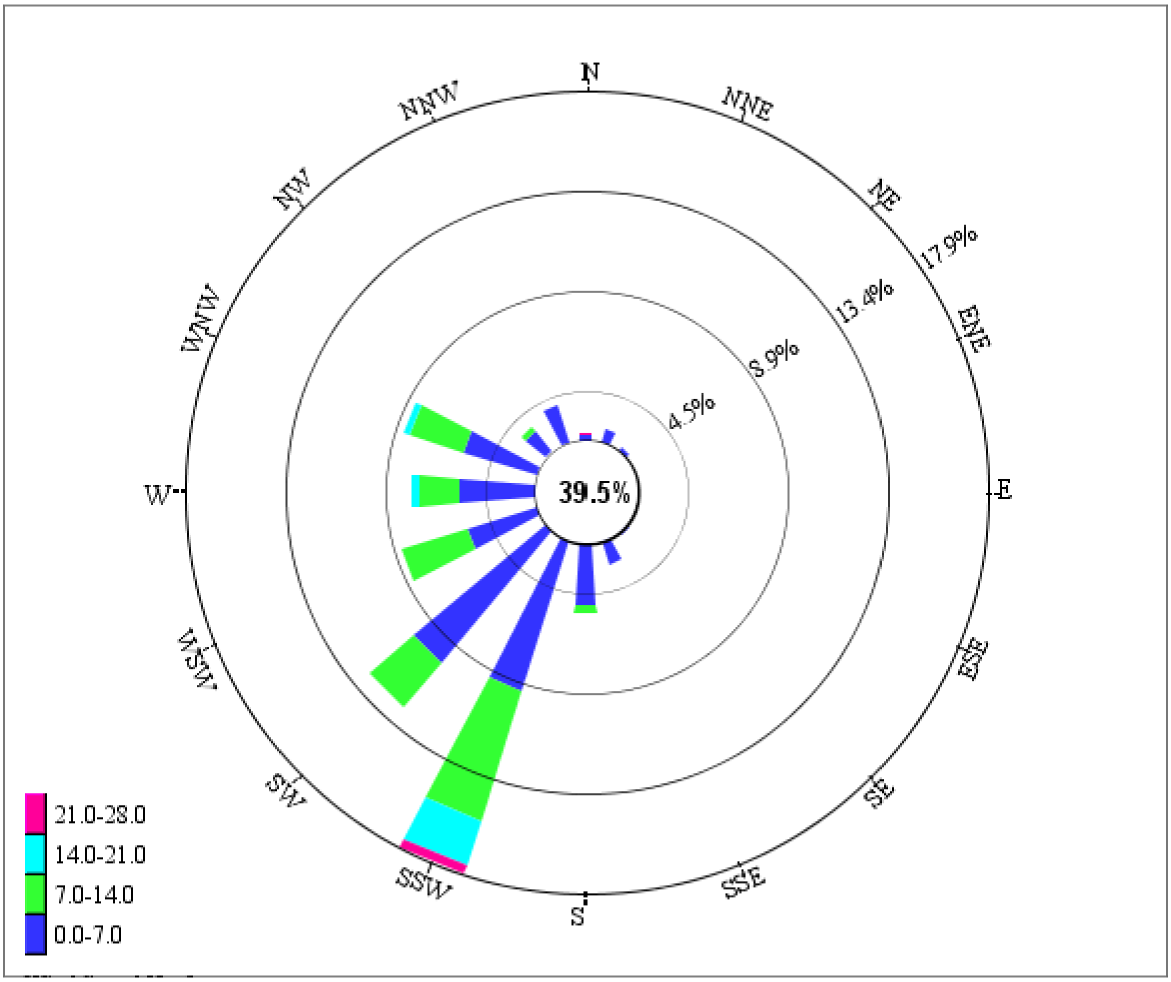
This Wind Rose Diagram reveals that at Kandla and Vadinar, during the monitoring period, the prevailing winds predominantly blow from the North at Kandla. At Vadinar, the winds were observed to blow from South South West Direction.

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)



Windrose-> from:17-08-2025 to:16-09-2025 Between: 00:00 & 23:00 hours

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 16th August to 15th September 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**.

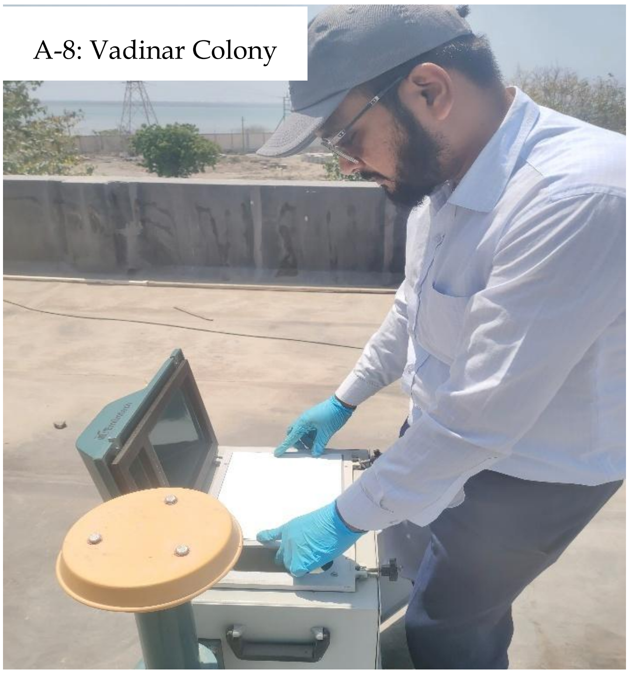
Table 4: Details of Ambient Air monitoring locations

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	Bansal Canteen	23.027197N 70.195451E	Vehicular activity and dust emission
4.		A-4	Sewa Sadan-3	23.009945N 70.221745 E	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

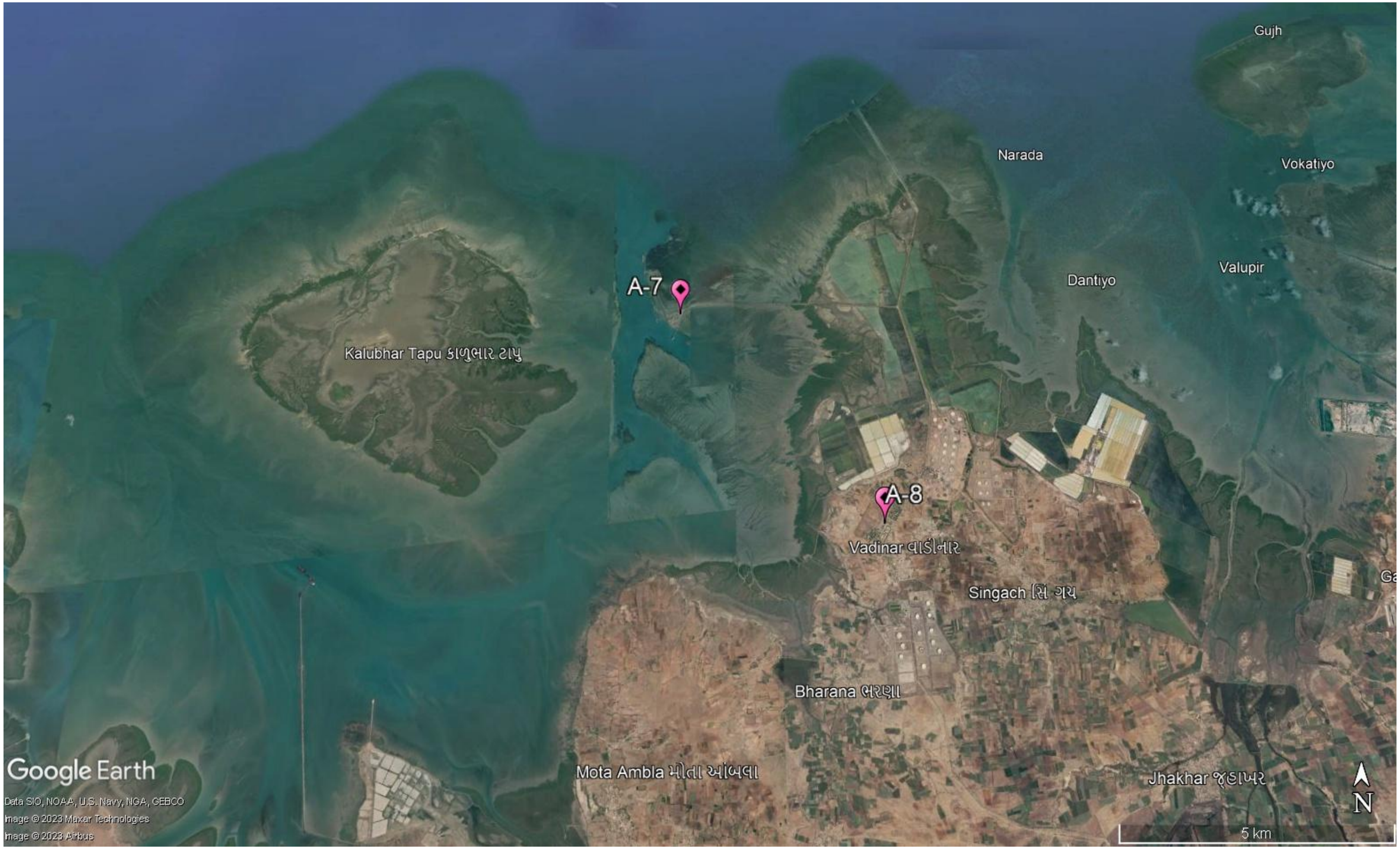
The two ambient air monitoring locations have been changed: Location A-3, previously at Kandla Port Colony, has now been shifted to Bansal Canteen, and Location A-4, earlier at Marine Bhavan, is now relocated to Sew Sadan-3. The monitoring locations at Kandla and Vadinar have been depicted in map in **Map 4 and 5** respectively.

Ambient Air monitoring photos

Kandla	
 A-1: Oil Jetty No. 1	 A-2: Oil Jetty No. 7
 A-3: Bansal Canteen	 A-4: Sewa Sadan-3
 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

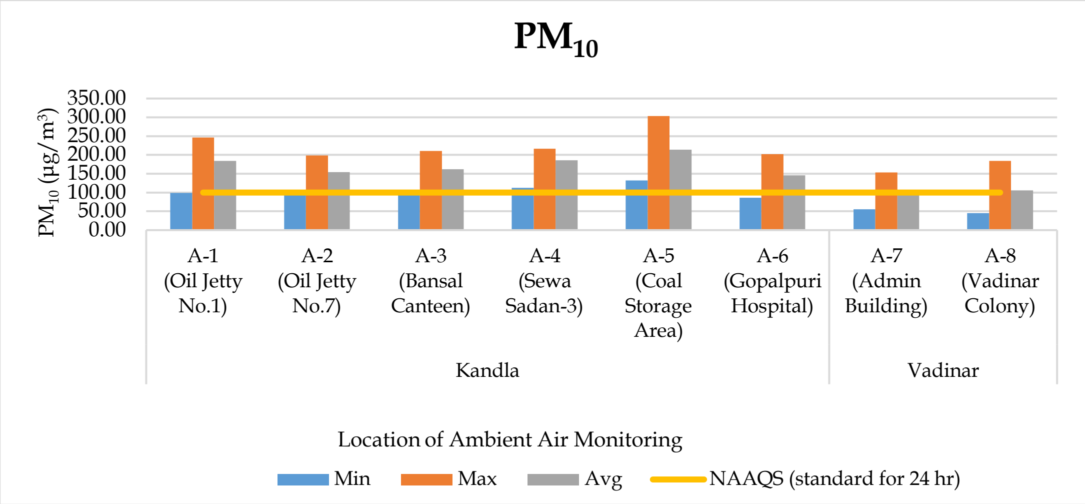
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	**PM_{10} (µg/m³)**	**$PM_{2.5}$ (µg/m³)**	**SO_2 (µg/m³)**	**NO_X (µg/m³)**	**VOC (µg/m³)**	**CO (mg/m³)**
	Duration	**(24 hr)**				**(2 hr)**	**(1 hr)**
	NAAQS by CPCB / **Monitoring days**	**100**	**60**	**80**	**80**	**-**	**2**
A-1: Oil Jetty No.1,	18-08-2025	156.24	31.25	8.36	12.21	0.12	0.81
	20-08-2025	166.33	33.27	9.65	<6	0.08	0.79
	25-08-2025	200.15	40.03	15.62	11.23	0.19	0.85
	28-08-2025	194.26	38.85	22.11	<6	0.21	0.81

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
Kandla	01-09-2025	99.12	19.82	26.54	13.24	0.13	0.82
	02-09-2025	246.58	49.32	6.21	22.05	0.16	0.86
	08-09-2025	210.21	42.04	21.36	<6	0.17	0.88
	10-09-2025	199.52	39.90	8.62	19.21	0.24	0.80
	Minimum	**99.12**	**19.82**	**6.21**	**11.23**	**0.08**	**0.79**
	Maximum	**246.58**	**49.32**	**26.54**	**22.05**	**0.24**	**0.88**
	Average	**184.05**	**36.81**	**14.81**	**15.59**	**0.16**	**0.83**
	Std. Deviation	**43.91**	**8.78**	**7.70**	**4.76**	**0.05**	**0.03**
A-2: Oil Jetty No.7, Kandla	18-08-2025	96.24	19.25	9.46	15.43	0.13	0.84
	20-08-2025	123.52	24.70	6.12	14.11	0.16	0.82
	25-08-2025	154.21	30.84	10.46	18.32	0.17	0.80
	28-08-2025	198.25	39.65	<5	14.33	0.12	0.83
	01-09-2025	162.35	32.47	18.42	<6	0.11	0.85
	02-09-2025	184.23	36.85	13.63	9.27	0.08	0.81
	08-09-2025	164.21	32.84	19.41	12.20	0.15	0.82
	10-09-2025	152.45	30.49	7.68	18.24	0.2	0.84
	Minimum	**96.24**	**19.25**	**6.12**	**9.27**	**0.08**	**0.80**
	Maximum	**198.25**	**39.65**	**19.41**	**18.32**	**0.20**	**0.85**
	Average	**154.43**	**30.89**	**12.17**	**14.56**	**0.14**	**0.83**
	Std. Deviation	**32.32**	**6.46**	**5.17**	**3.22**	**0.04**	**0.02**
A-3: Bansal Canteen , Kandla	18-08-2025	165.24	33.05	15.22	<6	0.22	0.79
	20-08-2025	101.25	20.25	9.45	15.23	0.23	0.82
	25-08-2025	154.65	30.93	18.43	14.28	0.08	0.83
	28-08-2025	177.20	35.44	15.46	<6	0.15	0.82
	01-09-2025	210.33	42.07	<5	16.36	0.12	0.79
	02-09-2025	138.24	27.65	14.53	17.57	0.14	0.84
	08-09-2025	145.22	29.04	7.45	13.43	0.16	0.86
	10-09-2025	205.24	41.05	16.32	12.23	0.07	0.80
	Minimum	**101.25**	**20.25**	**7.45**	**12.23**	**0.07**	**0.79**
	Maximum	**210.33**	**42.07**	**18.43**	**17.57**	**0.23**	**0.86**
	Average	**162.17**	**32.43**	**13.84**	**14.85**	**0.15**	**0.82**
	Std. Deviation	**35.93**	**7.19**	**3.92**	**1.95**	**0.06**	**0.02**
A-4: Sewa Sadan - 3, Kandla	18-08-2025	188.24	37.65	6.31	6.68	0.18	0.81
	20-08-2025	200.33	40.07	<5	<6	0.19	0.80
	25-08-2025	195.44	39.09	6.43	11.23	0.18	0.85
	28-08-2025	216.24	43.25	8.13	<6	0.18	0.80
	01-09-2025	164.27	32.85	10.34	14.55	0.13	0.81
	02-09-2025	206.61	41.32	<5	<6	0.05	0.87
	08-09-2025	112.36	22.47	13.52	15.63	0.08	0.88
	10-09-2025	202.32	40.46	<5	17.69	0.12	0.82
	Minimum	**112.36**	**22.47**	**6.31**	**6.68**	**0.05**	**0.78**
	Maximum	**216.24**	**43.25**	**13.52**	**17.69**	**0.19**	**0.89**

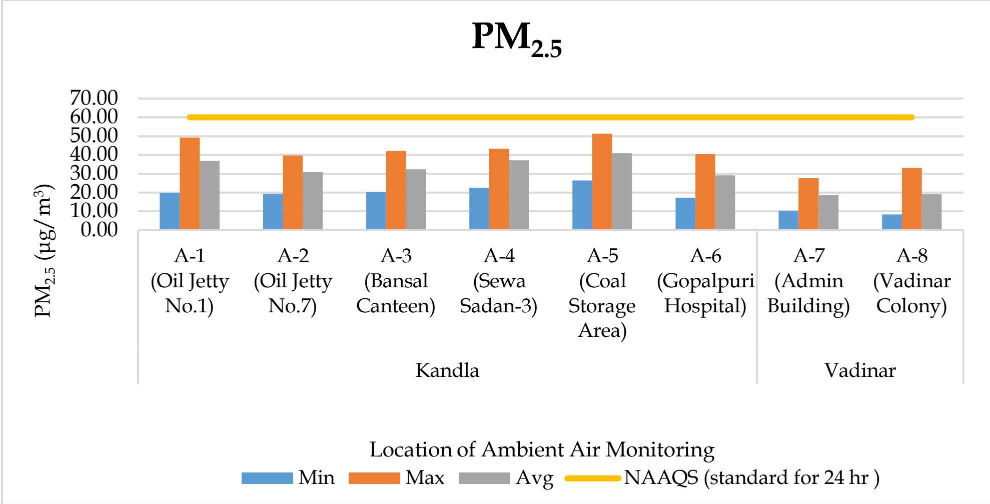
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
	Average	**185.73**	**37.15**	**8.95**	**13.16**	**0.14**	**0.83**
	Std. Deviation	**33.38**	**6.68**	**3.03**	**4.31**	**0.05**	**0.03**
A-5: Coal Storage Area, Kandla	18-08-2025	210.66	42.13	29.54	11.34	0.2	0.81
	20-08-2025	186.32	37.26	14.52	9.22	0.06	0.82
	25-08-2025	132.26	26.45	15.12	18.42	0.26	0.88
	28-08-2025	200.52	40.10	21.21	26.32	0.07	0.90
	01-09-2025	303.45	46.25	21.42	17.17	0.15	0.75
	02-09-2025	212.36	42.47	20.36	26.26	0.15	0.85
	08-09-2025	209.51	41.90	17.54	25.43	0.17	0.86
	10-09-2025	256.44	51.29	12.26	19.43	0.13	0.83
	Minimum	**132.26**	**26.45**	**12.26**	**9.22**	**0.06**	**0.75**
	Maximum	**303.45**	**51.29**	**29.54**	**26.32**	**0.26**	**0.90**
	Average	**213.94**	**40.98**	**19.00**	**19.20**	**0.15**	**0.84**
	Std. Deviation	**49.95**	**7.21**	**5.43**	**6.61**	**0.07**	**0.05**
A-6: Gopalpuri Hospital, Kandla	18-08-2025	86.52	17.30	7.21	<6	0.09	0.71
	20-08-2025	112.22	22.44	9.26	10.32	0.1	0.79
	25-08-2025	132.68	26.54	8.54	16.43	0.14	0.81
	28-08-2025	154.22	30.84	8.23	11.21	0.16	0.85
	01-09-2025	121.32	24.26	6.45	<6	0.09	0.79
	02-09-2025	172.54	34.51	8.02	<6	0.1	0.66
	08-09-2025	202.33	40.47	10.22	<6	0.11	0.84
	10-09-2025	187.41	37.48	<5	12.43	0.15	0.81
	Minimum	**86.52**	**16.14**	**6.12**	**6.45**	**0.09**	**0.79**
	Maximum	**202.33**	**34.47**	**9.76**	**13.46**	**0.16**	**0.84**
	Average	**146.16**	**25.54**	**7.56**	**9.68**	**0.12**	**0.81**
	Std. Deviation	**39.87**	**6.42**	**1.20**	**3.01**	**0.03**	**0.02**
A-7: Admin Building, Vadinar	18-08-2025	91.25	16.42	7.42	13.46	0.04	0.65
	20-08-2025	55.22	10.32	10.25	19.23	0.19	0.63
	25-08-2025	126.21	22.71	32.65	<6	0.13	0.69
	28-08-2025	153.26	27.58	23.21	<6	0.15	0.7
	01-09-2025	84.25	15.16	<5	<6	0.19	0.72
	02-09-2025	101.41	18.25	<5	<6	0.16	0.73
	08-09-2025	122.08	21.55	<5	12.55	0.09	0.72
	10-09-2025	92.35	16.52	6.21	7.22	0.18	0.75
	Minimum	**55.22**	**10.32**	**6.21**	**7.22**	**0.04**	**0.63**
	Maximum	**153.26**	**27.58**	**32.65**	**19.23**	**0.19**	**0.75**
	Average	**103.25**	**18.56**	**15.95**	**13.12**	**0.14**	**0.70**
	Std. Deviation	**30.04**	**5.29**	**11.53**	**4.92**	**0.05**	**0.04**
A-8: Vadinar Colony,	18-08-2025	84.52	15.21	8.26	9.45	0.25	0.70
	20-08-2025	101.22	18.21	12.34	<6	0.2	0.62
	25-08-2025	111.56	20.08	30.21	10.36	0.11	0.59
	28-08-2025	184.13	33.14	15.34	8.45	0.22	0.65

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**
Vadinar	01-09-2025	45.21	8.43	5.21	<6	0.15	0.71
	02-09-2025	123.36	22.20	<5	<6	0.14	0.54
	08-09-2025	102.27	18.40	<5	29.51	0.13	0.58
	10-09-2025	95.24	17.14	7.54	9.11	0.14	0.56
	Minimum	**45.21**	**8.43**	**5.21**	**8.45**	**0.11**	**0.54**
	Maximum	**184.13**	**33.14**	**30.21**	**29.51**	**0.25**	**0.71**
	Average	**105.94**	**19.10**	**13.15**	**13.38**	**0.17**	**0.62**
	Std. Deviation	**39.18**	**6.99**	**9.11**	**9.05**	**0.05**	**0.06**

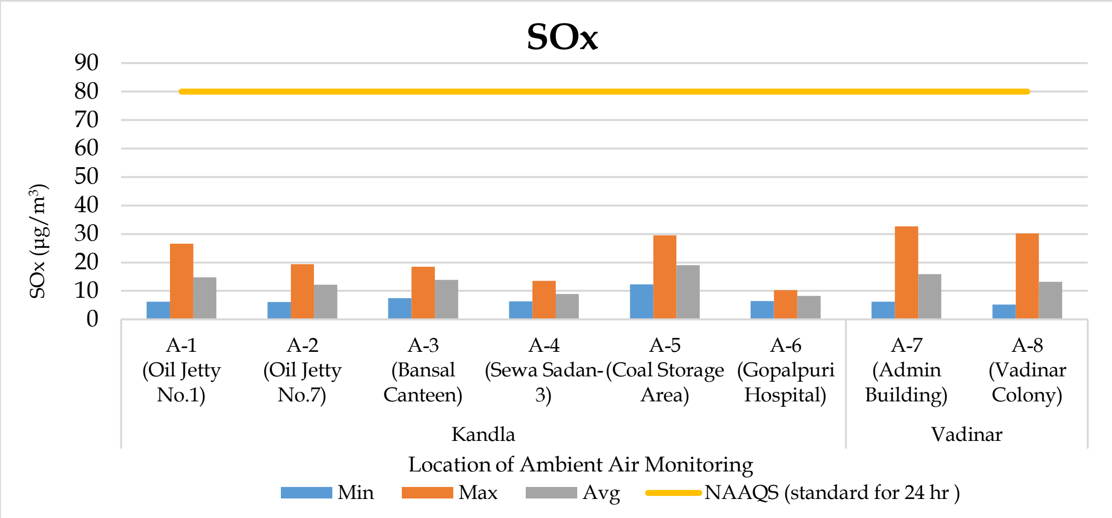
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar)



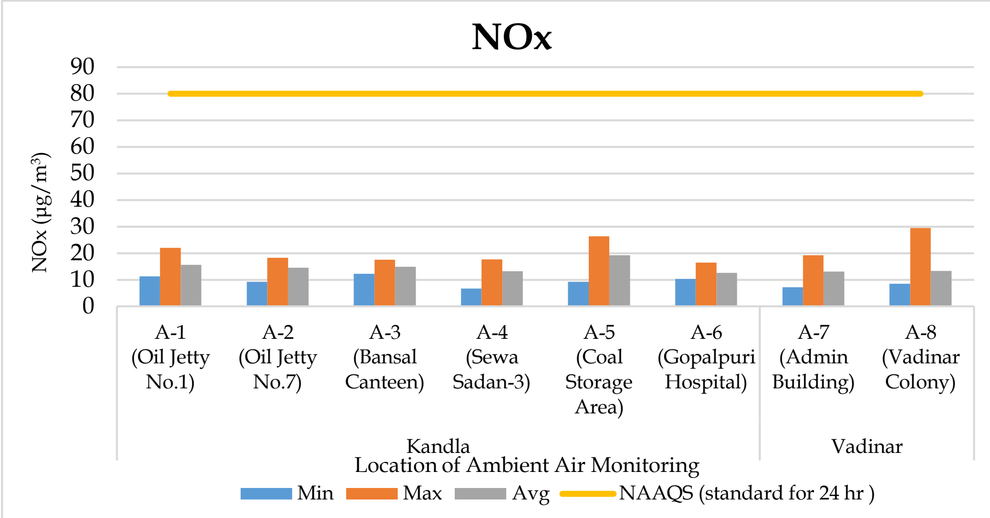
Graph 1: Spatial trend in Ambient PM_{10} Concentration



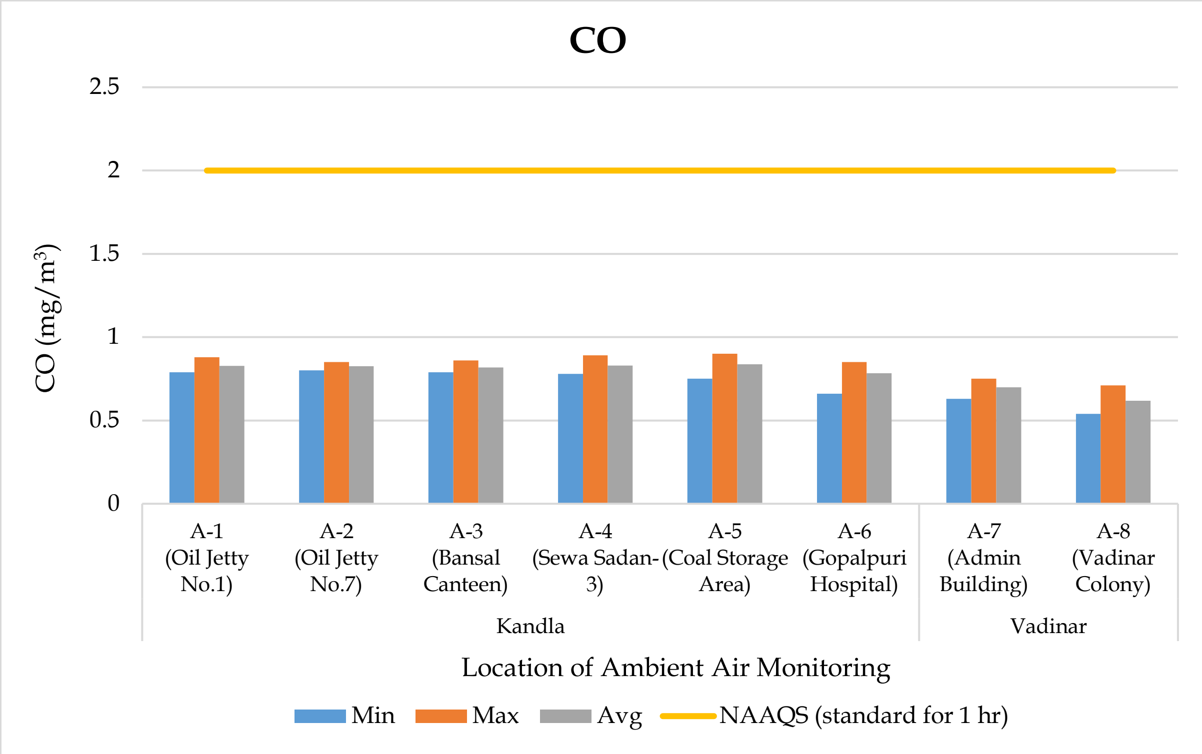
Graph 2: Spatial trend in Ambient $PM_{2.5}$ Concentration



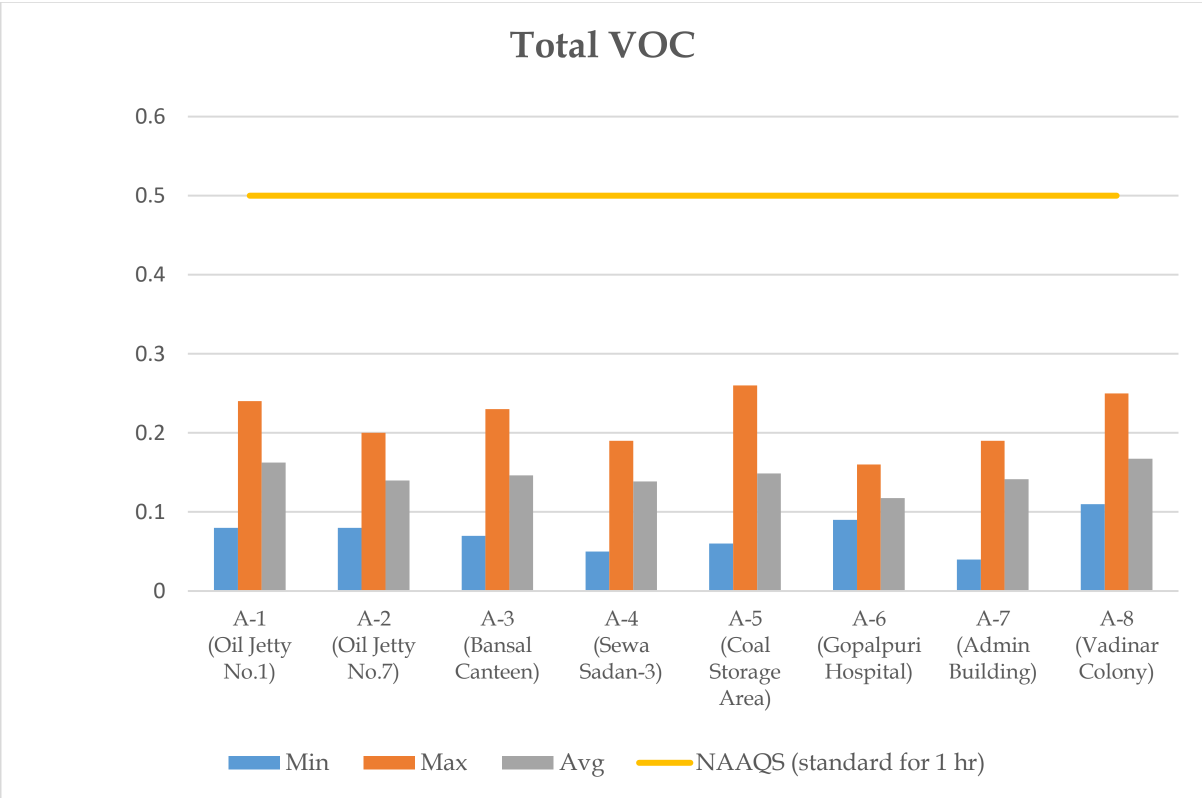
Graph 3: Spatial Trend in Ambient SOx Concentration



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	0	0	0	0	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	0.450	0.680	0.180	0.180	1.520	1.170	0.000	0.000
2	Acenaphthylene	0.050	0.090	0.110	0.960	0.460	0.500	0.050	0.000
3	Acenaphthene	0.010	0.040	0.420	0.060	0.650	0.000	0.000	0.000
4	Fluorene	0.500	0.250	0.220	0.240	0.210	0	0.000	0.000
5	Anthracene	0.300	0.360	0.290	0.620	0.330	0.100	0.090	0.000
6	Phenanthrene	0.075	0.075	0.080	0.080	0.000	0.240	0.030	0.000
7	Fluoranthene	0.060	0.840	0.610	0.180	0.600	0.390	0.000	0.000
8	Pyrene	0.085	0.640	0.420	0.720	0.710	0.300	0.060	0.000
9	Chrycene	0.920	1.220	0.620	0.510	0.760	1.120	0.150	0.070
10	Banz(a)anthracene	0.750	1.010	0.490	0.410	0.440	0.880	0.080	0.000
11	Benzo[k]fluoranthene	0.000	0.000	0.000	0.000	0.000	3.200	0.480	0.510
12	Benzo[b]fluoranthene	0.000	0.000	0.000	0.000	0.000	1.250	0.070	0.120
13	Benzopyrene	2.110	3.265	2.020	1.990	3.101	2.210	0.310	0.480
14	Indeno [1,2,3-cd] fluoranthene	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	Dibenz(ah)anthracene	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	Benzo[ghi]perylene	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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	0	0	0	0	0	0	0

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 **86.52 to 256.44 µg/m³** with an average value of **172.91 µg/m³**. PM_{10} exceeded NAAQS of all the monitoring locations in Kandla. Whereas, at Vadinar, the concentration varies from **45.21 to 184.13 µg/m³**, with an average value of **104.60 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 **17.30 to 51.29 µg/m³** with average **34.58 µg/m³**. The **$PM_{2.5}$** concentration falls within the NAAQS limit for all locations of Kandla. Whereas, at Vadinar its concentration varies from **8.43 to 33.14 µg/m³** with average **18.83 µg/m³**. Also, due to construction and demolition all around the port contributing in increased particulate matter levels.
- The concentrations of **PM_{10}** at the Vadinar sampling locations are exceeding the limits prescribed by the National Ambient Air Quality Standards (NAAQS), primarily due to ongoing construction activities in the Vicinity.
- The concentration of **SO_x** varies from **6.12 to 29.54 µg/m³** with average concentration as **12.84 µg/m³** at Kandla and **5.21 to 32.65 µg/m³** with average as **14.55 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 **6.68 to 26.32 µg/m³** with average **14.99 µg/m³** at Kandla and **7.22 to 29.51 µg/m³** with average **13.25 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 **0.66 to 0.90 µg/m³** with average **0.82 µg/**m³ at Kandla and **0.54 to 0.75 µg /m³** with average **0.66 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 0.26 µg/m³** at Kandla and **in range of 0.04 to 0.25 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 not detected on the location of Kandla & 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 Value to be **0 µg/m^3**. While at Vadinar, the concentration of NM-VOC falls is found to be **0 µg /m^3** 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 NAAQ
S 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.

- Store fine particulate cargo (e.g., coal, fertilizers) in covered sheds or domes.
- Shrouding shall be carried out in the work site enclosing the dock/proposed facility area. This will act as dust curtain as well achieving zero dust discharge from the site. These curtain or shroud will be immensely effective in restricting disturbance from wind in affecting the dry dock operations, preventing waste dispersion, improving working conditions through provision of shade for the workers.
- Develop green belts using dust-tolerant species along port boundaries and roads.
- 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	70.23	34.65
2.	Sulphur Dioxide (SO_2) (PPM)	100	1.03	N.D.
3.	Oxides of Nitrogen (NO_x) (PPM)	50	23.46	13.25
4.	Carbon Monoxide (CO) (%)	1	0.23	0.03
5.	Carbon Dioxide (CO_2) (%)	-	1.12	1.33

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	55.8	42.5	49.4	70	41.7	34.2	45
2	N-2	West Gate No.1	A	75	61.4	46.2	53.9	70	47.5	41.2	46.2
3	N-3	Canteen Area	B	65	59.2	47.4	52.6	55	49.2	34.6	45.8
4	N-4	Main Gate	A	75	57.9	46.8	52	70	45.2	38.2	45.5
5	N-5	Main Road	A	75	56.2	45.6	50.9	70	43.2	36.2	45.1
6	N-6	Marin Bhavan	B	65	59.1	41.6	51.4	55	47.1	34.6	45.4
7	N-7	Port & Custom Building	B	65	56.2	40.3	49.5	55	45.1	37.4	45.2
8	N-8	Nirman Building	B	65	56.4	41.6	49.3	55	42.6	35.4	45.1
9	N-9	ATM Building	B	65	55.7	42.2	50.5	55	49.7	38.9	45.9
10	N-10	Wharf Area/ Jetty	A	75	58.6	41.2	51.6	70	48.7	36.2	45.5
11	N-11	Near Main Gate	A	75	63.5	54.2	58.8	70	54.3	43.8	49.0
12	N-12	Near Vadinar Jetty	A	75	62.4	56.9	59.8	70	54.7	49.4	52.0
13	N-13	Port Colony Vadinar	C	55	42.9	36.7	39.8	45	38.6	31.7	35.1

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 **40.3 dB(A) to 61.4 dB(A)**, while at Vadinar, he noises levels for the three-location ranged from **36.7 dB(A) to 63.5 dB(A).** Whereas, during Night Time the average Noise Level ranged from **34.2 dB(A) to 49.7 dB(A)** at Kandla and **31.7 dB(A) to 54.7 dB(A)** at Vadinar. In some locations at the Kandla site, spikes in noise levels were observed due to construction and demolition activities.

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	-	9.21	8.85	9.23	8.33	8.16	8.45
2	Conductivity	µS/cm	6548	4265	654	9578	155	298
3	Inorganic Phosphate	Kg/ha	1.26	0.88	1.68	1.1	0.24	0.18
4	Organic Carbon	%	0.26	0.44	0.44	0.28	0.65	0.56
5	Organic Matter	%	0.33	0.56	1.1	0.47	0.72	0.26
6	SAR	meq/L	8.56	9.12	1.35	13.25	0.16	0.2
7	Aluminium	mg/Kg	13562.26	10255.68	6587.16	12365.33	28563.35	21472.38
8	Chromium	mg/Kg	65.32	55.21	45.16	60.25	82.14	55.21
9	Nickel	mg/Kg	31.26	27.54	18.62	22.15	28.54	25.11
10	Copper	mg/Kg	45.21	55.47	32.51	42.13	66.21	72.14
11	Zinc	mg/Kg	53.33	60.21	22.14	42.18	42.15	59.21
12	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	3.65	2.11	4.21	6.25	0.55	0.29
14	Arsenic	mg/Kg	0.2	0.07	1.01	2.12	BQL	BQL
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	60.13	50.24	38.52	51.23	55.12	62.54
17	Sand	%	32.08	57.51	62.12	48.21	66.21	69.57
18	Silt	%	42.31	38.23	33.36	23.14	26.14	28.21
19	Clay	%	25.61	4.26	4.52	28.65	7.65	2.22
20	Texture	-	slit sandy	Sandy loam	sandy loam	Loam	sandy loam	Sandy loam

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 **8.21 to 9.23,** highest at location S-3 (Khori Creek) and lowest at S-4 (Nakti Creek); while the average pH for Kandla was observed to be **8.905**.

Whereas, at Vadinar the pH value observed at S-5 i.e., **Near SPM (8.16)** and at S-6 i.e., **Near Jetty Area (8.45).** 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 **654-9578 µs/cm**, highest at location S-4 (Nakti Creek) with the average as 5261.25 **µs/cm**. Whereas, at Vadinar the range of conductivity was between the range of **155 to 298 µs/cm** with an average value of 226.5 **µs/cm**.

- At Kandla, the concentration of **Inorganic Phosphate** varied from **0.88-1.68 Kg/ha**, with average **1.23 Kg/ha**. Whereas, at the locations of Vadinar, the Inorganic Phosphate was observed at S-5 i.e., Near SPM (**0.24 Kg/ha**) and detected at S-6 i.e., near Jetty Area (**0.18 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 **0.26 to 0.44 %** while the average TOC at Kandla was detected as **0.35 %.** Whereas, at Vadinar the average TOC was found to be **0.60%** where the observed TOC value found at S-5 i.e. Near SPM (**0.65%**) and S-6 i.e. near Jetty Area to be **0.56 %** respectively.

- The concentration of **Water Holding Capacity** in the soil samples of Kandla and Vadinar varies from **38.52-60.13 %** and **55.12-62.54 %** respectively.

- The concentration of **Sodium Adsorption Ratio** ranges from **1.35–13.25 meq/L** with an average value **8.07 meq/L** at Kandla. Whereas, at Vadinar, the concentration of Sodium Adsorption Ratio ranges from 0.16 to 0.20 **meq/L** with an average SAR was found to be **0.18 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, loamy sand, and silty sand were the soil textures observed at all the monitoring locations of Kandla and Vadinar.

Heavy Metals

For the sampling period, the concentration of **Aluminium** varied from **6587.16 to 13562.26 mg/kg** at Kandla and **21472.38 to 28563.35 mg/kg** at Vadinar and the average value was observed to be **10692.61 and 25017.87 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Chromium** varied from **45.16 to 65.32 mg/kg** at Kandla and **55.21 to 82.14 mg/kg** at Vadinar and the average value was observed to be **56.48 and 68.67 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Nickel** varied from **18.62 to 31.26 mg/kg** at Kandla and **25.11 to 28.54 mg/kg** at Vadinar and the average value was observed to be **24.89 and 26.82 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Zinc** varied from **22.14 to 60.21 mg/kg** at Kandla and **42.15 to 59.21 mg/kg** at Vadinar and the average value was observed to be **44.46 and 50.68 mg/kg** at Kandla and Vadinar monitoring station, respectively

- The concentration of **copper** varied from **32.51 to 55.47 mg/kg** at Kandla and **66.21 to 72.14 mg/kg** at Vadinar and the average value was observed to be **43.83 and 69.17 mg/kg** at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Arsenic** varied from 0.07 **to 2.12 mg/kg** at Kandla and the average value was observed to be **0.85** at Kandla while at Vadinar the average value was observed to be **BQL**.

- The concentration of **Lead** varied from **2.11 to 6.25 mg/kg** at Kandla and the average value was observed to be **4.05** at Kandla while at Vadinar the average value was observed to be **0.42 mg/kg**.

- While other heavy metals in the Soil i.e., **Mercury, 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 analysed 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**	**-**	7.55	7.92	7.50	7.62	7.42	7.36	7.22	7.56	7.12	6.56	7.01	6.95	7.21	7.54	6.92	7.26	7.30	7.15	6.94	7.36
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	-	-	238	20.3	32.6	26.5	40.2	65.8	29.4	36.6	75.4	132.3	155.4	125.8	55.4	49.7	142	16.3	29.7	96.5	232	75.2
4.	Salinity	PSU	-	-	0.16	0.05	0.03	0.03	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.06	0.03	0.02	0.08	0.03	0.03	0.05	0.15	0.02
5.	Turbidity	NTU	**1**	**5**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
6.	Chloride	mg/L	**250**	**1000**	45.63	3.56	10.25	16.24	8.45	15.27	8.13	9.34	22.36	29.57	40.23	29.37	20.13	16.44	36.36	11.05	13.25	25.27	42.45	13.25
7.	Total Hardness	mg/L	**200**	**600**	6	BQL	5	5.5	6	8	3	2.5	5	18	18	23	2.5	3.5	18	BQL	2	6	132	20
8.	Ca Hardness	mg/L	-	-	2	BQL	3	3.5	3.5	6	2.5	1.5	2	10	9	12	1.5	3	8	BQL	1	4	67	9
9.	Mg Hardness	mg/L	-	-	4	BQL	2	2	2.5	2	BQL	1	3	8	9	11	1	BQL	10	BQL	BQL	2	65	11
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**	132	12	16	18	20	31	15	17	32	52	82	62	26	30	74	18	21	60	180	38
12.	TSS	mg/L	-	-	BQL	BQL	4	BQL	BQL	BQL	BQL	3	BQL	BQL	4	BQL	BQL	3	BQL	BQL	1	BQL	BQL	BQL
13.	Fluoride	mg/L	**1.0**	**1.5**	0.42	BQL	0.39	BQL	0.41	0.25	0.31	BQL	0.42	0.38	0.39	0.35	0.26	0.31	0.394	0.39	0.30	0.31	0.65	0.29
14.	Sulphate	mg/L	**200**	**400**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	21.25	BQL
15.	Nitrate	mg/L	**45**	**-**	7.65	BQL	BQL	BQL	BQL	BQL	BQL	BQL	1.54	BQL	BQL	BQL	1.10	BQL	BQL	BQL	BQL	BQL	1.65	BQL
16.	Nitrite	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17.	Sodium	mg/L	-	-	36.21	BQL	2.12	3.95	1.92	1.85	1.24	2.21	3.62	4.11	4.23	6.54	4.69	3.12	9.52	1.02	1.52	3.67	19.54	BQL
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	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	**0.003**	**-**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	**0.05**	**1.5**	BQL	BQL	0.010	BQL	0.005	BQL	BQL	BQL	0.004	0.020	0.004	0.018	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.011
24.	Iron	mg/L	**0.3**	**-**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	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	BQL	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**		60	20	50	BQL	BQL	100	BQL	80	BQL	BQL	30	BQL	15	BQL	BQL	40	BQL	BQL	BQL	40

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 **6.56 to 7.92** with an average pH of **7.28.** In Vadinar, its values ranged from **6.94 to 7.36,** with an average pH of **7.15.** remarkably, the pH values at project locations are within the permissible range of 6.5 to 8.5 specified under IS: 10500:2012.
- **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 & Vadinar, the turbidity was reported **BQL** for All 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 132 mg/L,** with an average concentration of **39.88 mg/L**. while in Vadinar, it ranged from **38 to 180 mg/L,** with average at **109 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 **16.3 to 238 µS/cm**, with an average value of **75.99 µS/cm**. In Vadinar, the EC values showed variation from **75.2 to 232 µS/cm,** with an average value of **153.60 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 **3.56 to 45.63 mg/L**, with an average value of **20.05 mg/L**. In Vadinar, it ranged from **13.25 to 42.45 mg/L**, with an average value of **27.85 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.
- **Total Hardness (TH):** Total Hardness varied from **2 to 23 mg/L**, with the average value as **8.25 mg/L**. While at Vadinar, the variation was observed from **20 to 132 mg/L**; with the average conc. at **76 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 Was found to be **Below Quantification Limit** at all Monitoring locations. In Vadinar, the sulphate

concentration was observed at DW-19 is **21.25 mg/L** & DW-20 is **Below Quantification Limit.**

- **Sodium:** During the monitoring period, at Kandla variation in the concentration of sulphate was observed to be in the range of **1.02 to 36.21 mg/L**, with the average concentration of **5.38 mg/L**. While at Vadinar, the Sodium concentration was Observed to be in range of **BQL to 19.54 mg/L**, with the average Concentration of **19.54 mg/L.**
- **Nitrate:** During the monitoring period, at Kandla & Vadinar variation in the concentration of Nitrate was observed to be in the range of **1.10 to 7.65 mg/L**, with the average concentration of **3.43 mg/L** also majority of the location recorded as "**BQL".** While at Vadinar, the concentration was observed at DW-19 is **1.658 mg/L** & DW-20 is **Below Quantification Limit.**
- **Fluoride:** The concentration was found to be in the range of **0.253 to 0.421** mg/**L** with an average concentration of **0.354 mg/L** at all the monitoring location at Kandla. While at Vadinar the concentration was found to be in the range of **0.298 to 0.658 mg/L** with an average concentration of **0.48 mg/L** for both the monitoring location.
- **Nitrite:** The Concentration was found to be **BQL** in all the monitoring location 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 for location at Kandla While at Vadinar, the Concentration recorded as Below Quantification Limit.
- **Copper:** During the monitoring period, at Kandla variation in the concentration of copper was observed to be in the range of **0.004 to 0.020 mg/L**, with the average concentration of **0.010 mg/L**. While at Vadinar, the concentration was observed at DW-19 is **Below Quantification limit** & DW-20 is **0.011**
- **TSS:** The Concentration was found to be **BQL** in most of the monitoring location except for location DW-3 (North Gate) i.e. 4 mg/L, DW-8 (Nirman Building) i.e. 3 mg/L and DW-11 (Wharf Jetty Area) i.e. 4 mg/L and more locations at Kandla. While at Vadinar, the Concentration was observed at DW-19 & DW-20 is **Below Quantification limit.**
- **Free Residual Chlorine:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration recorded at both location is found Below Quantification Limit.
- **Lead:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla. While at Vadinar, the Concentration recorded as Below Quantification Limit at all the Monitoring locations.
- **Potassium:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration was found to be BQL in both Location.
- **Manganese:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration was found to be BQL in both Location.
- **Zinc:** The Concentration was found to be **BQL** in all of the monitoring location at Kandla While at Vadinar, the Concentration was found to be BQL in both Location.

- **Arsenic:** The concentration was found to be **Below Quantification Limit** in all of the Monitoring Location at Kandla. While at Vadinar was Observed **Below Quantification Limit** at both the locations.
- The parameters such **as Hexavalent Chromium**, and **the metals Arsenic, Cadmium, Total Chromium** 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 Total coliform was observed to be in the range of **BQL to 100 MPN/100ml**. While at Vadinar, the concentration recorded at DW-19 is **Below Quantification Limit** and at DW-20 is **40 MPN/100ml.**

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:

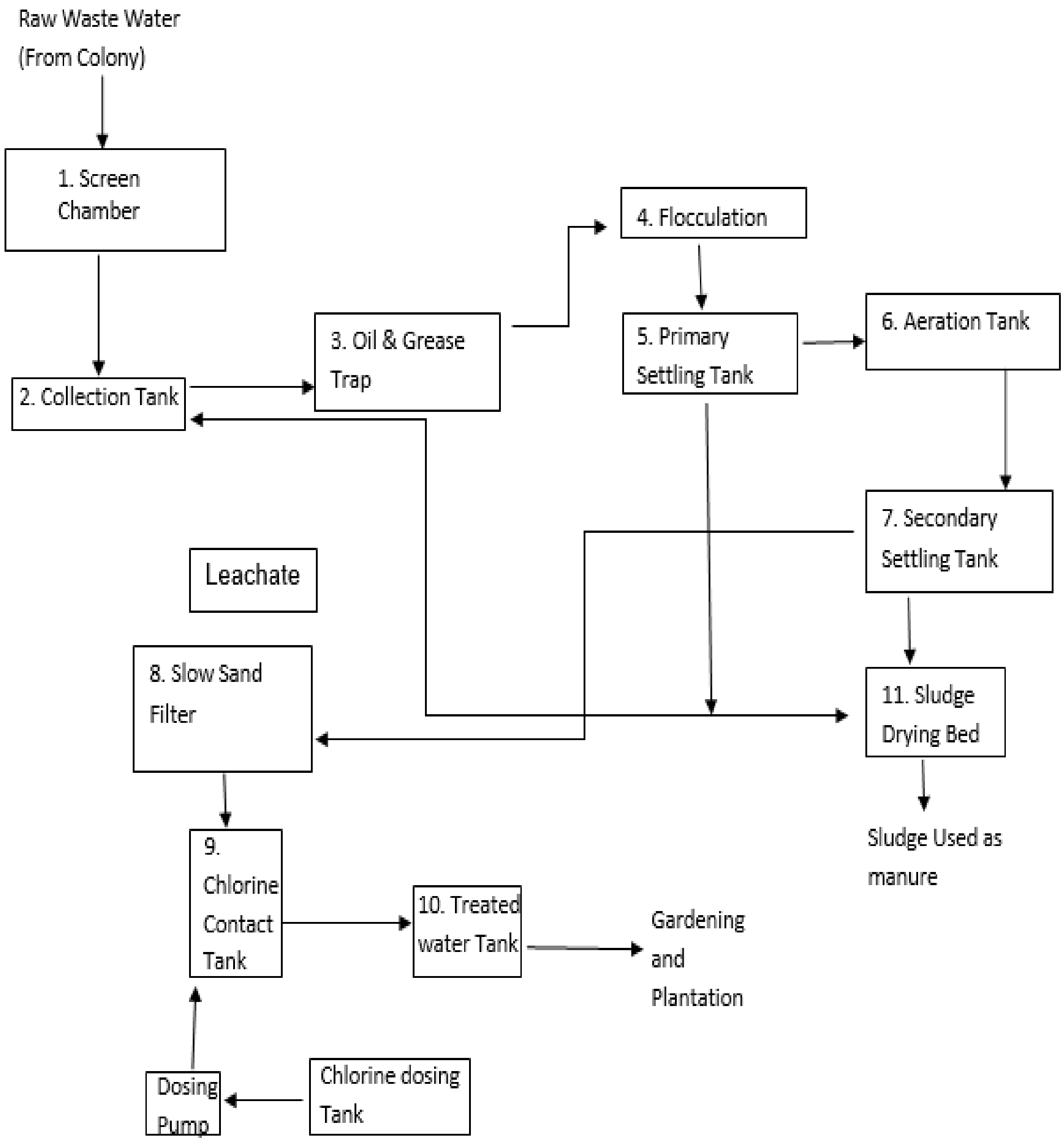


Figure 3: Process flow diagram of STP at Kandla

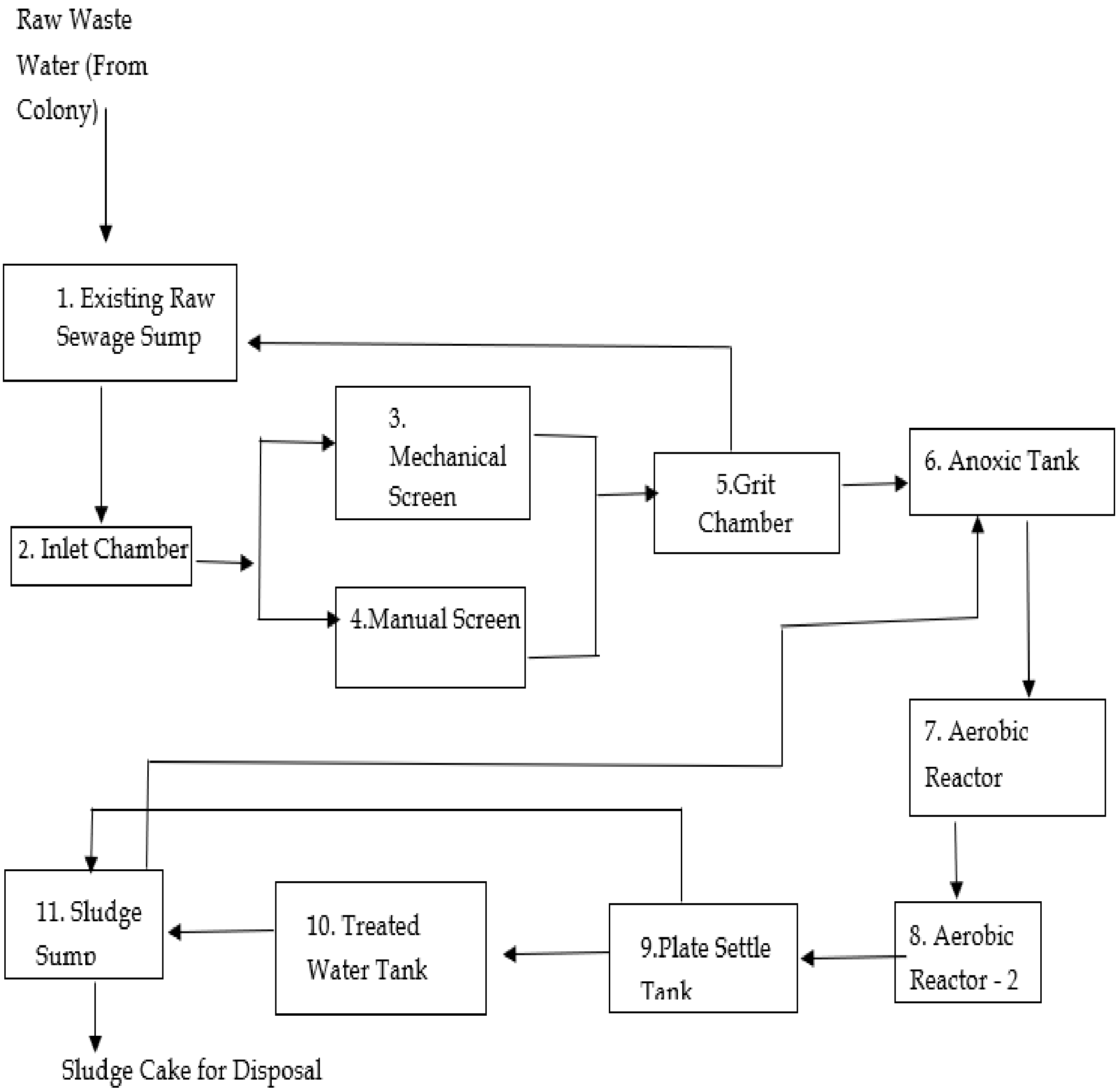


Figure 4: Process flow diagram of STP at Gopalpuri

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:

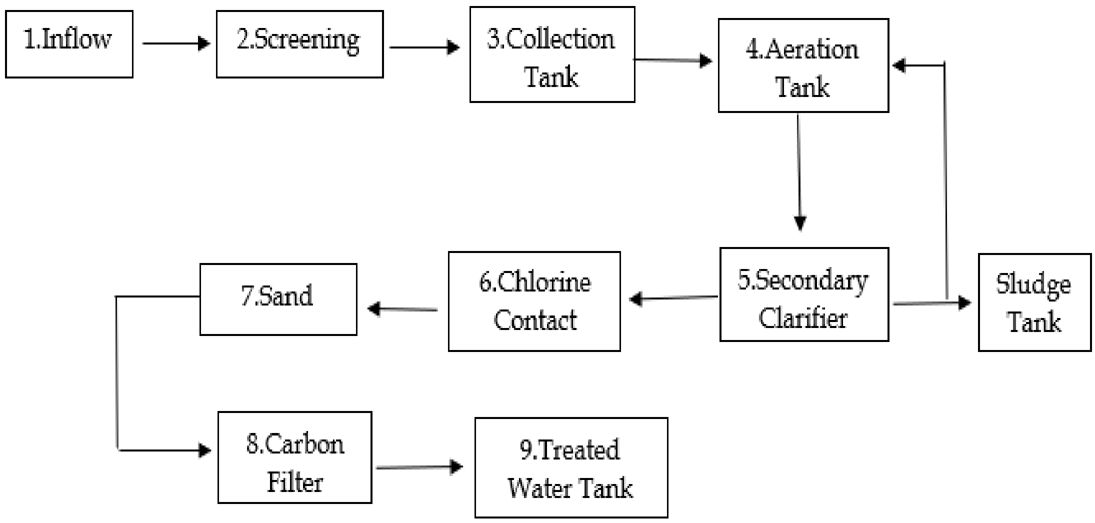


Figure 5: Process flowchart for the STP at Vadinar

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 August				Week 4 of August				Week 1 of September				Week 2 of September			
				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**	7.50	7.21	7.04	7.25	7.12	7.02	6.96	7.24	7.62	7.41	7.51	7.10	7.22	7.18	7.35	7.22
2.	TDS	mg/L	**-**	1354	1289	1268	1516	1423	1254	1438	1516	1321	1220	1126	1023	1365	1254	865	821
3.	TSS	mg/L	**100**	30	15	92	16	39	28	56	14	65	28	96	45	45	25	101	22
4.	COD	mg/L	**-**	132	55.2	206.5	68.8	198	112	227.6	36.6	112.3	58.4	71.1	28.3	122.0	60.0	111.0	41.0
5.	DO	mg/L	**-**	BQL	2.1	BQL	2.1	BQL	3.5	BQL	2.8	BQL	3.9	BQL	4.2	BQL	3.6	BQL	4.1
6.	BOD	mg/L	**30**	30.26	18.5	61.95	8.60	20.36	12.25	68.28	4.58	36.58	12.25	40.26	19.25	29.54	12.36	40.23	15.69
7.	SAR	meq/L	**-**	14.56	5.55	5.83	4.71	5.23	2.2	12.11	13.03	10.65	4.22	6.35	4.25	6.24	2.36	3.25	1.52
8.	Total Coliforms	MPN/ 100ml	**<1000**	1600	210	500	23	1600	120	1600	20	1600	50	1600	120	1600	220	1600	23

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

Sr No.	Parameter	Units	GPCB Norms (Vadinar)	Vadinar							
				Week 3 of August		Week 4 of August		Week 1 of September		Week 2 of September	
				STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)
1.	pH	-	**5.5-9**	6.98	7.01	7.64	7.60	7.06	7.08	7.34	7.99
2.	TDS	mg/L	**-**	406	378	368	332	448	390	418	330
3.	TSS	mg/L	**20**	10	10	10	4	14	4	12	10
4.	COD	mg/L	**50**	100.8	36.3	96.8	36.3	94.9	39.5	105.7	28.5
5.	DO	mg/L	**-**	4.6	6.1	3.8	4.0	2.8	5.3	4.1	7.5
6.	BOD	mg/L	**10**	15.12	4.54	12.10	4.54	17.79	4.94	19.82	3.56
7.	SAR	meq/L	**-**	2.19	2.38	1.76	1.84	3.01	2.19	3.02	2.38
8.	Total Coliforms	MPN/100ml	**100-230**	1600	100	1600	50	1600	20	1600	23

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 **7.02 to 7.41** at Kandla and **7.01 to 7.99** at Vadinar respectively.
- The **TDS** of treated sewage at Kandla was ranges from **821 to 1516 mg/L**, whereas for Vadinar it ranges from **330 to 390 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 14 **to 45 mg/L and** 4 **to 10 mg/L** respectively as mentioned in their respective CCA.
- **COD** value for Kandla was observed in the range of **28.30 to 112 mg/L**. Whereas for Vadinar the value of COD falls within the range of **28.50 to 39.50 mg/L**.
- The value of **DO** was observed in the range of **2.10 to 4.20 mg/L** at Kandla, whereas for Vadinar it was observed in the range of **4.00 to 7.50 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 **1.52 to 13.03 meq/L**, whereas for Vadinar, it was observed in the range of **1.84 to 2.38 meq/L**.
- The value of **Total Coliforms** for Kandla was observed in the range of **20 to 220 MPN/100 ml**, whereas for Vadinar, it was observed in the range of **20 to 100 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	

<table>
<tr><th>Sr. No</th><th>Parameters</th><th>Units</th><th>Reference method</th><th>Instrument</th></tr>
<tr><td>16.</td><td>Nitrite</td><td>mg/L</td><td>APHA, 23rd Edition, 4500 NO2- B: 2017</td><td></td></tr>
<tr><td>17.</td><td>Sodium</td><td>mg/L</td><td>APHA, 23rd Edition, 3500 Na- B: 2017</td><td rowspan="2">Flame photometer</td></tr>
<tr><td>18.</td><td>Potassium</td><td>mg/L</td><td>APHA, 23rd Edition, 3500 K- B: 2017</td></tr>
<tr><td>19.</td><td>Manganese</td><td>µg/L</td><td>APHA, 23rd Edition, ICP Method 3120 B: 2017</td><td rowspan="3">ICP-OES</td></tr>
<tr><td>20.</td><td>Iron</td><td>mg/L</td><td>APHA, 23rd Edition, ICP Method 3120 B: 2017</td></tr>
<tr><td>21.</td><td>Total Chromium</td><td>µg/L</td><td rowspan="2">APHA, 23rd Edition, 3500 Cr B: 2017</td></tr>
<tr><td>22.</td><td>Hexavalent Chromium</td><td>µg/L</td><td>UV- Visible Spectrophotometer</td></tr>
<tr><td>23.</td><td>Copper</td><td>µg/L</td><td rowspan="5">APHA, 23rd Edition, ICP Method 3120 B: 2017</td><td rowspan="6">ICP-OES</td></tr>
<tr><td>24.</td><td>Cadmium</td><td>µg/L</td></tr>
<tr><td>25.</td><td>Arsenic</td><td>µg/L</td></tr>
<tr><td>26.</td><td>Lead</td><td>µg/L</td></tr>
<tr><td>27.</td><td>Zinc</td><td>mg/L</td></tr>
<tr><td>28.</td><td>Mercury</td><td>µg/L</td><td>EPA 200.7</td></tr>
<tr><td>29.</td><td>Floating Material (Oil grease scum, petroleum products)</td><td>mg/L</td><td>APHA, 23rd Edition, 5520 C: 2017</td><td>Soxhlet Assembly</td></tr>
<tr><td>30.</td><td>Total Coliforms (MPN)</td><td>MPN/ 100ml</td><td>IS 1622: 2019</td><td>LAF/ Incubator</td></tr>
</table>

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	-	1.02	1.021	1.022	1.023	1.021	1.02	1.023	1.022
2.	pH	-	6.5-9.0	7.23	7.54	7.84	7.72	7.48	7.92	7.77	7.51
3.	Color	Hazen	No Noticeable	1	1	1	1	1	1	5	5
4.	EC	µS/cm	-	51,300	51,700	51,400	51,300	51,500	51,100	52,100	52,900
5.	Turbidity	NTU	-	142	156	174	155	98	75	12.36	8.21
6.	TDS	mg/L	-	37,168	37,256	37,214	37,159	37,145	36,847	35,264	34,156
7.	TSS	mg/L	-	251	232	255	210	210	199	242	286
8.	COD	mg/L	-	36.2	61.1	40.7	30.5	72.3	50.8	60.54	41.23
9.	DO	mg/L	3.0 mg/L	6.9	6.2	7.1	6.9	6.1	6.6	7.3	6.9
10.	BOD	mg/L	5.0 mg/L	3.2	3.5	3.3	BQL	BQL	4.1	BQL	BQL
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	2568.3	2654.8	2695.1	2415.3	2587.6	2459.3	2514.62	2856.37
13.	Nitrate	mg/L	-	3.255	3.369	3.568	3.321	3.125	3.198	1.569	1.328
14.	Nitrite	mg/L	-	BQL	BQL	0.156	BQL	BQL	BQL	BQL	BQL
15.	Phosphate	mg/L		BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
16.	Silica	mg/L	-	4.56	4.21	4.22	4.01	3.58	4.10	1.52	1.02
17.	Sodium	mg/L	-	3,562	3,965	4,235	6,154	4,802	3,826	>10000	>10000
18.	Potassium	mg/L	-	121.0	136.0	145.0	212.0	169.0	154.0	524.0	658.00
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	BQL	BQL	BQL	BQL	BQL	BQL	BQL
24.	Iron	mg/L	-	1.489	1.548	1.266	1.85	1.269	0.514	0.189	BQL
25.	Lead	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
26.	Manganese	mg/L	-	0.060	0.073	0.050	0.065	0.039	0.022	BQL	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	-	1.25	1.45	1.69	1.39	1.2	0.41	0.09	BQL
31.	Total Coliforms	MPN/ 100ml	500/100 ml	4	8	4	2	8	16	18	22

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 **1.02 to 1.023 kg/m³**, with the average of **1.02 kg/m³.** Whereas for the location of Vadinar, it was observed **1.023 kg/m³** at MW-7 and **1.022 kg/m³** at MW-8, with the average of **1.023 kg/m³**.
- **pH** at Kandla was observed in the range of **7.23 to 7.92,** with the average pH as **7.62**. Whereas for the locations of Vadinar, it was observed in the range of be **7.51 to 7.77**, with the average pH as **7.64**. 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 **1 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 **51,100 to 51,700 µS/cm**, with the average EC as **51,383.3 µS/cm** for the locations of Kandla, whereas for the locations of Vadinar, it was observed in the range of **52,100 to 52,900 µS/cm**, with the average EC as **52,500 µS/cm**.
- For all monitoring locations of Kandla the value of **Turbidity** was observed in the range of **75 to 174 NTU**, with average value of **133.33 NTU**. For Vadinar it ranges from **8.21 to 12.36 NTU**, with average of **10.28 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 **36,847 to 37,256 mg/L**, with an average value of **37,131.50 mg/L**. Similarly, at Vadinar, the TDS values ranged from **34,156 to 35,264 mg/L**, with an average value of 34,710 **mg/L**.
- **TSS** values in the studied area varied between **199 to 255 mg/L** at Kandla and **242 to 286 mg/L** at Vadinar, with the average value of **226.17 mg/L and 264 mg/L** respectively for Kandla and Vadinar.

- **COD** varied between **30.5 to 72.3 mg/L** at Kandla and **41.23 to 60.54 mg/L** at Vadinar, with the average value as **48.60 and 50.88 mg/L** respectively for Kandla and Vadinar.
- **DO** level in the studied area varied between **6.1 to 7.1 mg/L** at Kandla and **6.9 to 7.3 mg/L** at Vadinar, with the average value of **6.63 mg/L and 7.10 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 **3.2 to 4.1 mg/L**, with average of **3.53 mg/L** for the location of Kandla and for the locations of Vadinar, it was detected **Below Quantification Limit** for all sampling locations.
- **Sulphate** concentration in the studied area varied between **2415.36 to 2695.12 mg/L** at Kandla and **2514.62 to 2856.37 mg/L** at Vadinar. The average value observed at Kandla was **2563.44 mg/L**, whereas **2685.49 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 **3.125 to 3.568 mg/L**, with the average of **3.31 mg/L**. Whereas for the Vadinar, recorded value was observed in the range of **1.328 to 1.569 mg/L**, with the average of **1.449 mg/L.**
- In the study area of Kandla the concentration of **Potassium** varied between **121 to 212 mg/L** and **524 to 658 mg/L** at Vadinar, with the average value as **156.17 mg/L and 591 mg/L** respectively for Kandla and Vadinar.
- **Silica** in the studied area varied between **3.58 to 4.56 mg/L**, with the average of **4.11 mg/L**, at Kandla. Vadinar, observed value was found to be **1.52 mg/L** at location MW-7 and **1.02 mg/L** at MS-8 location.
- **Sodium** in the study area varied between **3562 to 6154 mg/L**, with average of **4424 mg/L**, at Kandla whereas at Vadinar the sodium concentration value was detected to be **more than 10,000 mg/L** at both locations.
- **Odour** was observed **1** for all locations of Kandla and Vadinar.
- **Copper** in the study area, was detected **below the quantification limit (BQL)" at** Kandla and whereas Vadinar was detected **below the quantification limit (BQL)"** for the all-sampling location.
- **Iron** in the studied area varied between **0.514 to 1.85 mg/L**, with the average of **1.32 mg/L,** at Kandla, and for Vadinar value were recorded **0.189 mg/L** for location MW-7 and **Below Quantification Limit** for location MW-8.
- **Lead** concentration at Kandla was detected **below the quantification limit (BQL)"** for the all-sampling location. and whereas Vadinar was detected **below the quantification limit (BQL)"** for the all-sampling location.
- **Manganese** in the studied area varied between **0.022 to 0.073 mg/L**, with the average of 0.052 mg/L, at Kandla and whereas Vadinar was detected **below the quantification limit (BQL)"** for the all-sampling location.
- **Particulate Organic Carbon** in the study area was observed in the range of **0.41 to 1.69**, with the average value of **1.23**. Whereas for the Vadinar, the value observed was **0.09** at MW-7 and **Below Quantification Limit** at MW-8.

- **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

<table>
<tr><th>Sr. No</th><th colspan="2">Location Code</th><th>Location Name</th><th>Latitude Longitude</th></tr>
<tr><td>1.</td><td rowspan="6">Kandla</td><td>MS-1</td><td>Near Passenger Jetty One</td><td>23.017729N 70.224306E</td></tr>
<tr><td>2.</td><td>MS-2</td><td>Kandla Creek</td><td>23.001313N 70.226263E</td></tr>
<tr><td>3.</td><td>MS-3</td><td>Near Coal Berth</td><td>22.987752N 70.227923E</td></tr>
<tr><td>4.</td><td>MS-4</td><td>Khori Creek</td><td>22.977544N 70.207831E</td></tr>
<tr><td>5.</td><td>MS-5</td><td>Nakti Creek (near Tuna Port)</td><td>22.962588N 70.116863E</td></tr>
<tr><td>6.</td><td>MS-6</td><td>Nakti Creek (near NH-8A)</td><td>23.033113N 70.158528E</td></tr>
<tr><td>7.</td><td rowspan="2">Vadinar</td><td>MS-7</td><td>Near SPM</td><td>22.500391N 69.688089E</td></tr>
<tr><td>8.</td><td>MS-8</td><td>Near Vadinar Jetty</td><td>22.440538N 69.667941E</td></tr>
</table>

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	1.02	4.23	2.65	1.56	0.91	0.94	0.91	0.62
2.	Phosphate	mg/Kg	321.25	512.36	436.51	320.16	265.21	220.14	423.65	303.54
3.	Organic Matter	%	1.2	1.96	1.56	1.12	1.45	1.20	1.45	1.72
4.	Sulphate as SO^{4-}	mg/Kg	303.21	108.51	110.36	85.46	100.25	92.17	125.36	136.28
5.	Calcium as Ca	mg/Kg	4200.00	1800.00	2200.00	1600.00	1900.00	1700.00	2300.00	1900.00
6.	Magnesium as Mg	mg/Kg	795.00	958.00	1475.00	745.00	1023.00	841.00	982.00	1265.40
7.	Silica	g/Kg	421.31	326.24	169.46	326.42	315.41	421.28	200.25	259.64
8.	Nitrite	mg/Kg	1.15	1.09	1.2	1.01	1.03	1.12	0.45	0.26
9.	Nitrate	mg/Kg	6.12	5.21	4.13	5.23	6.42	6.31	15.24	8.29
10.	Sodium	mg/Kg	2861	2215	2856	2036	3014	3954	7546	8952
11.	Potassium	mg/Kg	1956	1854	1926	2136	2525	3067	1347	3256
12.	Copper	mg/Kg	38.22	42.57	45.56	32.17	42.1	29.53	16.25	22.31
13.	Aluminium	mg/Kg	35268.4	36529.5	37514.6	25187.6	35268.6	29543	15423.61	25146.25
14.	Chromium	mg/Kg	72.36	74.65	71.39	72.55	62.58	51.36	40.26	35.28
15.	Nickel	mg/Kg	29.35	25.21	22.59	21.85	36.27	21.26	20.24	30.58
16.	Zinc	mg/Kg	101.26	268.54	362.14	101.22	85.36	79.58	18.25	39.41
17.	Cadmium	mg/Kg	BQL	BQL	BQL	0.54	BQL	BQL	0.006	BQL
18.	Lead	mg/Kg	7.31	10.25	19.24	12.33	9.51	6.22	3.26	8.47
19.	Arsenic	mg/Kg	4.12	3.62	6.28	7.26	4.26	3.2	2.59	5.21
20.	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21.	Texture	-	Silt Loam	Sandy Loam	Silt Loam	Loam	Silt Loam	Silt 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 **0.91 to 4.23** Kg/ha for Kandla. Whereas for Vadinar the value observed at location MS-7 (Nakti creek) is 0.91 Kg/ha and MS-8 (Near Vadinar Jetty) is 0.62 Kg/ha. For Kandla and Vadinar the average value of Inorganic Phosphate was observed 1.89 and 0.77 Kg/ha respectively.
- The concentration of **Phosphate** was observed in range of **220.14 to 512.36 mg/Kg** for Kandla and for Vadinar the value observed at location MS-7 (Nakti creek) as 423.65 mg/Kg and MS-8 (Near Vadinar Jetty) as 303.54 mg/Kg. For Kandla and Vadinar the average concentration of Phosphate was observed 345.94 and 363.60 mg/Kg respectively.

- The **Organic Matter** for the sampling period was observed in the range of **1.12 to 1.96%** for Kandla with the average value of 1.42% and for Vadinar the value recorded at location MS-7 and MS-8 was observed 1.45% & 1.72% respectively, with average concentration as 1.59 %.
- The concentration of **Sulphate** was observed in the range of **85.46 to 303.21 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 125.36 mg/Kg and at MS-8 is 136.28 mg/Kg. For Kandla and Vadinar the average value of Sulphate was observed 133.33 and 130.82 mg/Kg respectively.
- The value of **Calcium** was observed in the range of **1600 to 4200 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 2300 mg/Kg and at MS-8, is 1900 mg/Kg. The average value of Calcium for the monitoring period was observed 2233.33 mg/Kg and 2100 mg/Kg at Kandla and Vadinar, respectively.
- The value of **Magnesium** for the sampling period was observed in the range of **745 to 1475 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 982 mg/Kg and at MS-8, is 1265.40 mg/Kg. For Kandla and Vadinar the average value of Magnesium was observed 972.83 mg/Kg and 1123.70 mg/Kg respectively.
- For the sampling period **Silica** was observed in the range of **169.46 to 421.31 mg/Kg** for Kandla with average value 330.02 mg/Kg and for Vadinar the value observed to be 200.25 and 259.64 mg/Kg at MS-7 and MS-8, respectively with average 229.95 mg/Kg.
- The value of **Nitrate** was observed in the range of **4.13 to 6.42 mg/Kg** for Kandla with average value 5.57 mg/Kg and for Vadinar the value observed to be 15.24 and 8.29 mg/Kg at MS-7 and MS-8, respectively with average 11.77 mg/Kg.
- The value of **Nitrite** was observed in the range of **1.01 to 1.20 mg/Kg** for Kandla with average value 1.10 mg/Kg and for Vadinar the value observed to be 0.45 and 0.26 mg/Kg at MS-7 and MS-8, respectively with average 0.36 mg/Kg.
- The value of **Sodium** was observed in the range of 2036 **to 3954 mg/Kg** for Kandla with average value 2822.67 mg/Kg and for Vadinar the value observed to be 7546 and 8952 mg/Kg at MS-7 and MS-8, respectively with average 8249 mg/Kg.
- The value of **Potassium** was observed in the range of **1854 to 3067 mg/Kg** for Kandla with average value 2244 mg/Kg and for Vadinar the value observed to be 1347 and 3256 mg/Kg at MS-7 and MS-8, respectively with average 2301.50 mg/Kg.
- The value of **Aluminium**, was observed in the range of **25187.6 to 37514.6 mg/Kg** for Kandla with average value 33218.62 mg/Kg and for Vadinar the value observed to be 15423.61 and 25146.25 mg/Kg at MS-7 and MS-8, respectively with average 20284.93 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**" and "Slit 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	4.12	3.62	6.28	7.26	4.26	3.2	2.59	5.21
2.	Copper	mg/Kg	38.22	42.57	45.56	32.17	42.1	29.53	16.25	22.31
3.	Chromium	mg/Kg	72.36	74.65	71.39	72.55	62.58	51.36	40.26	35.28
4.	Nickel	mg/Kg	29.35	25.21	22.59	21.85	36.27	21.26	20.24	30.58
5.	Lead	mg/Kg	7.31	10.25	19.24	12.33	9.51	6.22	3.26	8.47
6.	Zinc	mg/Kg	101.26	268.54	362.14	101.22	85.36	79.58	18.25	39.41
7.	Cadmium	mg/Kg	BQL	BQL	BQL	0.54	BQL	BQL	0.006	BQL

- **Arsenic** was observed in the range of **3.2 to 7.26 mg/Kg** for Kandla with average value 4.79 mg/Kg and for Vadinar the value observed to be 2.59 and 5.21 mg/Kg at MS-7 and MS-8, respectively with average 3.90 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 **29.53 to 45.56 mg/Kg** for Kandla with average value 38.36 mg/Kg and for Vadinar the value observed to be 16.25 and 22.31 mg/Kg at MS-7 and MS-8, respectively with average 19.28 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to copper falls in Moderately polluted class.
- **Chromium** was observed in the range of 71.39 **to 99.39 mg/Kg** for Kandla with average Value 79.03 mg/Kg and for Vadinar the value observed to be 40.26 and 35.28 mg/Kg at MS-7 and MS-8, respectively with average 37.77 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to chromium falls under moderately polluted class.

- **Nickel** was observed in the range of **21.26 to 36.27 mg/Kg** for Kandla with average value 26.09 mg/Kg and for Vadinar the value observed to be 20.24 and 30.58 mg/Kg at MS-7 and MS-8, respectively with average 25.41 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 **6.22 to 19.24 mg/Kg** for Kandla with average value 10.81 mg/Kg and for Vadinar the value observed to be 3.26 and 8.47 mg/Kg at MS-7 and MS-8, respectively with average 5.87 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 **79.58 to 195.43 mg/Kg** for Kandla with average value 119.21 mg/Kg and for Vadinar the value observed to be 18.25 and 39.41 mg/Kg at MS-7 and MS-8, respectively with average 28.83 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to zinc falls in moderately polluted class
- **Cadmium** was observed BQL for all locations at Kandla and Vadinar except MS-7 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, $\sum$ = 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	202	89	55	120	65	101	91	112
2.	Net Primary Productivity	mg/L/hr	BQL	0.42	BQL	BQL	0.26	BQL	BQL	BQL
3.	Gross Primary Productivity	mg/L/hr	0.21	0.32	1.02	1.31	1.21	0.36	0.71	1.02
4.	Pheophytin	mg/m^3	BQL	1.12	0.72	1.29	1.08	0.62	1.05	1.32
5.	Chlorophyll-a	mg/m^3	3.16	1.2	1.35	1.18	1.22	1.16	1.48	1.62
6.	Particulate Oxidisable Organic Carbon	mg/L	1.52	1.25	0.35	0.79	1.02	0.91	0.6	0.78
7.	Secchi Depth	ft	0.72	0.62	0.45	0.81	0.91	0.76	1.26	1.33

- **Biomass:**
  With reference to the **Table 39**, the concentration of **Biomass** reported from location ME-1 to ME-6 in range between **55 to 202 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 **91 mg/L** at ME-7 (Near SPM) and **112 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 0.21 to 1.31 mg/L/ Hr where the highest value recorded for ME-4 (khori Creek)) and lowest recorded at ME-1 (Near Passenger Jetty One). In Vadinar, the value of GPP was observed 0.71 at ME-7 (Near SPM) and 1.02 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) except ME-2 and ME-5.** 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 **0.62 to 1.29 mg/m³** where the highest value observed at ME-4 (Khori Creek) and the lowest value observed at ME-1 (Near Passenger Jetty One). While in Vadinar, the value of Pheophytin was observed 1.05 mg/m3 at ME-7 and **1.32 mg/m³** at ME-8 monitoring station.

- **Chlorophyll-a**

In the sub surface water, the value of Chlorophyll-a reported in range from **1.16 to 3.16 mg/m^3**. The highest value observed at ME-1 (Near Passenger Jetty One) while the lowest value observed at ME-6 (Nakti Creek (near NH - 8A)). In Vadinar, the value of chlorophyll-a was observed **1.48 mg/m^3** at ME-7 (Near SPM) and **1.62 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 **0.35 to 1.52 mg/L** from monitoring location ME-1 to ME-6 at Kandla, whereas for Vadinar, the value of POC observed **0.60 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 **0.45 to 0.91 ft** whereas at Vadinar, the value recorded at ME-7 i.e. Near SPM is **1.26 ft** and in Near Vadinar Jetty is **1.33 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 are 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.	156	136	-	-	212	-	-	-
Biddulphia sp.	-	-	231	122	-	-	133	148
Chaetoceros sp.	185	-	-	-	132	-	-	-
Chlamydomonas sp.	-	147	-	184	-	121	-	-
Cyclotella sp.	172	-	194	-	156	-	-	-
Coscinodiscus sp.	-	176	-	189	-	148	184	200
Ditylum sp	256	-	152	176	-	-	-	-
Fragilaria sp.	-	-	-	-	-	235	-	188
Bacteriastrum sp.	168	-	136	157	185	-	238	195
Pleurosigma sp.	-	185	-	-	-	152	182	-
Navicula sp.	212	-	189	-	-	-	-	-
Merismopedia sp.	-	201	-	158	-	174	-	-
Synedra sp.	-	-	-	-	145	-	-	141
Skeletonema sp.	-	194	-	-	-	222	-	166
Oscillatoria sp.	-	-	137	-	165	-	210	-
Thallassiosira	142	169	-	198	-	201	-	232
Gomphonema sp.	-	-	213	-	194	-	247	-
Density-Units/L	**1291**	**1208**	**1252**	**1184**	**1189**	**1253**	**1194**	**1270**
No. of genera	**7**	**7**	**7**	**7**	**7**	**7**	**6**	**7**

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 14 genera; green algae were represented by 1 genera and filamentous Cynobacteria were represented by 2 genera during the sampling period.

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from **1184 to 1291 units/L,** while for Vadinar its density of phytoplankton observed **1194 units/L at ME-7 and 1270 units/L at ME-8.** During the sampling, phytoplankton communities were dominated, *Bacteriastrum sp., Chlamydomonas sp., Cyclotella sp, Thallassiosira , Gomphonema sp, in* Kandla, while *Biddulphia sp., Bacteriastrum sp., Cosinodiscus sp.* in Vadinar.

The details of Species richness Index and Diversity Index in Phytoplankton are 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	7	7	7	7	7	7	6	7
Individuals	1291	1208	1252	1184	1189	1253	1194	1270
Shannon diversity	1.93	1.88	1.90	1.85	1.86	1.89	1.71	1.92
Simpson 1-D	0.85	0.86	0.85	0.83	0.85	0.85	0.83	0.85
Species Evenness	0.99	0.97	0.98	0.95	0.96	0.97	0.95	0.99
Margalef richness	0.84	0.85	0.84	0.85	0.85	0.84	0.71	0.84
Berger-Parker	0.20	0.17	0.18	0.17	0.18	0.19	0.21	0.18
Relative abundance	0.54	0.58	0.56	0.59	0.59	0.56	0.50	0.55

- **Shannon- Wiener's Index (H)** of phytoplankton communities was in the range of **1.85 to 1.93** between selected sampling stations from ME-1 to ME-6 with an average value of **1.89** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of phytoplankton communities recorded to be **1.71** at location ME-7 and **1.92** at ME-8 with an average value of **1.82**. 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 0.86** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.85** Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was **0.83** at location ME-7 and **0.85** at ME-8 with an average of **0.84**.

- **Margalef's diversity index** (Species Richness) of phytoplankton communities in Kandla and nearby creeks sampling stations was varying from **0.84 to 0.85** with an average of **0.85** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of phytoplankton communities observed **0.71** at ME-7 and **0.84** at ME-8 with an average value of **0.78**

- **Berger-Parker Index (d)** of phytoplankton communities was in the range of **0.17 to 0.20** between selected sampling stations from ME-1 to ME-6 with an average value of **0.18** at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of **0.18 to 0.21** with an average value of **0.20**. 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 **0.95 to 0.99** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed **0.95** at location ME-7 & **0.99** at ME-8 location.

- During the sampling period, **Relative Abundance** of phytoplankton communities was in range of **0.54 to 0.59** between selected sampling stations from ME-1 to ME-6 with an average value of **0.57** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **0.50** at ME-7 and **0.55** at ME-8 with an average value **0.53**, 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 are 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	-	2	2	-	1
Acrocalanus	2	-	-	1	1	1	2	-
Amoeba	-	2	2	-	-	2	-	-
Brachionus sp.	1	-	-	2	2	-	-	1
Calanus sp.	2	-	-	1	-	-	-	1
Cladocera sp.	-	2	1	-	2	-	2	-
Cyclopoid sp.	-	-	2	-	1	-	-	-
Copepod larvae	1	-	-	2	-	2	-	2
Diaptomus sp.	2	1	-	-	-	1	2	-
Eucalanus sp.	-	-	2	1	1	-	1	1
Mysis sp.	1	2	1	-	-	1	-	-
Paracalanus sp.	-	-	-	1	-	-	2	2
Density Unit/L	**9**	**8**	**9**	**8**	**9**	**9**	**9**	**8**
No. of genera	**6**	**5**	**6**	**6**	**6**	**6**	**5**	**6**

A total of 12 zooplankton genera were recorded in Kandla and Vadinar during the study period. The zooplankton community was mainly composed of *Acartia sp., Acrocalanus, Cladocera sp., Copepod larvae, and Mysis sp.*, which showed the highest occurrence across stations. From **ME-1 to ME-6** (Kandla), the density of zooplankton ranged between **8 to 9 units/L**. In Vadinar (**ME-7 and ME-8**), the density ranges from **8 to 9 units/L**. At Kandla stations, *Acartia sp., Cladocera sp., Brachiomus sp., Copepod larvae, and Mysis sp* were the most frequently observed genera, while *Acrocalamus, Diaptomus sp., Cladocera sp. and paracalanus sp.* also had strong representation at Vadinar stations.

The details of Species richness Index and Diversity Index in Zooplankton communities are 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	6	5	6	6	6	6	5	6
Individuals	9	8	9	8	9	9	9	8
Shannon diversity	1.74	1.49	1.74	1.65	1.74	1.74	1.58	1.65
Simpson (1-D)	0.92	0.89	0.92	0.93	0.92	0.92	0.89	0.93
Species Evenness	0.97	0.93	0.97	0.92	0.97	0.97	0.98	0.92
Margalef	2.28	1.92	2.28	2.4	2.28	2.28	1.82	2.4
Berger-Parker	0.22	0.25	0.22	0.25	0.22	0.22	0.22	0.25
Relative abundance	66.67	62.5	66.67	75	66.67	66.67	55.56	75

- **Shannon- Wiener's Index (H)** of zooplankton communities was in the range of **1.49 to 1.74** between selected sampling stations from ME-1 to ME-6 with an average value of **1.68** at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of zooplankton communities recorded to be **1.58** at ME-7 and **1.65** at ME-8 with an average value of 1.61**.** 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 **0.89 to 0.93** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.91.** Similarly, for Vadinar Simpson diversity index (1-D) of zooplankton communities was **0.89** ME-7 and **0.93** at ME-8 with an average of **0.91.**

- **Margalef's diversity index** (Species Richness) of zooplankton communities in Kandla and nearby creeks sampling stations was varying from **1.92 to 2.40** with an average of **2.24** during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of zooplankton communities observed **1.82** at ME-7 and **2.40** at ME-8 with an average value of **2.11**.

- **Berger-Parker Index (d)** of zooplankton communities was in the range of **0.22 to 0.25** 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 **0.22** at ME-7 and **0.25** 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 **0.92 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 **0.92** at ME-8 the locations**,** during the monitoring month.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of **62.5 to 75** between selected sampling stations from ME-1 to ME-6 with an average value of **67.36** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **55.56** at ME-7 and **75** at ME-8 with an average value **65.28**, 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** are 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	2	-	-	-	2	-	1	2
Mollusca	-	1	1	1	-	2	-	-
Odonata	-	-	2	2	-	1	1	-
Lymnidae	1	-	-	1	1	-	-	-
Planorbidae	-	2	1	-	-	1	-	-

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

Few benthic organisms were observed in the collected samples using Van-Veen grabs at Deendayal Port (Kandla and Vadinar). The dominant macro-benthic groups included *Thiaridae, Mollusca, Trochidae, Atydae, and Turbinidae,* which were present across multiple stations. *Turbinidae* was observed at all sites (**ME-1 to ME-8**). While *Mollusca sp and Trochidae* occurred at most of the locations, indicating their broad distribution. The number of benthic families/classes varied between 5 to 6 across all stations.

At ME-1, the most dominant groups were *Thiaridae, Turbinidae and Trochidae* each with a density of **2 units/L**. The least represented benthic fauna included *Lymnidae and Talitridae* which was observed only at ME-1 with a Density of **1 units/L**.

The details of Species richness Index and Diversity Index in Benthic Organisms are 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	5	5	6	6	5	6	6	5
Individuals	8	7	8	8	6	8	7	8
Shannon diversity	1.56	1.47	1.73	1.73	1.39	1.73	1.65	1.56
Simpson 1-D	0.89	0.9	0.93	0.93	0.93	0.93	0.95	0.89
Species Evenness	0.97	0.91	0.97	0.97	0.86	0.97	0.92	0.97
Margalef's	1.92	2.06	2.4	2.4	2.23	2.4	2.57	1.92
Berger-Parker	0.25	0.29	0.25	0.25	0.33	0.25	0.29	0.25
Relative abundance	62.5	71.43	75	75	83.33	75	85.71	62.5

- **Shannon- Wiener's Index (H)** of benthic organism was in the range of **1.39 to 1.73** between selected sampling stations from ME-1 to ME-6 with an average value of **1.60** 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 & **1.56** at ME-8 location with an average value of **1.60**. 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 **0.89 to 0.93** at all sampling stations in the Kandla creek and nearby creeks, with an average of **0.**91. Similarly, for Vadinar Simpson diversity index (1-D) of benthic organism was **0.95** at ME-7 and **0.89** at ME-8 location with an average of **0.92.**

- **Margalef's diversity index** (Species Richness) of benthic organism in Kandla and nearby creeks sampling stations was varying from **1.92 to 2.40** with an average of **2.23** 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 **1.92** at ME-8 location with an average of **2.24**.

- **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 **0.27** 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 **0.25** at ME-8 location with an average value of **0.27**. 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 0.97** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of **0.92** at ME-7 and 0.97 at ME-8.

- During the sampling period, **Relative Abundance** of Benthic organisms was **62.5 to 83.33** between selected sampling stations from ME-1 to ME-6 with an average value of **73.71** at Kandla creek and nearby creeks. Whereas for Vadinar the Index value **85.71** at ME-7 and **62.5** at ME-8 location, with an average value **74.11**, 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

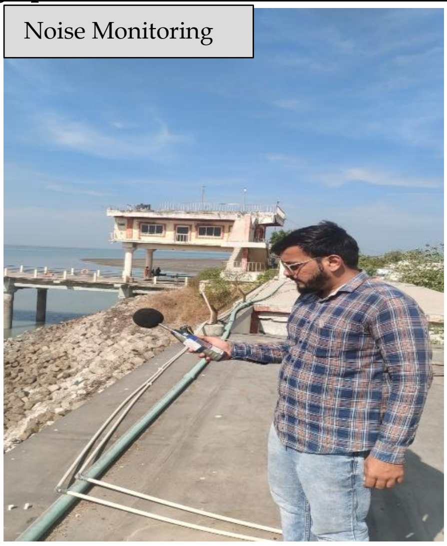
Marine Monitoring

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

Head Office

Plot No. B 246 & 247, G.I.D.C. Electronic Estate,

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"We Provide Environmental Solutions"

Annexure – C

DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

ISO 9001-2015 &
ISO 14001-2015 Certified Port

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

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY
www.deendayalport.gov.in

CivilEng./Pipeline/4778/CAAQMS/2025/27 Dated: 24/06/2025

To,
The Gujarat Institute of Desert Ecology (GUIDE),
P.O.Box No. 83,
Opp. Changleshwar Temple, Mundra Road,
Bhuj (Kachchh)-370 001,
Gujarat (India).
E-mail: desert_ecology@yahoo.com

Kind Attention: Dr. V. Vijay Kumar, Director, M/s GUIDE, Bhuj.

Sub: "Monitoring of Ambient Air Quality in the Port Area of Deendayal Port Authority through Continuous Ambient Air Quality Monitoring System (CAAQMS)"-Work Order reg.

Ref: GUIDE, Bhuj proposal vide letter No. GUIDE/DPA/CAAQMS/450/2024-25 dated 21/05/2025

Sir,

The proposal submitted by GUIDE, Bhuj for the subject work vide above referred letter dated 21/05/2025 (**copy Attached-Annexure A**) for the work "**Monitoring of Ambient Air Quality in the Port Area of Deendayal Port Authority through Continuous Ambient Air Quality Monitoring System (CAAQMS)**" amounting to **Rs. 9,27,63,504.00 plus applicable GST (Rupees Nine Crores Twenty-Seven Lakhs Sixty-Three Thousand Five Hundred and Four Only)** for the scope of work, time period, including all terms & conditions mentioned in the proposal, has been accepted by the Competent Authority of DPA.

1) **Brief Scope of work**:
   a) To conduct site suitability assessment for installation of two CAAQMS including civil work, power supply, data connectivity in consultation with DPA.
   b) To Install Two CAAQMS at identified locations by DPA with all related components comprising of sensors, analysers, data acquisition system at identified locations, ensuring proper positioning for Accurate Air Quality Monitoring.
   c) To establish a real-time data transmission system to integrate with Pollution Control Boards for continuous remote monitoring.
   d) To conduct routine maintenance schedules and periodic calibrations to ensure uninterrupted operations of the equipment's.
   e) To formulate a detailed inception plan comprising of relevant technical specifications of the equipment's, monitoring frequency, proposed site details for installation of equipment's, connectivity with/to Pollution Control Boards.
   f) To document the monitored data on monthly basis.

g) Data will be transmitted to State and Central Pollution Control Boards
h) Broad Scope of work is as per **Annexure A**

2) **Payment terms:**
* 25% of contract price against submission of Inception Report and successful installation & commissioning of two CAAQMS System at identified Location.
* Balance 75% of contract Price: Monthly payment on Pro Rata basis for a period of 36 months

3) **Deliverables:**
- Inception report comprising of relevant technical specifications of the equipment's, monitoring frequency, proposed site details for installation of equipment's, connectivity with/to Pollution Control Boards.
- Installation of two (2) CAAQMS at proposed site
- Operations and maintenance of two installed CAAQMS for a period of 36 months
- Monthly submission of reports for a period of three years depicting the operations and output of online Continuous Ambient Air Quality Monitoring System including Wind Rose plot.

4) **Time Period:**

1. **For submission of Inception report & successful installation & commissioning of Two CAAQMS system at DPA: –** 60 days from the date of receipt of Work Order

2. **Operations & Maintenance of two CAAQMS:** 36 months after successful commissioning of CAAQMS.

3. Kindly sent the acceptance of this work order & start the work w.e.f 01/07/2025

Kindly send the acknowledgment of this Work Order.

Thanking you.

Yours faithfully,

24/6/25

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

Annexure–D

First Year - Annual Report
(2024-2025)

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

Submitted to

DEENDAYAL PORT AUTHORITY
Administrative Office Building
Post Box No. 60, Gandhidham (Kuchchh)
Gujarat-370201

Submitted by

Gujarat Institute of Desert Ecology
P.O Box No. #83, Opp. Changleshwar Temple,
Mundra Road Bhuj - 370001
Gujarat - India

May 2025

First Year - Annual Report
(2024-2025)

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

Submitted to

DEENDAYAL PORT AUTHORITY

DEENDAYAL PORT AUTHORITY
Administrative Office Building
Post Box No. 60, Gandhidham (Kuchchh)
Gujarat-370201

Submitted by

Gujarat Institute of Desert Ecology
P.O Box No. #83, Opp. Changleshwar Temple,
Mundra Road Bhuj - 370001
Gujarat - India

May 2025

Gujarat Institute of Desert Ecology

Dr. V. Vijay Kumar
Director

CERTIFICATE

This is to state that this final report of work entitled "**Regular monitoring of Marine ecology in and around the Deendayal Port Authority and Continuous Monitoring Programme**" has been prepared as per the work order issued by DPA vide no EG/WK/4751/Part (Marine Ecology Monitoring)/72 dt.10.06.2024 for the period 2024-2025 as per EC and CRZ clearance accorded by the MOEF& CC, GOI dated 19.12.2016,18.2 2020,19.2.2022 and 20.11.2020 with specific conditions xviii, xxiii, xv iv and xxv respectively.

Authorized signatory

Bhuj
Gujarat Institute of Desert Ecology

Institute seal

P.O. Box No. 83, Opp. Changleshwar Temple, Mundra Road, Bhuj (Kachchh) - 370 001, Gujarat (India)
Tel : 02832 - 235025-29
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Project Coordinator

Dr. V. Vijay Kumar, Director

Principal Investigator		
Dr. Durga Prasad Behera	Scientist	Phytoplankton & Zooplankton, Physico-chemical parameters, Seaweed, Seagrass , halophytes, Marine Fisheries and Intertidal fauna
Co-Principal Investigator		
Dr. Kapilkumar Ingle	Project Scientist	Mangrove Ecology
Dr. Dhara Dixit	Project Scientist	Physico-chemical
Team Member		
Dr. L. Prabha Devi	Advisor	Management Plan
Dr.S.K Sajan	Scientist	Avifauna
Mr. Viral. D. Vadodariya	Project Fellow	Avifauna
Mr. Dayesh Parmar	Project officer	GIS & Remote sensing
Mr. Rupak Kumar Dey	Project Scientist	GIS & Remote sensing
Mr. Samir Mashru	Project assistant	Physico-chemical& Macrobenthos
Ms, Shivani Singh	Project assistant	Physico-chemical& Biological

Abstract May-2024 to May 2025

S. No	Components of the Study	Remarks
1	**MoEF & CC Sanction Letter and Details**	• EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/12/16 Dev. Of 7 integrated facilities – specific condition no. xviii. • EC & CRZ clearance granted by the MoEF &CC, GoI dated 18/2/2020 Dev. Remaining 3 integrated facilities – specific condition no. xxiii. • EC & CRZ clearance granted by the MoEF &CC, GoI dated 19/2/2020 Dev. integrated facilities (Stage II-5 -specific condition no. xv. • 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. • 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 theProject	Three years-from 24.05.2021 to 23.05.2024
4	Period Of Survey Carried out	Three years-from 2024-2027
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 DPA port jurisdiction
7	**Components of the report**	
7a	**Mangroves**	During the monsoon 2024, the overall average tree density recorded was 2,189 trees/ha, with Tuna Creek exhibiting the highest mean density (2,535 trees/ha) and S-6 having the highest individual density (3,673 trees/ha). During post-monsoon 2024-2025, the overall tree density recorded as 1,986 trees/ha, with Kharo Creek leading at 2,788 trees/ha and S-6 remaining the densest (3,156 trees/ha). During pre-monsoon 2025, the overall tree density recorded was 1,907 trees/ha and S-6 continued to show the highest density (3,113 trees/ha), with an impressive 6,774 trees per hectare

7b	**Mudflats**	The sediment organic carbon of DPA varied from may 2024 to May 2025 was 0.5% to 3.2 % with average variation of 1.8% to 2.5%. Through out season the highest percentage of organic carbon was observed in post-monsoon followed by monsoon and pre-monsoon. The sediment bulk density varied from 1.10 gm/cm3 to 1.89 gm/cm3 with overall average variation of 1.21 gm/cm3 to 1.68 gm/cm3 . Highest bulk density was observed in Pre-monsoon followed by post-monsoon and post-monsoon

	Phytoplankton	The density of different phytoplankton group varied from 4000 No/L to 24320 No/L with average variation of 7,627 No/L to 24, 320. Highest phytoplankton density was observed in post-monsoon followed by Pre-monsoon and Monsoon. During monsoon 15 genera such as *Cheatoceros, Coscinodiscus, Dictylum, Eucampia, GyrosigmaMelosira, Navicula, Nitzschia, Odontella, Pleurosigma, Pseudonitzschia, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix* represent 100% of occurrence. But in Post-monsoon and pre monsoon represent less number i.e 8 and 5 number of genera represent 100% of occurrence.
7c	**Zooplankton**	The density of zooplankton from May 2024 to May 2025was 8,000 No/L to 20,000 No/L with average variation of 7,653 No/L to 17,660 No/ L. Highest Zooplankton density was observed in Post-mon soon followed by pre-monsoon and Monsoon. 12 genera such as *Acartia, Acrocalanus, Bivalve larvae, Brachyuran larvae, Calanus, Cirripede nauplius, Codonellopsis, Eucalanus, Gastropod larvae,Globigerina, Microsetella, Tintinnopsis* occurred 100% of occurrence.
7d	**Intertidal Fauna**	The survey of the intertidal Fauna of DPA Kandla area recorded the presence of 4 phyla (Arthropoda, Chordata, Mollusca). The faunal diversity was the highest for phylum Mollusca followed by Arthropoda and Chordata respectively. The organism such as Austruca iranica, Austruca sindensis, and Austruca variegata contribute highest percentage of composition. The density of Intertidal organism among different station was varied from 17No/m2 to 133 No/m2 with overall variation in 3 season was 18 No/m2 to 97No/m2. Monsoon contribute highest density of organism followed by Pre- and Post-Monsoon.
7e	**Sub-tidal Macrobenths**	The number of macro benthic fauna of the various groups from the DPA port environment includes Annelida, Arthropoda, Mollusca and Nematoda. The average density and population of subtidal macrobenthos from May 2024 to May 2025 varied from 307 N0/m2 to 507 No./m 2 and 12 to 20 in number. In station wise density of subtidal macrobenthos varied from 25 no/m2 to 1150 no /m2 with average variation of 100 no/m2 to 754 no/m2 . Highest dinsith was observed in Pre-monsoon and lowest was observed during post-monsoon. The species such as *Mysis larvae, Nereis sp, Glauconome angulata* and *Pirenella cingulata* was dominated

7f	Seaweeds and Seagrasses	No species of sea weeds and sea grass was recorded from the the stations sampled.
7g	Halophytes	During the period of May 2024 to May 2025 four major halophytes were recorded along the selected study stations of Deendayal Port Authority sites during the 3 seasons, were Salicornia brachiata, Aeluropus lagopoides, Salvadora persica and Sesuvium portulacastrum. Maximum percentage coverage of halophytes belongs to species Salicornia brachiate shared highest percentage of coverage in all season (100%) followed Sesuviumportulacastrum (30-45%)
7h	**Mammals**	No species of mammals was recorded from the stations sampled
7i	**Reptiles**	During the Monsoon AND Post- period of 2024-2025 field surveys it was encounter at S-10 located in the Southern part of Sat Saida bet
7j	**Fisheries**	The major fish catch activity is carried out in extensive creek systems of Khari creek, Tuna creek, Navalakhi creek and Jhangi creek. For the period of period 2024-2025, cast net was operated in different creek system of Kandla and major fish catch was include during monsoon Mugil cephalus, is major catch within 10 minutes around 1 km of distance.
7k	**Avifauna**	A total of 64 species (34 species terrestrial and 30 aquatic bird) representing 11 order, 26 families and 46 genera were recorded during the study period. Among 64 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

Comparison Study of Marine Biodiversity of Deendayal Port Authority (DPA) Since 2019-2025

Habitat/ Groups	Major Taxa/Genera/Species	Year 2019-2020		Year 2020-2021		Year May 2021- May 2022			Year May 2022- May 2023		
		Pre Monsoon	Post monsoon	Pre monsoon	Post monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon	Pre monsoon
Mangroves	*Avicennia marina*, *Ceriops tagal*, *Rhizophora mucronata*, *Aegiceras corniculatum*	4	4	4	4	4	4	4	4	4	4
Intertidal Habitat	Gastropods, Bivalves, Crustaceans Polychaetes, fishes, amphipods and Isopods	19	10	10	12	21	16	16	14	14	13
Subtidal Habitat	Polychaetes, molluscs, crustaceans,echinoderms	26	28	30	48	22	22	11	14	21	32
Phytoplankton	*Bacillaria, Navicula, Nitzschia, Chaetoceros, Coscinodiscus, Triceratium, Bidulphia, Melosira, Thassiosira*	32	26	23	19	35	23	23	24-33	22-26	21-26
Zooplankton	Copepods, Harpacticoids, Cyclopoids. brachyurans, cirripedes, Bivalve veligers	33	36	29	27	42	35	42	41	45	40
Seaweeds	Nil (Drifted tufts only)	Nil	Nil	drifted	drifted	drifted	drifted	drifted	NIL	NIL	NIL

Habitat/ Groups	Major Taxa/Genera/Species	Year		Year		Year			Year		
		2019-2020		2020-2021		May 2021- May 2022			May 2022- May 2023		
		Pre-M	Post-M	Pre-M	Post-M	Monsoon	Post-M	Pre-M	Monsoon	Post-M	Pre-M
Sea grasses	Nil (Drifted tufts only)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Halophytes	*Sesuvium portulacastrum, Salvadora persica, Aeluropus*	3	4	4	4	4	4	4	4 Salicrnia dominance	4 Salicrnia dominance	5 Salicrnia dominance
Avifauna	Charadriiformes, Phoenicopteriformes, Pelecaniformes, Passeriformes	49	89	49	69	62	84	52	49	79	53
Fishes	*Mugil cephalus, Harpodon nehereus, Pampus argenteus, Hilsa, Engraulis, Coilia* sp. *Peneaus,Portunus,lobester*	10	8	5	4	7	5	7		160 kg	50 kg
Marine Mammals	Dolphin, *Sousa plumbea*	1	1	Nil	Nil	1	Nil	Nil	1	1	Nil
Reptiles in the	The saw-scaled viper, *Echis*	1	1	Nil	1	Nil	Nil	1	1	1	Nil

For the period May 2023 to May 2024

Habitat/ Groups	Major Taxa/Genera/Species	Year		
		May 2023- May 2024		
		Monsoon	Post monsoon	Pre monsoon
Mangroves	*Avicennia marina*, *Ceriops tagal*, *Rhizophora mucronata, Aegiceras corniculatum*	4	4	4
Intertidal Habitat	Annelida, Arthropoda, Chordata Mollusca	15	15	14
Subtidal Habitat	Annelida,Arthropoda,Mollusca Chordata	26	21	15
Phytoplankton	*Coscinodiscus* dominance in all season	20-25	8-27	11-20
Zooplankton	The phylum Arthropoda was the predominant represented 16 groups in monsoon and post-monsoon (9) and pre-monsoon it contain 6 group which mainly include Copepoda, Harpacticoida, Cyclopoida, Decapoda, Crab larvae and Malacostrac	29-36	15-36	15-31
Seaweeds	No observation of seaweed during the study period	NIL	NIL	NIL

Habitat/ Groups	Major Taxa/Genera/Species	Year		
		May 2023- May 2024		
		Monsoon	Post monsoon	Pre monsoon
Sea grasses		NIL	NIL	NIL
Halophytes	*Sesuvium portulacastrum*, , Aeluropus lagopoides, *Salicornia brachiata*, *Suaeda nudiflora*	Present	Present	Present
Avifauna	55 species, 71 species , 68 species	55 species 8 order,24 families 23 genera	71 species 9 orders 29 families 55 genera	68 species 8 orders 28 families 53 genera
Marine Mammals	*Sousa plumbea*	No observation	S-6 and S-11	No observation
Fishes	*Mugil cephalus, Planiliza klunzingeri, Planiliza planiceps, Planiliza macrolepis*	*Mugil cephalus* More catch	*Mugil cephalus* More catch	Mugil cephalus
Reptiles	*Echis carinatus sochureki*	No observation	S-10	No observation

For the period May 2024 to May 2025

Habitat/ Groups	Major Taxa/Genera/Species	Year		
		May 2024- May 2025		
		Monsoon	Post monsoon	Pre monsoon
Mangroves	*Avicennia marina*, *Ceriops tagal*, *Rhizophora mucronata, Aegiceras corniculatum*	4	4	4
Intertidal Habitat	Arthropoda ,Chordata, Mollusca	Total density 53	Total density 42	Total density 45
Subtidal Habitat	Annelida,Arthropoda, Mollusca, Nematoda 307, 412,508	Total density 307	Total Total density density 42 412	Total Total density density 42 508 45 Total Total density density 42 45
Phytoplankton	*Pennales, Centrales* dominated	65.1% 54.55	59.4% 33.9%	42.4% 33.1%
Zooplankton	The phylum Arthropoda was the predominant represented include Copepoda, Harpacticoida, Cyclopoida, Decapoda, Crab larvae and Malacostrac	14420	20000	18560
Seaweeds	No observation of seaweed during the study period	Nil	Nil	Nil

Habitat/ Groups	Major Taxa/Genera/Species	Year		
		May 2024- May 2025		
		Monsoon	Post monsoon	Pre monsoon
Sea grasses		NIL	NIL	NIL
Halophytes	*Sesuvium portulacastrum*, , Aeluropus lagopoides, *Salicornia brachiata*, *Suaeda nudiflora*	Present	Present	Present
Avifauna	A total of 64 species (34 species terrestrial and 30 aquatic bird) representing 11 order, 26 families and 46 genera were recorded during the study period.	53	64	60
Marine Mammals	*Sousa plumbea*	no	no	no
Fishes	*Mugil cephalus, Planiliza klunzingeri, Planiliza planiceps, Planiliza macrolepis*	*Mugil cephalus*	*Mugil cephalus*	Mugil cephalus
Reptiles	*Echis carinatus sochureki*	S-10	S-10	NO

List of Plates

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 the 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, 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 and petroleum products. 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 demand for cargo handling during the recent times. A developmental initiative of this magnitude is going on since the 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. The 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 the 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) within the 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 Jafar wadi (3) Setting up barrage port at Veera (4) Administrative 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. PA 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, no damage to 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 characteristics 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 ecologically 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 of the selected sampling sites located in around DPA area.
- ToInvestigate 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).

Table 1 . Sampling locations of study area (2024-2025)

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

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). The water samples were collected from each pre-designated site in pre-clean 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 distillation unit.

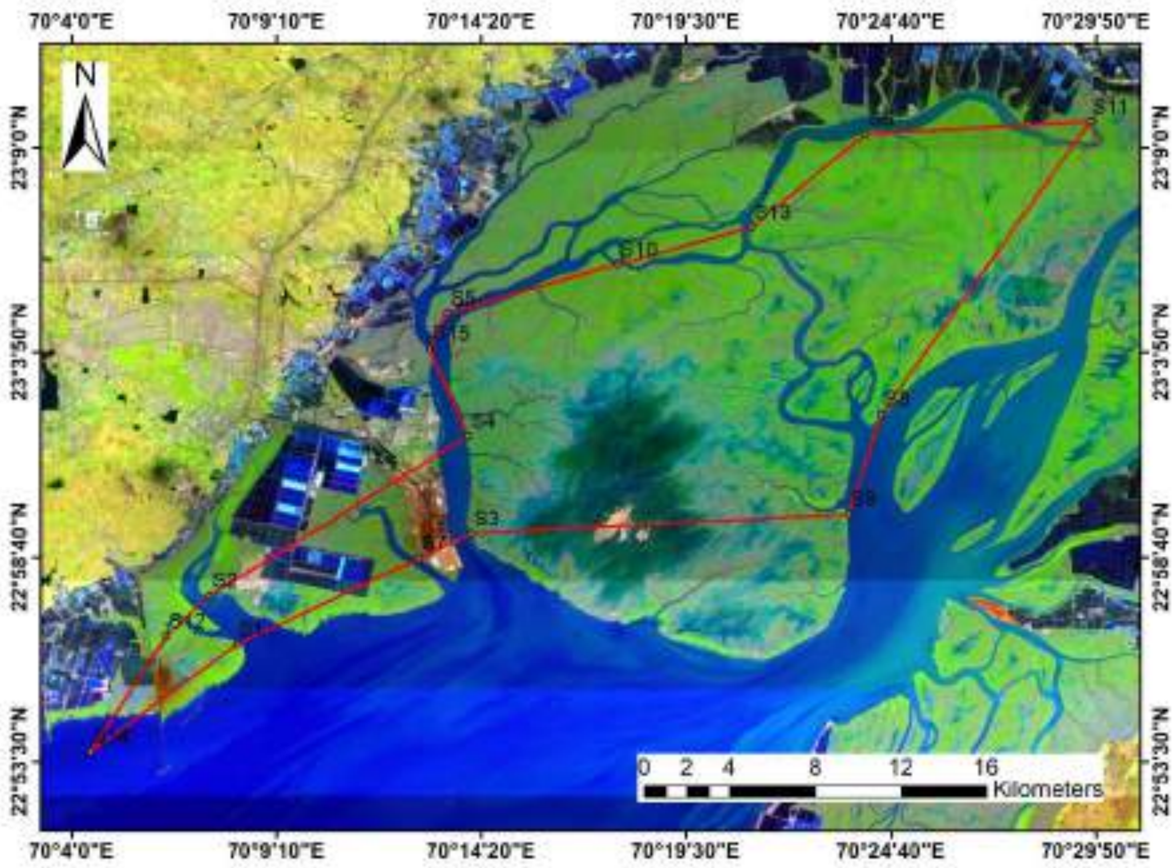


Figure 1. Sampling locations of Study area

2, Land use Land Cover Changes

In order to understand the spatial and temporal changes in the vicinity of the Deendayal port jurisdiction area, Remote Sensing and GIS technique has been employed. Land cover classification was carried out using digital satellite imageries. Images for the Deendayal Port area were acquired for the period of April 2017, December 2019 and March 2020, November 2020, April 2021, March 2022 and March 2023 were used for the study. These were brought to UTM projection with spheroid and datum named WGS 84 in UTM zone 42 north.

Table 2 Satellite Imagery Used for Land Use Land Cover Map

Image use	Satellite name	Sensor	Spatial Resolution	Date acquired
2017	IRS-R2A	LISS IV	5.8m	26 April- 2017
2019	IRS-R2A	LISS IV	5.8m	24-DEC-2019
2020	IRS-R2A	LISS IV	5.8m	29-March-2020
2020	IRS-R2	LISS IV	5.8m	17-Nov-2020
2021	IRS-R2	LISS IV	5.8m	10-APR-2021
2022	IRS-R2	LISS IV	5.8m	12-March-2022
2023	IRS-R2	LISS IV	5.8m	31-March-2023

2.1 Methodology

Training samples were collected from these imageries. Selecting training samples from these cloud-free mosaics was straightforward due to the very distinctive signature of mangrove area. High contrast with open water, saltpan and mudflat helped in selecting the training data successfully. Same training samples with slight modifications in each imageries mosaic (addition and removal of few training samples) were used for the classification of all different date images. Six major classes viz., mangrove, water, mudflat, other vegetation, salt pan and port were delineated. For the tonal variation and pixel values in the imageries, NDVI (Normalised Differential Vegetative Index) and a supervised Maximum Likelihood Classification (MLC) methods were used for the classification. ERDAS Imagine 9.3 was used for satellite image processing, classification and data transformation whereas ARC GIS 10.3 was used for the map formation. Forgraphs and databases processing, MS WORD and MS EXCEL were used.Ground truth study comprises data collection of ground features along with the respectivegeographical positions in terms of latitudes and longitudes with Garmin e-Trex Vista GPS. Thus, the data were interpreted using all the collected information.

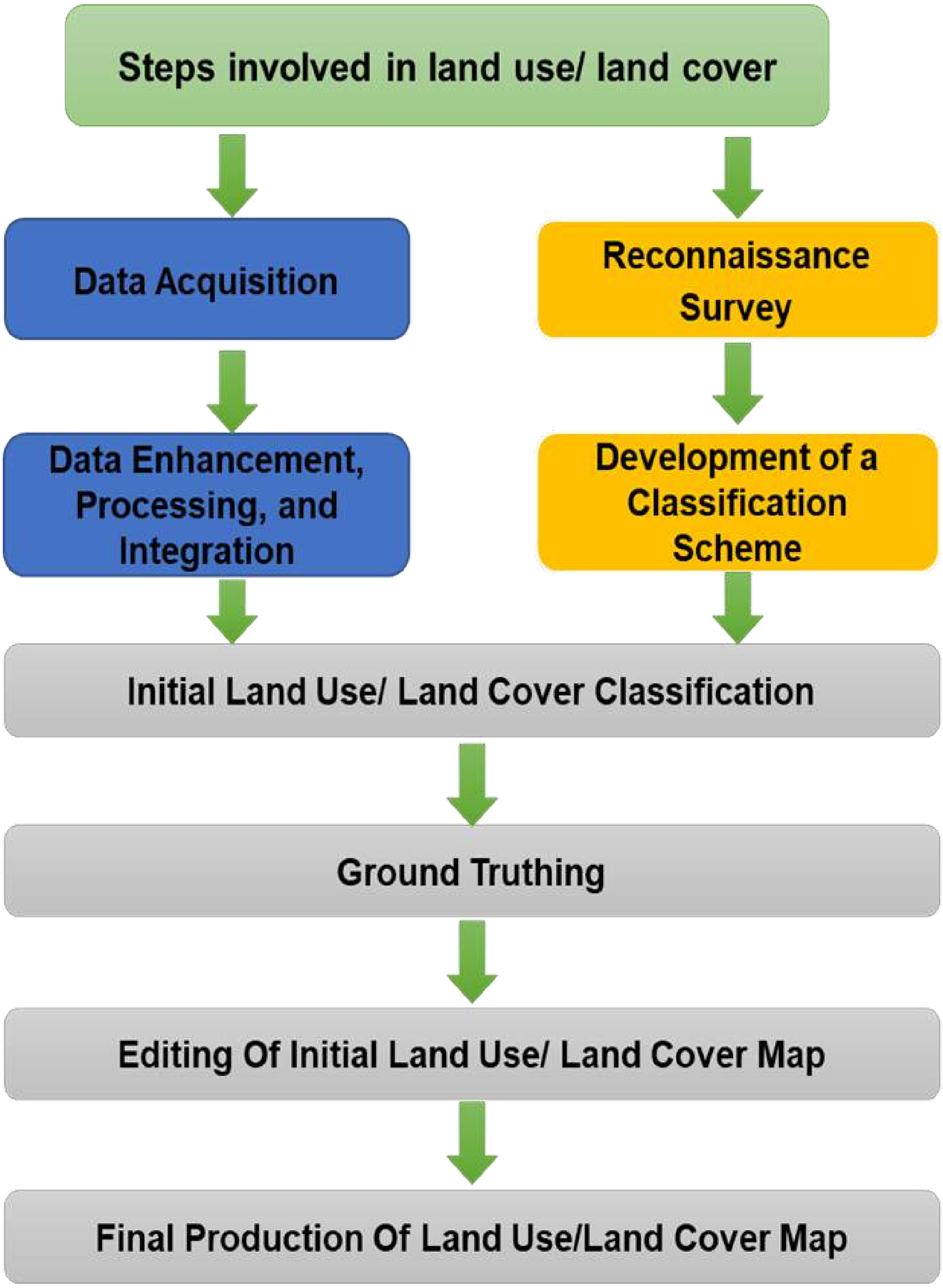


Figure 2. Methodology for land use Land cover

2.2.1Land use Land Cover

Classified imageries are presented in Fig 3 to Fig 4 and detailed presented in table 2 and 3.

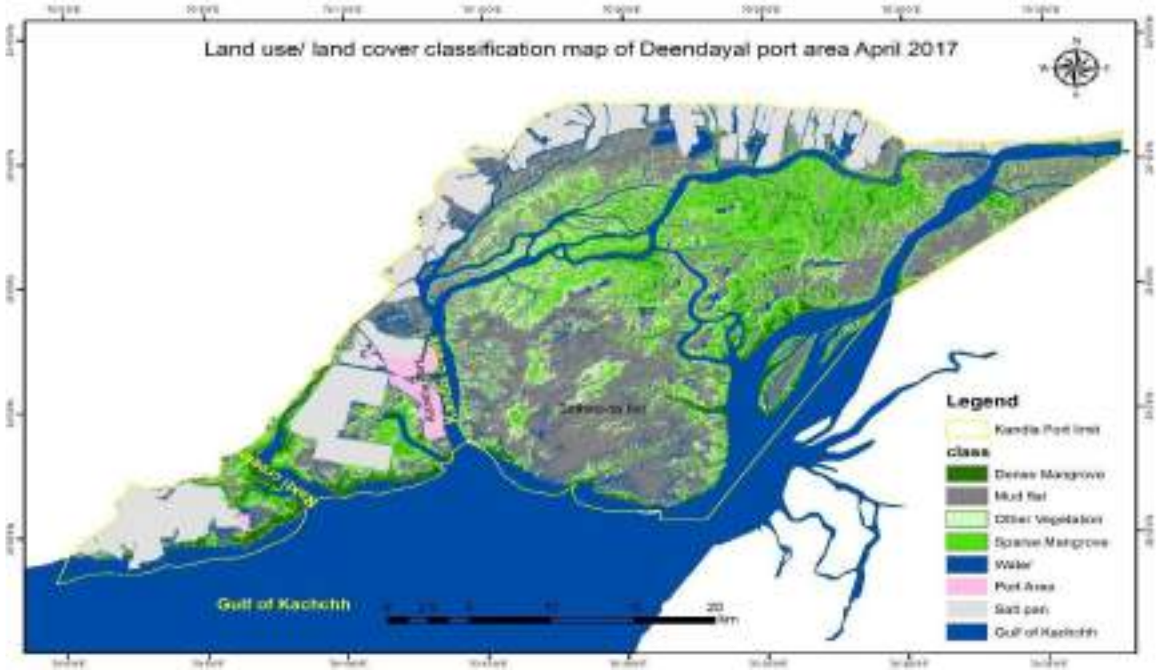


Figure 3. Land use/ Land cover classification in DPA area- April-2017

Figure 4. Land use/ land cover classification in DPA area December-2019

Table 3. Land use /Land cover statistics in the DPA area - April-2017

Class Name	Area (ha)	Percentage
Mangrove (Dense + Sparse)	19319.71	19.32
Mudflat	31293.43	31.3
Other veg	12438.8	12.44
Port Area	1243.67	1.24
Salt pan	15016.1	15.02
Water	20674.3	20.68
Total	**99986.01**	**100**

Table 4. Land use /Land cover statistics in the DPA area - December-2019

Class Name	Area (ha)	Percentage
Mangrove	23060.04	23.06
Mudflat	31179.87	31.18
Other vegetation	12333.21	12.33
Water	16953.68	16.96
Port area	1346.21	1.35
Salt pan	15113	15.12
Total	**99986.01**	**100**

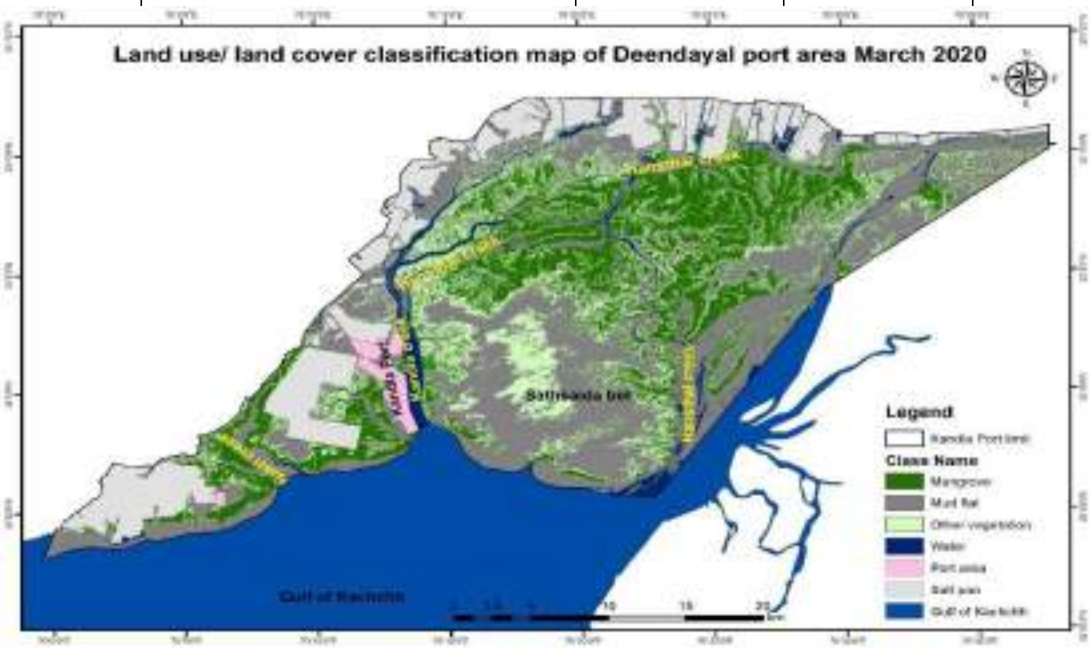


Figure 5. Land use/ land cover classification in DPA area March-2020

Table 5. Land use /land cover statistics in the DPA area- March-2020

Class name	Area (ha)	Percentage
Mangrove	23168.4	23.17
Mudflat	40714.6	40.72
Other vegetation	15991.69	15.99
Port area	1346.21	1.35
Salt pan	15054.5	15.06
Water	3710.61	3.71
Total	**99986.01**	**100**

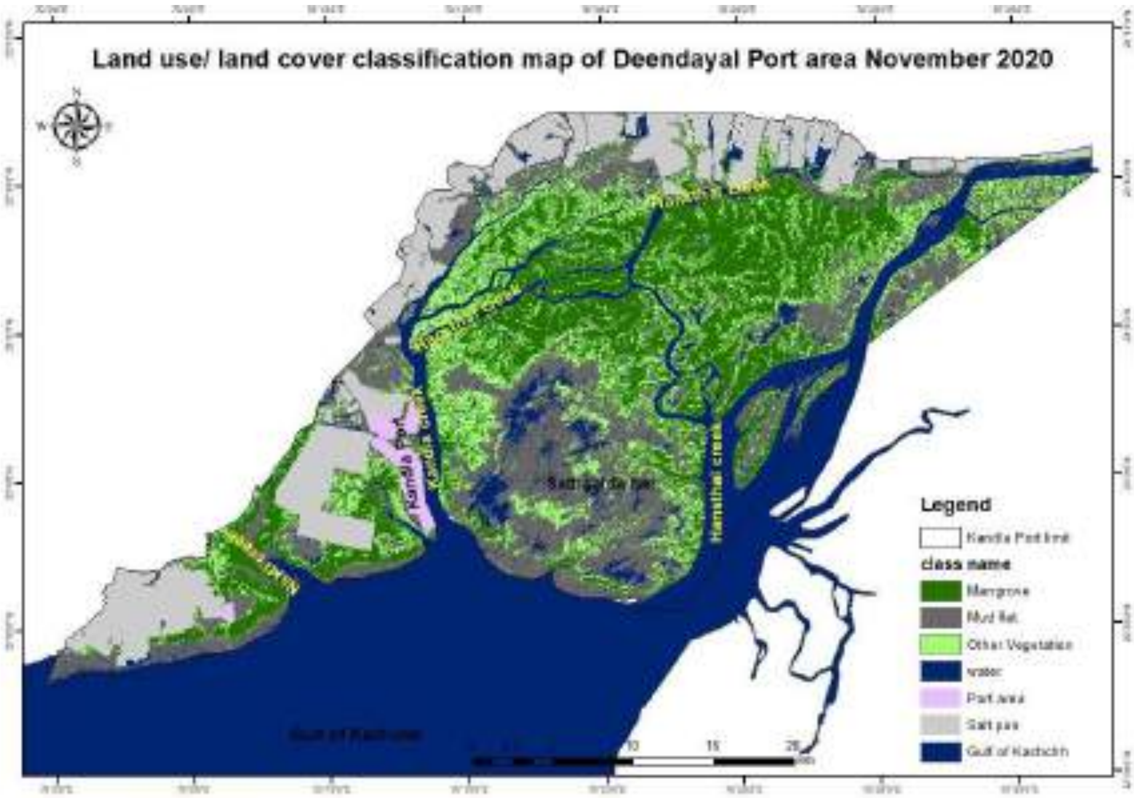


Figure 6. Land use/ land cover classification in Deendayal port area November 2020

Table 6. Land use /land cover statistics in the DPA area- November2020

Class	Area (ha)	Percentage
Mangrove	23856.8	23.86
Mudflat	28764.6	28.77
Other Vegetation	16346.1	16.35
Port area	1346.21	1.35
Salt pan	15193.5	15.2
water	14478.8	14.48
Total	99986.01	100

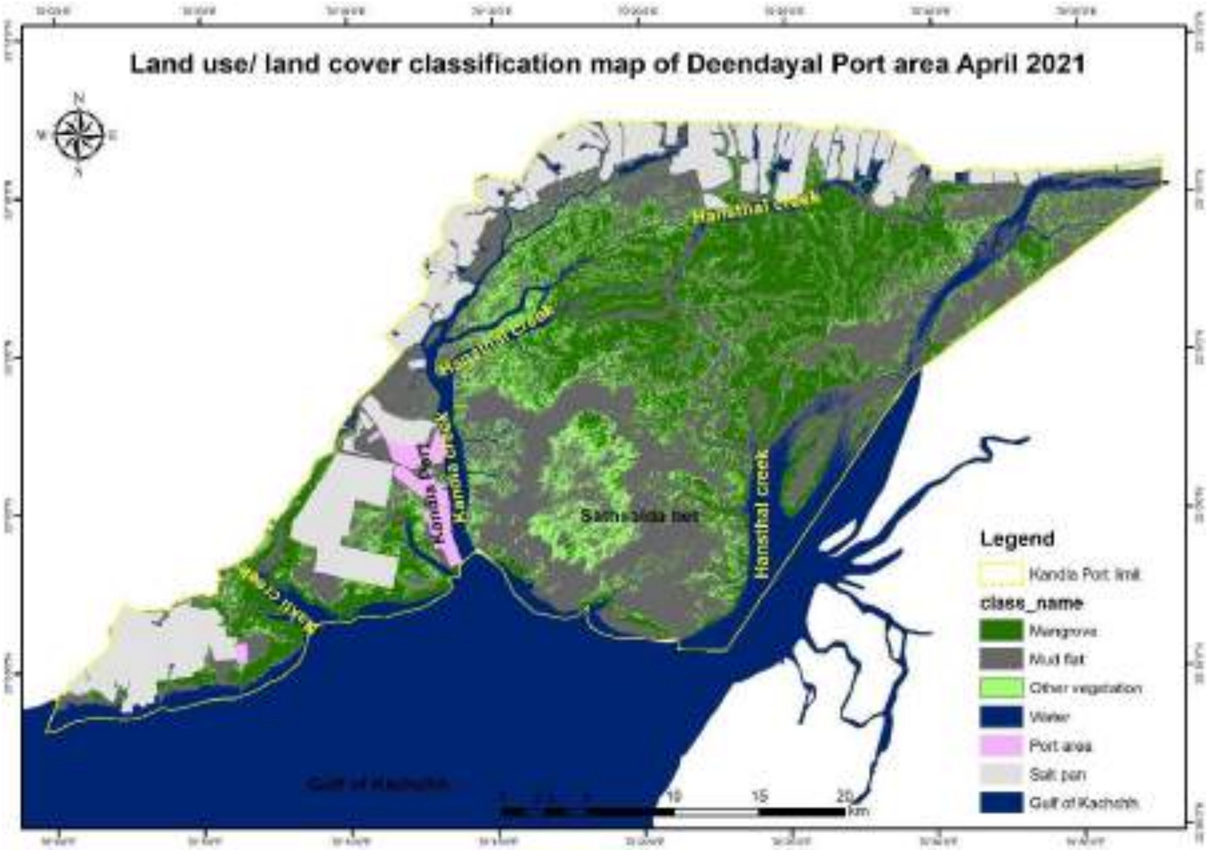


Figure 7. Land use/ land cover classification in Deendayal port area April-2021

Table 7. Land use /land cover statistics in the DPA area April-2021

class name	Area (ha)	Percentage
Mangrove	23967.4	23.97
Mudflat	36909.3	36.91
Other vegetation	11230.4	11.23
Port area	1346.21	1.35
Salt pan	15236.6	15.24
Water	11296.1	11.3
total	**99986.01**	**100**

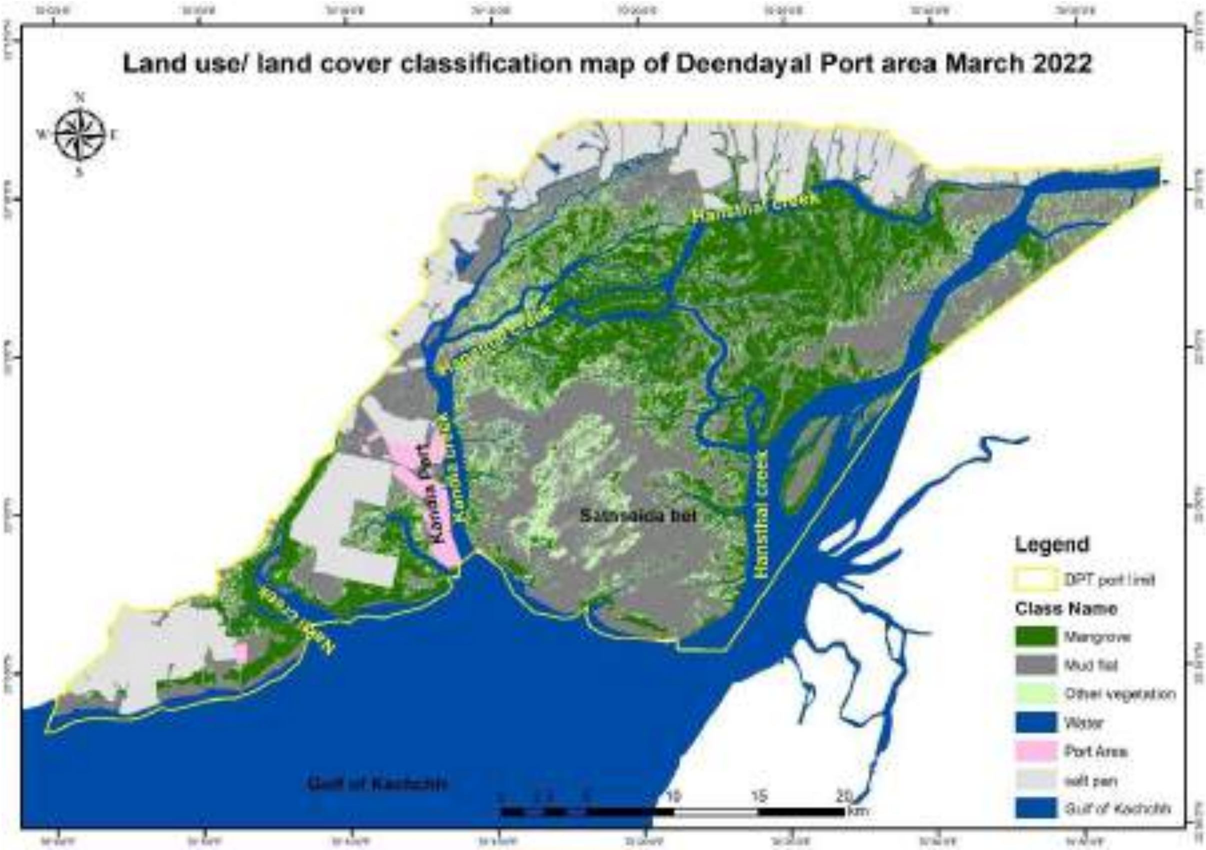


Figure 8.Land use/ land cover classification in Deendayal port area March-2022

Table 8. Land use /land cover statistics in the DPA area March-2022

class name	Area (ha)	Percentage
Mangrove	24328.7	24.33
Mudflat	31089.06	31.09
Other vegetation	11561.2	11.56
Port Area	1436.75	1.44
salt pan	15545.7	15.55
Water	16024.6	16.03
Total	**99986.01**	**100**

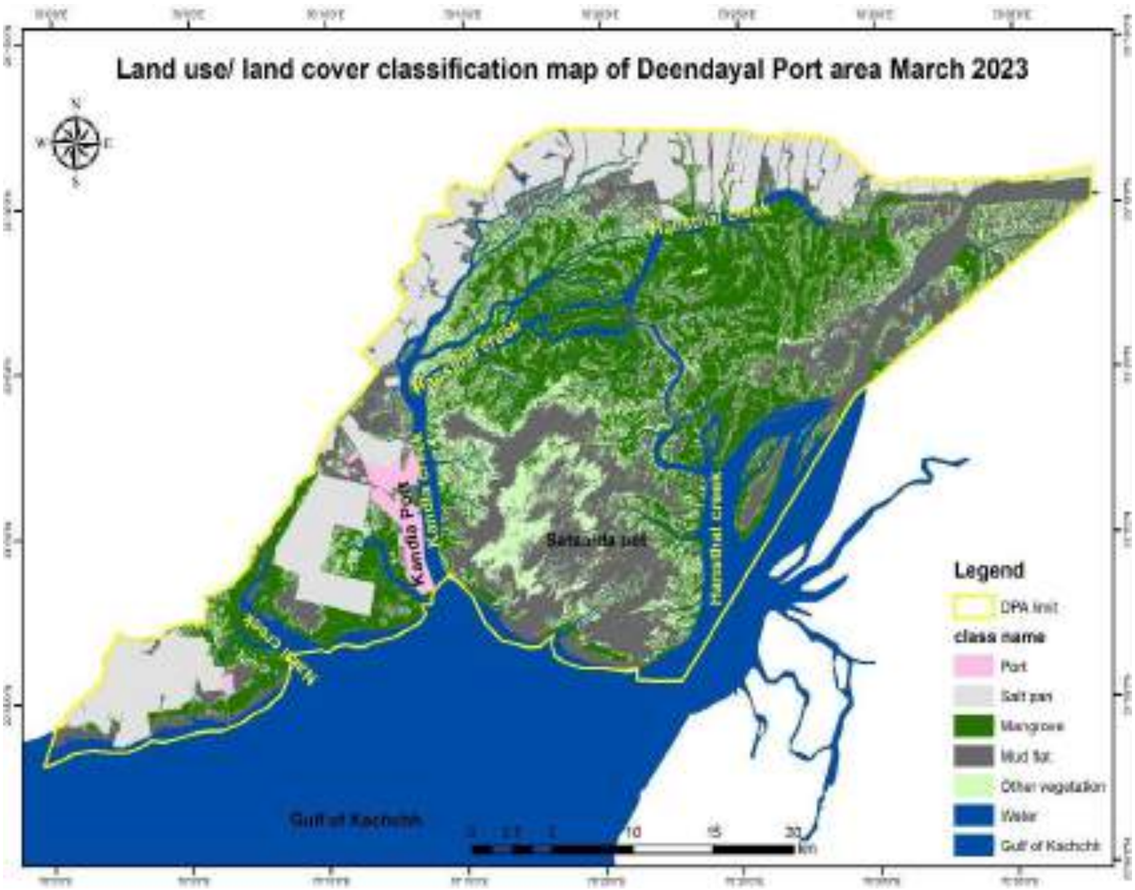


Figure 9. Land use/ land cover classification in Deendayal port area March-2023

Table 9. Land use /land cover statistics in the DPT area for March-2023

class name	Area (ha)	Percentage
Mangrove	26520.56	26.52
Mud flat	27547.90	27.55
Other vegetation	15969.90	15.97
Port	1436.75	1.44
Salt pan	16094.80	16.10
Water	12416.10	12.42
Total	**99986.01**	**100.00**

2.2.2. Comparative Analysis of Land use Land Cover Study

From April 2017 to March 2023 the overall mangrove area increased from 19319 ha to 26520.5 ha, i.e. 7 % of the total area of DPA. Mangrove area is replacing on the mostly on mudflat, hence there is a decreasing trend of the mudflat is clearly seen. Since this area comes under the influence of the tidal time mudflat area comes high value in that case water area decrease. But overall trends show mudflat is replaced by mangroves. (Fig 3.9). Good monsoon and favorable environment have positively impacted the mangroves to flourish. The below graph shows clearly, year on year mangrove area in DPA vicinity is increasing, currently, around 26.5% of the total area of DPT is covered by mangroves.

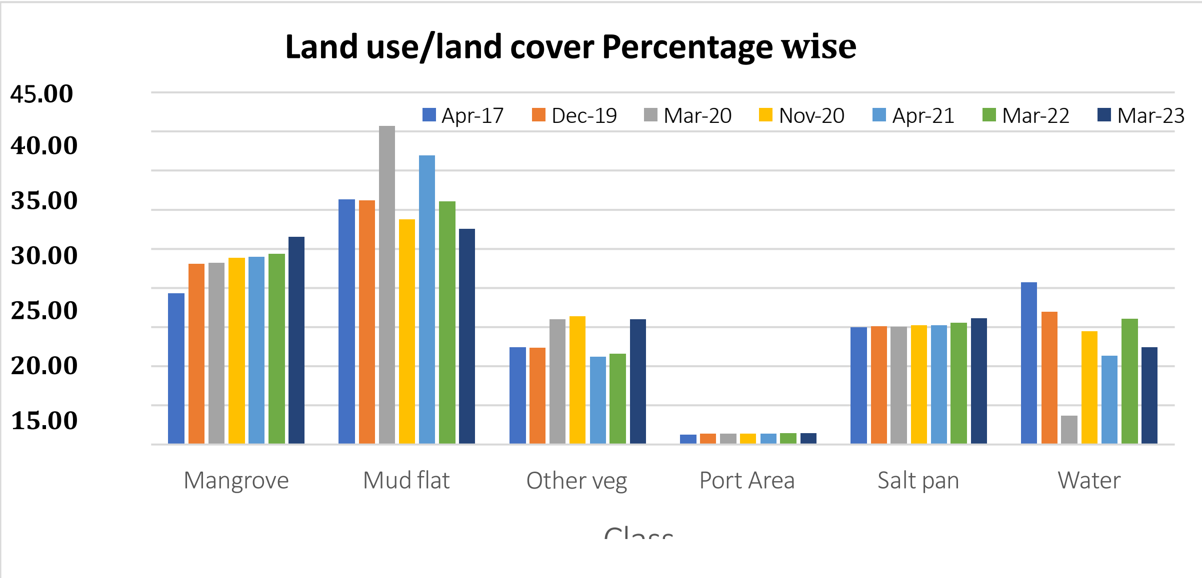
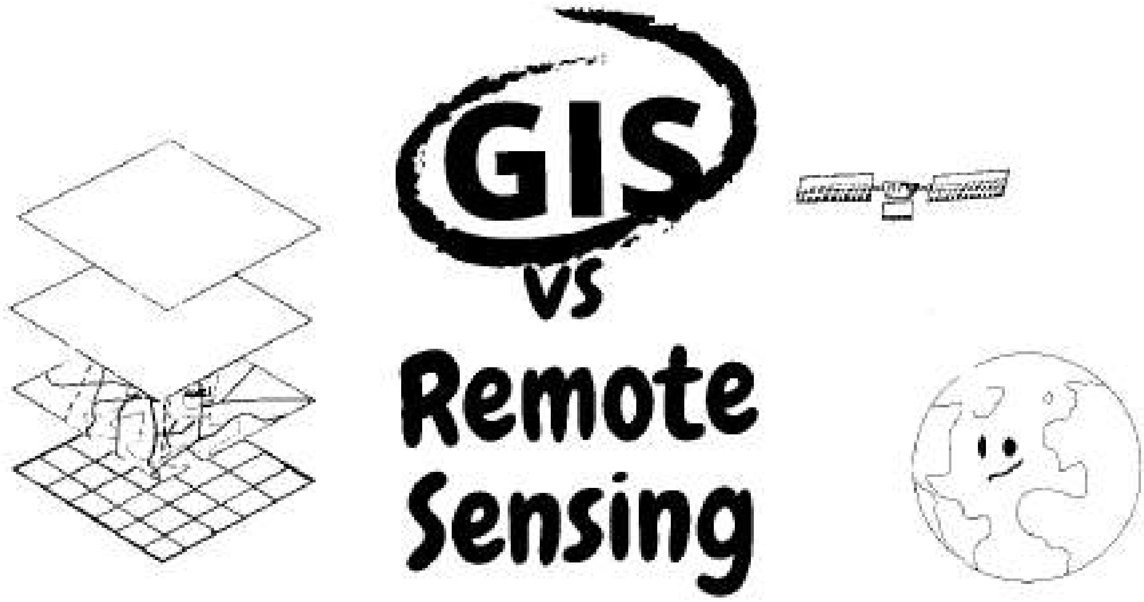


Figure 10. LU/LC Percentage area for the period 2017 to 2023 in Deendayal Port Authority

Table 10. Land use /land cover Percentage wise in the vicinity of DPA area for the study period 2017-2023

Month-Year	**Apr-17**	**Dec-19**	**Mar-20**	**Nov-20**	**Apr-21**	**Mar-22**	**Mar-23**
Class Name	Area (ha)						
Mangrove	19.32	23.06	23.17	23.86	23.97	24.33	26.52
Mudflat	31.30	31.18	40.72	28.77	36.91	31.09	27.55
Other veg	12.44	12.33	15.99	16.35	11.23	11.56	15.97
Port Area	1.24	1.35	1.35	1.35	1.35	1.44	1.44
Salt pan	15.02	15.12	15.06	15.20	15.24	15.55	16.10
Water	20.68	16.96	3.71	14.48	11.30	16.03	12.42
Total	100	100	100	100	100	100	100



3. Methodology

3.1.Physico-chemical Parameters, Water and Sediment

A port is a location on a coast or shore containing one or more harbors where ships can dock and transfer people or cargo to or from land. Port locations are selected to optimize access to land and navigable water, for commercial demand, and for shelter from wind and waves. Harbors can be natural or artificial. An artificial harbor has deliberately constructed breakwaters, sea walls, or jetties, or otherwise, they could have been constructed by dredging, and these require maintenance by further periodic dredging.Ports are economic instruments for trade and a vital component in the nation's economy. Nevertheless, port activities such as land reclamation, dredging and large-scale construction and its continuous expansion negatively affect the marine ecosystems in its vicinity.

In a port environment, activities like dredging, continuous movement of vessels and humans create major impacts at the marine/coastal environment and the living resources. This will have several impacts on the coastal environmental health which can be reflected by the nature of the physico-chemical characteristics of water which in turn indicates in its productivity. The change in productivity pattern of the marine environment is highly influenced by the flow of nutrients which generally originates from natural and anthropogenic sources. This change in quality of marine water, impacts the composition and availability of aquatic organisms directly and also affects the natural process in the marine ecosystem biological component, coral reefs and seagrass habitats etc. Similar to water, marine sediments also receive pollutants / such as heavy metals, petroleum hydrocarbons, polyaromatic hydrocarbons, polychlorinated biphenyls etc as contaminants from various activities, both off shore and on shore near ports and harbours. Hence assessing the water and sediment characteristics is imperative to understand the environmental changes and to suggest scientific interventions to restore the ecosystem integrity

3.1.1. Sampling Parameters & Water sample collection

Sampling was carried out for the coastal water (surface) and sediment for the determination of physical and chemical characteristics from the prefixed sampling sites. The biological parameters (benthic and pelagic fauna, flora and productivity) were also estimated (Table 11).

Table 11: 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 sites in pre-cleaned polyethylene bottles. Prior to sampling, the bottles were rinsed with sample water to be collected and stored in an ice box for transportation to laboratory and refrigerated at 4°C till further analysis. The analysis of the water quality parameters was carried out by following standard methods (APHA, 2017). All extracting reagents were prepared using metal-free, AnalaR grade chemicals (Qualigens Fine Chemicals Division of Glaxo SmithKline Pharmaceuticals Limited, Mumbai) and double distilled water prepared from quartz double distillation assembly. There is one water sample will be collect from each designated sampling locations and period of survey will be carried out June to September as Monsoon, October to January will be designated as Post-monsoon and February to May will be designated as Pre-monsoon.

3.1.2.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.

3.1.3.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).

3.1.4.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.

3.1.5. 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.

3.1.6.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.

3.1.7. Dissolved Oxygen (DO)

The amount of dissolved oxygen (DO) was determined by Winkler's method (Strickland and Parsons,1972).

3.1.8.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). The 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 (APHA,2017).

3.1.9. 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 Grasshoff et.al. (1999).

3.1.10.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).

3.1.11.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.

3.1.12.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.

3.2 Sediment Characteristic (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 by 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.

3.2.1.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%.

3.2.2.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).

3.3. Biological Characteristics of water and Sediment

3.1.1.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).

3.1.2.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. The 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).

3.1.3.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 labelled 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.

3.1.4.Intertidal Fauna

The Intertidal faunal assemblages were studied for their density, abundance and frequency of occurrence during Pre-monsoon 2025 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 x1m^{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; 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).

3.1.5.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), 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 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 2a: Collection of Plankton

2 b. Collection macrobenthos in subtidal habitat

3.4. Mudflats

Mudflats are ecologically and socio-economically vital ecosystems that bring benefits to human populations around the globe. These soft-sediment intertidal habitats, with >10% silt and clay (Dyer, 1979), sustain global fisheries through the establishment of food and habitat (including important nursery habitats), support resident and migratory populations of birds, provide coastal defences, 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 kilometres 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 (Lesuerd *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 mudflat sediment 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).

3.5. Mangrove assessment

Mangroves are widely distributed on the Deendayal Port Authority jurisdiction area along the Kandla coast. The 15 sites were selected at the different creeks belong to Deendayal Port Authority jurisdiction 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 were 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 centre 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.

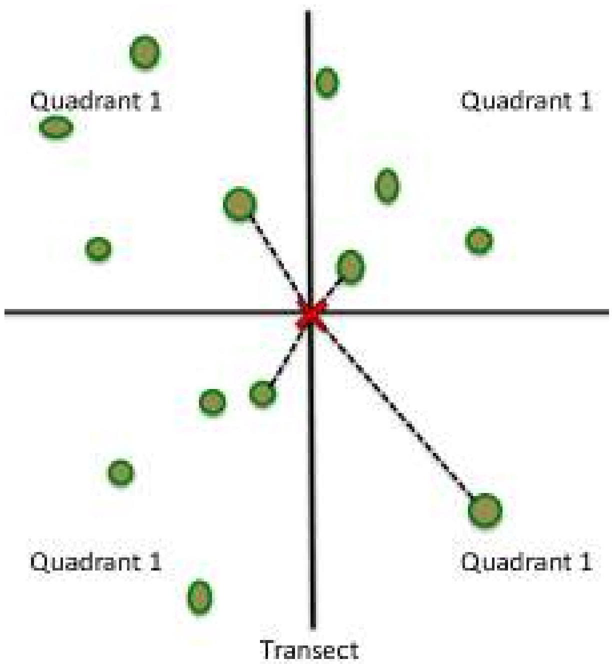


Figure 11 . Point Centred Quadrate Method

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

3.6. Halophytes

To quantify and document the halophytes at Deendayal Port Authority region, quadrate method was followed. At each sampling location quadrates of various sizes have been laid during every seasonal sampling. For recording the plant density at each transect, a quadrate 1 x 1m^2 has been laid within the site each tree quadrates were used randomly (Mishra,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

3.7. Marine Fishery

Fishery resources and the diversity were assessed from the selected sampling sites. Finfish and shellfish samples were collected using a gill net with a 10 mm mesh size. The net was operated onto the water from a canoe or by a person standing in waist deep water during the high tide using a cast net (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: Fisheries Information from DPA environment

3.8. Avifauna

The Avifauna population was determined along DPA mangrove stands 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, Post -Monsoon and Pre-monsoon season (May 2024- May 2025. Survey was done in 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.

Figure .12 Line transect method for Avifauna survey

3.9 Data analysis

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

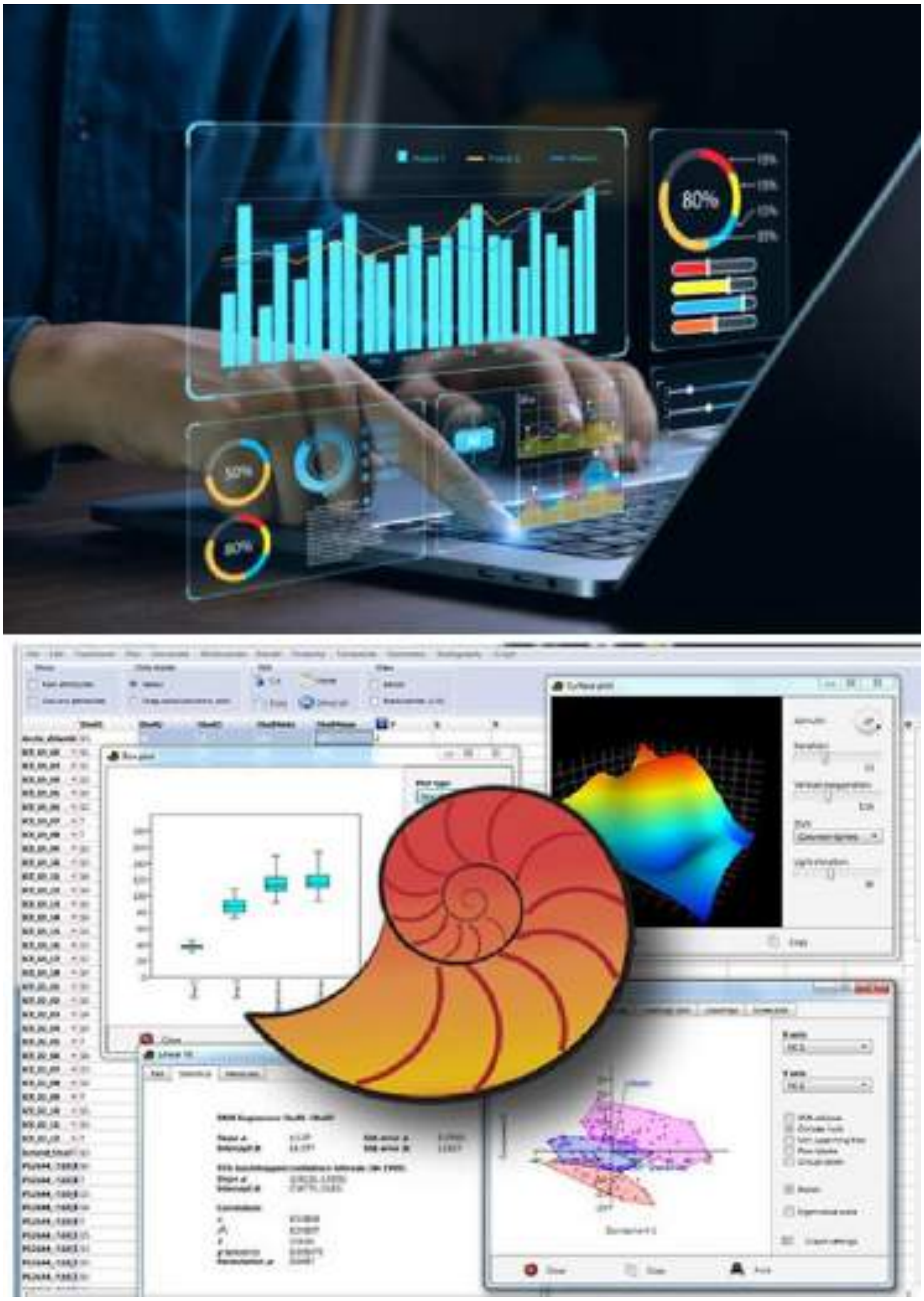


Plate 7 Statistical Data analysis methods

4.Results

4.1. Physico-Chemical Characteristics of water and Sediment

4.1.1.Water quality assessment

The data on the mean water quality parameters measured at the time of sampling of the biological components from the 15 study sites are presented in Table12.

Table-12 Physico-chemical characteristics of the DPA Jurisdiction From May 2024- May 2025

Parameter		Monsoon 2024	Post Monsoon 2024-25	Pre Monsoon 2025
Temperature (°C)	max	30	27	29
	min	23	12	25
pH	max	8.1	8.5	8.3
	min	7.7	7.3	7.8
Salinity	max	42	42	41
	min	34	32	32
Dissolved oxygen (mg/L)	max	8.2	7.7	5.3
	min	2.9	3.9	3.2
Total Suspended Solids (TSS) (mg/L	max	729	579	722
	min	205	222	253
Total Dissolved solids (TDS) (mg/L)	max	139862	95571	41300
	min	26876	9829	3035
Turbidity (NTU)	max	160	133	489
	min	20	38	61.4
Nitrate (NO3) (mg/L)	max	0.003	0.140	0.019
	min	0.001	0.020	0.009
Nitrite (NO2) (mg/L)	max	0.173	0.003	0.128
	min	0.001	0.001	0.003
Total Phosphorus (mg/L)	max	73.24	65.90	27.12
	min	36.18	30.60	3.16
Total silicate	max	0.058	0.07	4.48
	min	0.012	0.01	1.02
PHs (µg/L)	max	10.10	70.80	8.32
	min	1.20	2.50	0.19
Chlorophyll a (mg/L)	max	0.89	0.65	2.98
	min	0.04	0.04	0.12

Temperature (°C)

The values for the Temperature obtained from 15 different sampling station for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure 13. During monsoon, the value ranged from 23°C to 30°C while in post monsoon observation, the value ranged from 12°C to 27°C. However, in pre monsoon the values were noted in the range of 25°C to 29°C. During monsoon, the highest temperature was noted at station S-7 while the lowest temperature was noted at S-6 and S-15. In post-monsoon maximum temperature was recorded at S-2 and S-4 and lowest at S-15 while in pre-monsoon highest temperature exhibited at S-2 & S-8 and lowest temperature observed at S-10.

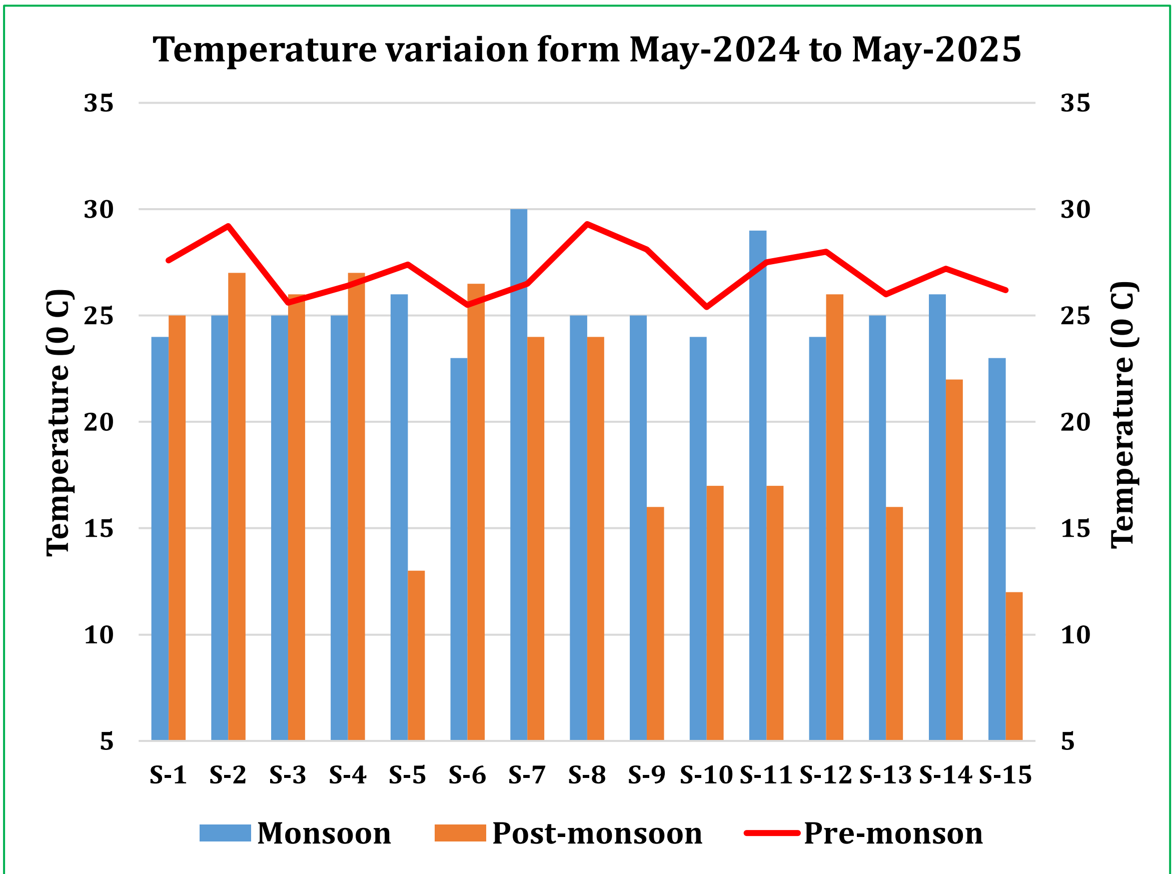


Figure 13. Temperature variation in DPA study sites during 2024-2025

The average temperature in Deendayal port authority jurisdiction varied from 21° C to 27°C in 3 seasons throughout the year.

pH

The pH obtained from 15 different sampling station for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure 12. During monsoon, the value ranged from 7.7 to 8.1 while in post monsoon observation, the value ranged from 7.3 to 8.5. However, in pre monsoon the values were noted in the range of 7.8 to 8.3. During monsoon, the highest pH was noted at station S-1, S-3, S-6, S-7, S-13, & S-14 while the lowest pH was noted at S-8 & S-11. On an average, the pH ranged between 7.3 to 8.5 throughout the year inclusive of all the three seasons.

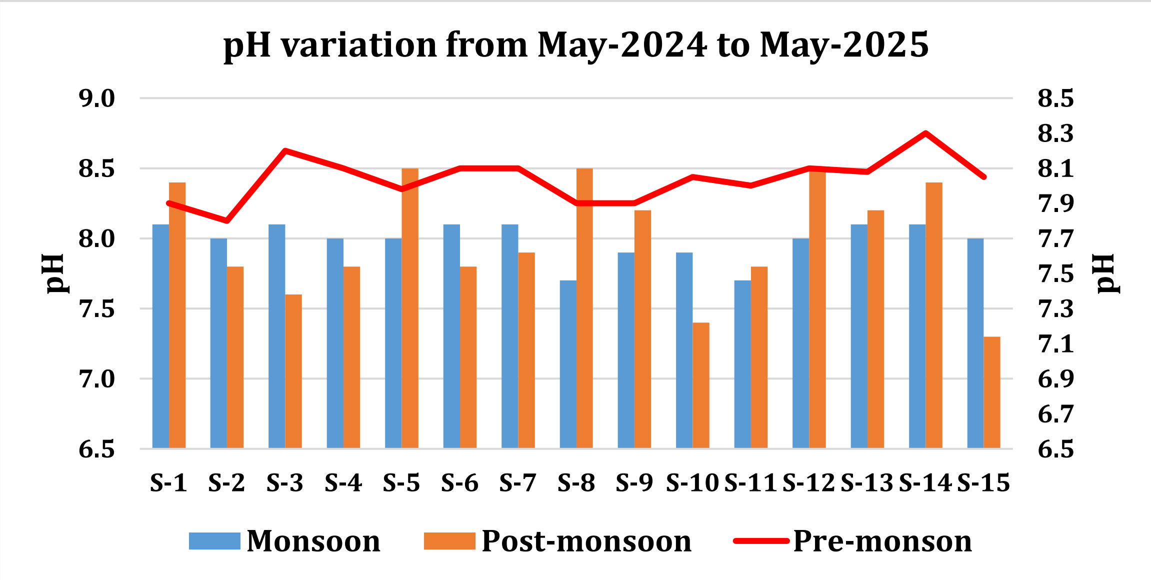


Figure 14. pH variation May 2024 to May 2025 in Deendayal Port Authority

Salinity (ppt)

The salinity obtained from 15 different sampling station for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure 15. During monsoon, the salinity ranged from 34 ppt to 42 ppt while in post monsoon observation, the value ranged from 32 ppt to 42 ppt. However, in pre monsoon the values were noted in the range of 32 ppt to 41 ppt. During pre-monsoon, the highest salinity was noted at stations S-10 & S-11 while the lowest salinity was recorded at S-5. It was observed that maximum salinity was recorded in pre-monsoon and post-monsoon seasons while the lowest was recorded during monsoon. The average salinity throughout the year in Deendayal port authority jurisdiction varied from 32 ppt to 42 ppt during 3 seasons.

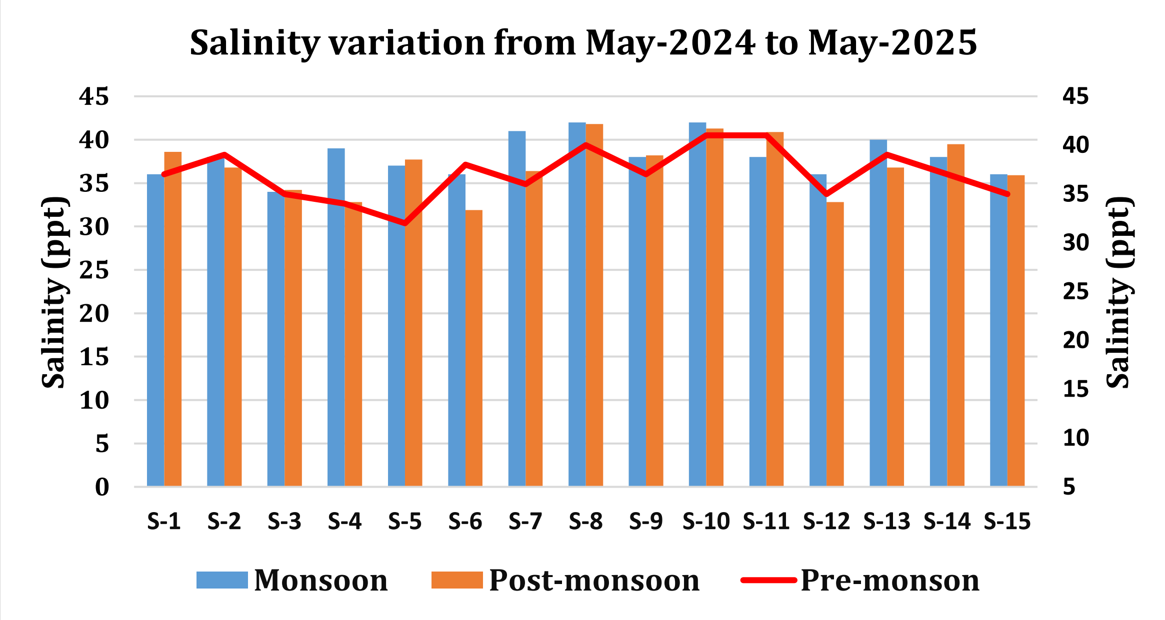


Figure 15. Seasonal variation of salinity during 2024-2025 at DPA

Dissolved oxygen (DO)

The maximum Dissolved Oxygen concentration of the sampling stations for three seasons varied from 5.3 mg/L to 8.2 mg/L with average of 4.1 mg/L to 5.8 mg/L from May 2024 to May 2025. The minimum DO values varied from 2.9 mg/L to 3.9 mg/L. The seasonal variation of water DO among stations is presented in Figure 16.

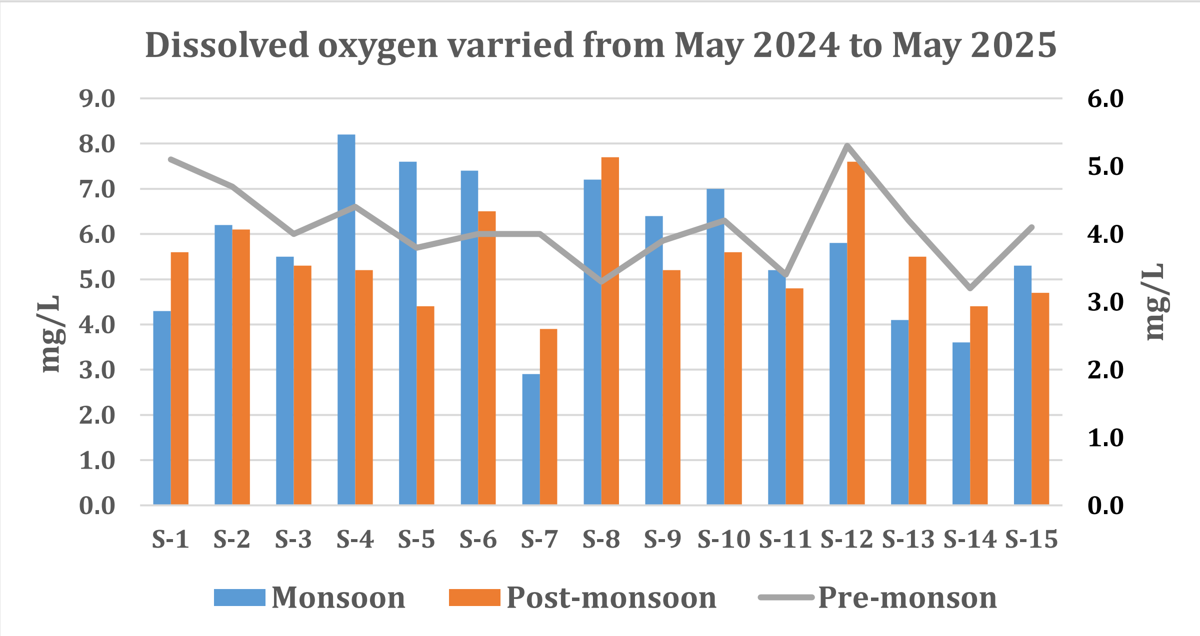


Figure 16. Seasonal variation Dissolved Oxygen from May 2024 to May 2025

During monsoon, the highest DO concentration was observed at station S-4 (8.2 mg/L), and the Lowest dissolved oxygen concentration was observed at S-7 (2.9 mg/L). In post-monsoon, the highest dissolved oxygen was observed at S-8 (7.7 mg/L) and the lowest value at S-7 (3.9 mg/L). During Pre-monsoon, the highest and lowest DO values were observed at stations S-12 (5.3 mg/L) and S-14 (3.2 mg/L) respectively.

Total Suspended Solids (TSS)

The values for the Total Suspended Solids (TSS) obtained from 15 different sampling sites for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure 15. During monsoon, the value ranged from 205 mg/L to 729 mg/L, while in post monsoon observation, the value ranged from 222 mg/L to 579 mg/L. However, in pre monsoon the values were noted in the range of 253 mg/L to 722 mg/L. During monsoon, the highest TSS was noted at site S-6 while the lowest TSS value was noted at S-13. The maximum TSS was obtained at S-15 and lowest at S-4 during post monsoon while site S-5 exhibited the highest TSS value and S-12 exhibited the lowest value during the pre-monsoon season (Figure 17).

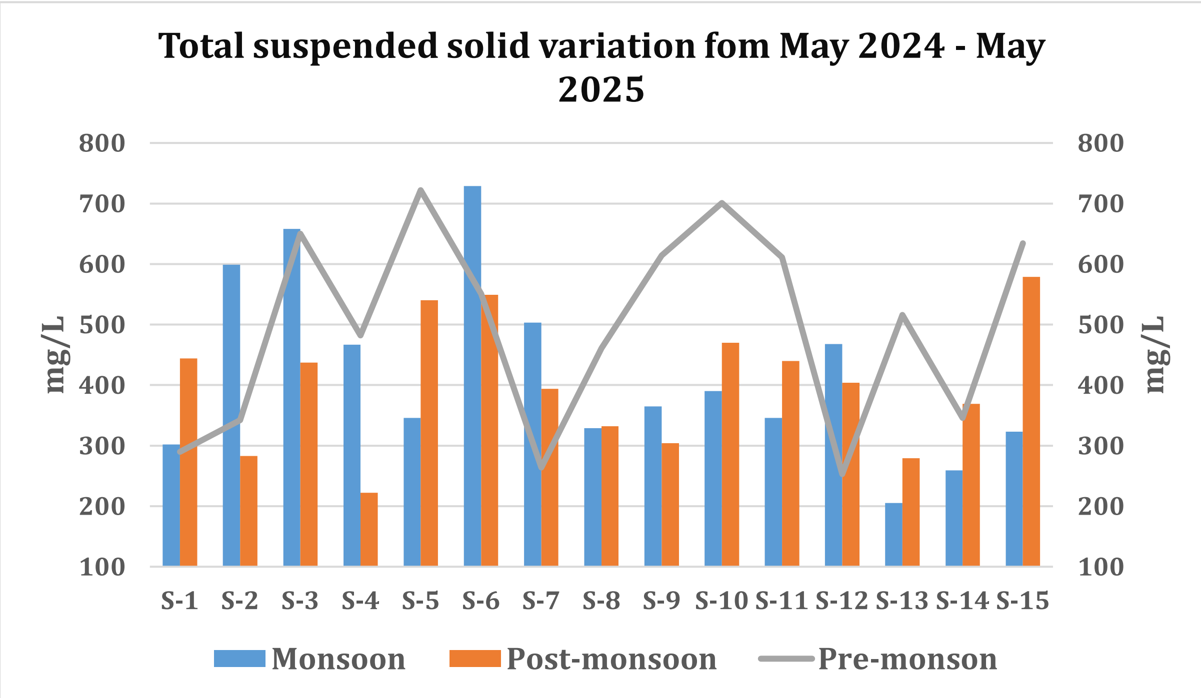


Figure 17 Seasonal variation of TSS during May 2024-May 2025

Total Dissolved solids (TDS)

The values for the Total Dissolved Solids (TDS) obtained from 15 different sampling sites for all the three seasons (Monsoon, post monsoon and pre monsoon) have been represented in Figure 18. During monsoon, the value ranged from 26876 mg/L to 139862 mg/L, while in the post monsoon observation, the value ranged from 9829 mg/L to 95571 mg/L. However, in pre monsoon the values were noted in the range of 3035 mg/L to 41300 mg/L. During monsoon, the highest TDS was noted at site S-10 while the lowest TDS value was noted at S-12. The maximum TDS was obtained at S-14 and the lowest was recorded at S-2 during post monsoon while site S-6 exhibited the maximum TDS value and S-12 showed the lowest value during the pre-monsoon season.

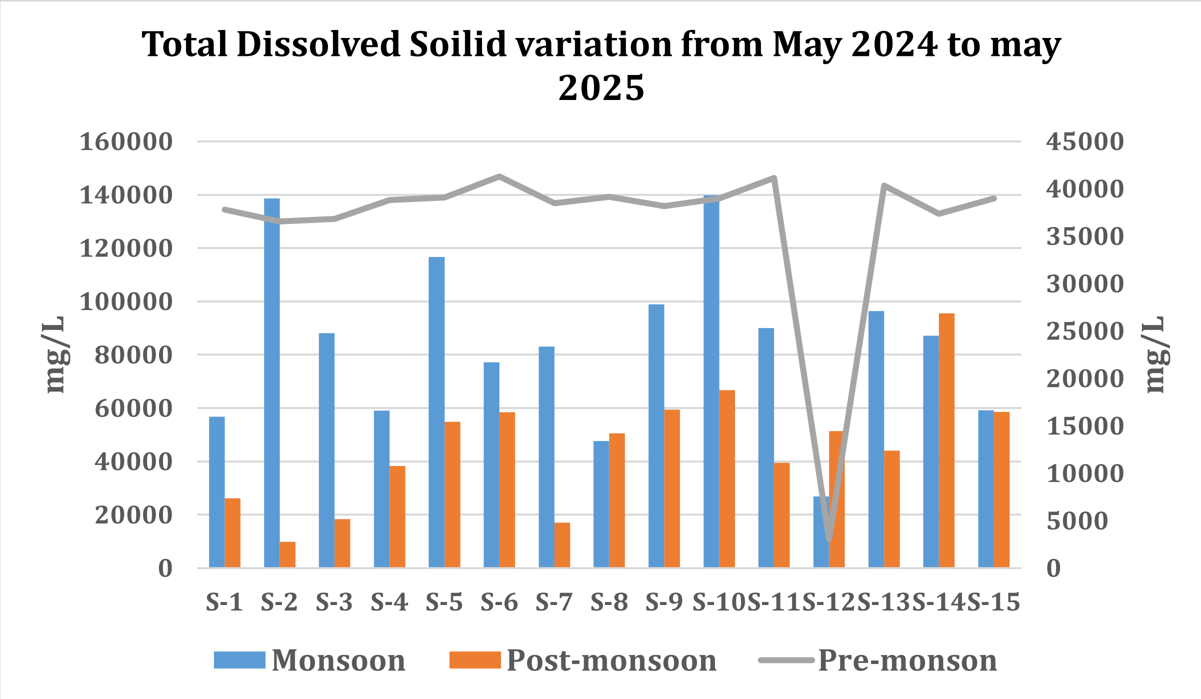


Figure 18 Total Dissolved Solids (TSS) from May 2024 to May 2025

Turbidity

The Turbidity of the sampling stations varied season wise from 20 NTU to 489 NTU for the period May 2024 to May 2025. The seasonal variation of water turbidity among the stations is presented in Figure 19.

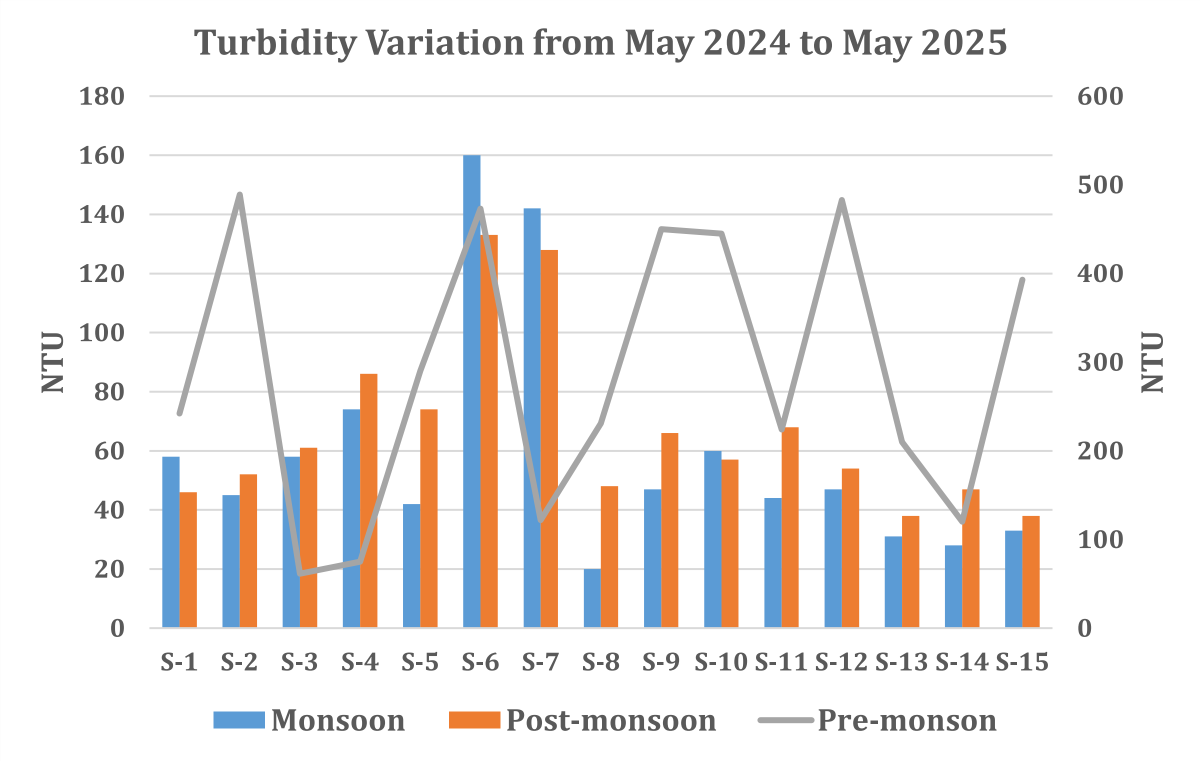


Figure 19 Seasonal variation during Turbidity from May 2024 to May 2025

During monsoon, the highest Turbidity was observed at S-6 (160 NTU) and the lowest was at S-8 (20 NTU). In post-monsoon, the highest Turbidity was observed at station S-6 (133 NTU) and the lowest was at stations S-13 & S-15 (38 NTU). Similarly in Pre-monsoon, the highest and lowest turbidity was observed at S-2 (489 NTU) and S-3 (61.4 NTU) respectively

Nitrate

The amount of Nitrate in the water sample is relatively low throughout the study period. The maximum Nitrate value for the three seasons was 0.140 mg/L from May 2024 to May 2025. This was noted at S-3 during post-monsoon study. The minimum Nitrate values noted during post monsoon were 0.020 mg/L and 0.009 mg/L (during pre-monsoon), both at site S-6. The seasonal variation of Nitrate content in water samples for all the stations is presented in figure 20. During monsoon, the highest Nitrate value observed was 0.003 mg/L at stations S-1, S-6, S-9, S-10 and S-15 whereas the lowest Nitrate value was 0.001 mg/L at station S-7. During post-monsoon study, the values increased and highest Nitrate was observed at S-3 (0.140 mg/L) and lowest at S-6 (0.020 mg/L).

Similarly in Pre-monsoon the highest (0.019 mg/L) and the lowest (0.009 mg/L) were reported S-11 & S-6 respectively.

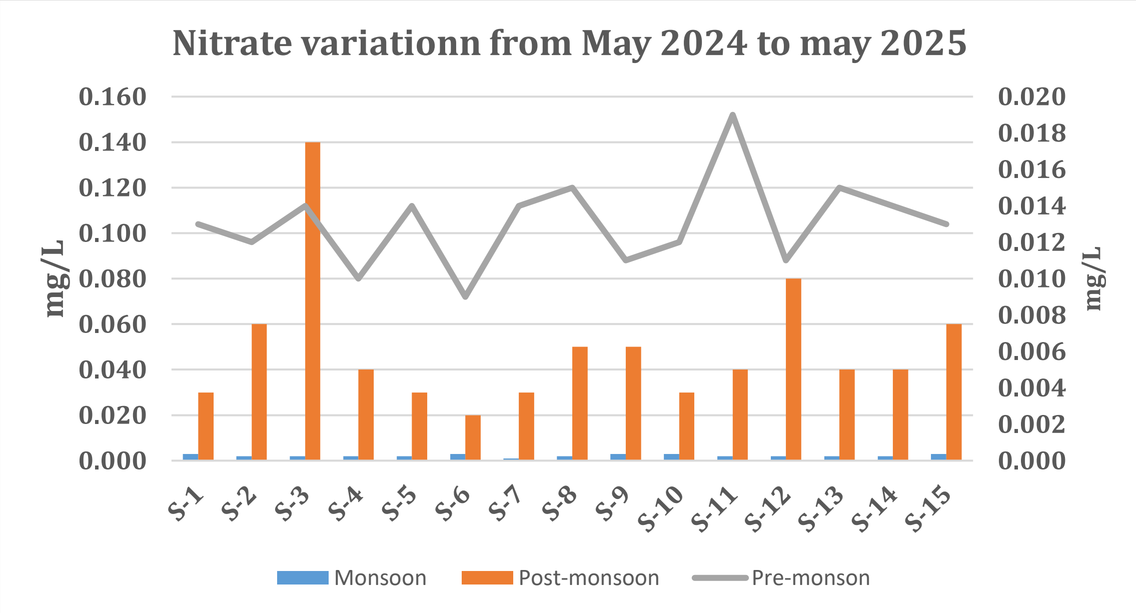


Figure 20. Seasonal variation of Nitrate concentration during May 2024 to May 2025

Nitrite

The amount of Nitrite in the water sample is relatively high compared to the nitrate content throughout the study period. The maximum Nitrite value for the three seasons was 0.173 mg/L from May 2024 to May 2025. This was noted at S-9 during monsoon study. The minimum Nitrite value noted during the study was 0.001 mg/L. The seasonal variation of Nitrite concentration is presented in Figure 21. During monsoon, the highest nitrite concentration was noted at S-9 (0.173 mg/L) and the lowest was recorded at S-14 (0.001 mg/L). In post-monsoon, the maximum value was found at S-1, S-6, S-8, S-12 and S-14 (0.003 mg/L) and lowest nitrite was observed at S-3, S-5, S-10 and S-15 (0.001mg/L). Similarly in Pre-monsoon, the highest nitrite content was (0.128 mg/L) and the lowest content (0.003 mg/L) was observed at S-1 and S-15 respectively.

Total Phosphorous

The total phosphate content at S-4 was highest during the pre-monsoon season during the study period. Seasonal observation revealed that the phosphate values were in the range of 3.16 mg/L to 73.24 mg/L. The seasonal variation for the total phosphorous among stations is presented in Figure 22.

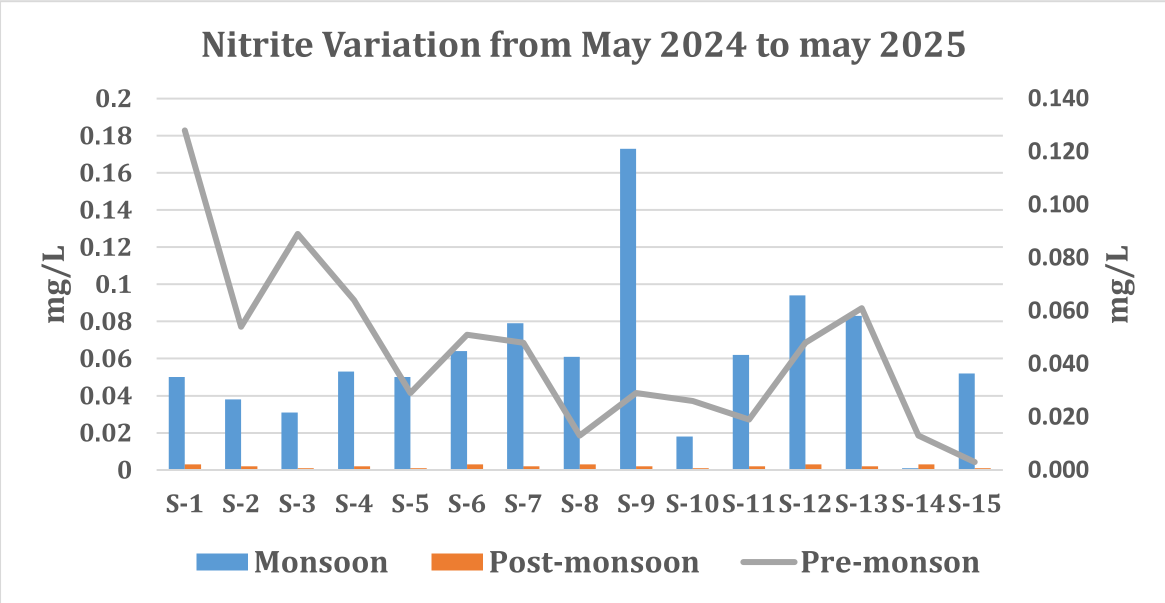


Figure 21. Nitrite concentration during May 2024 to May 2025

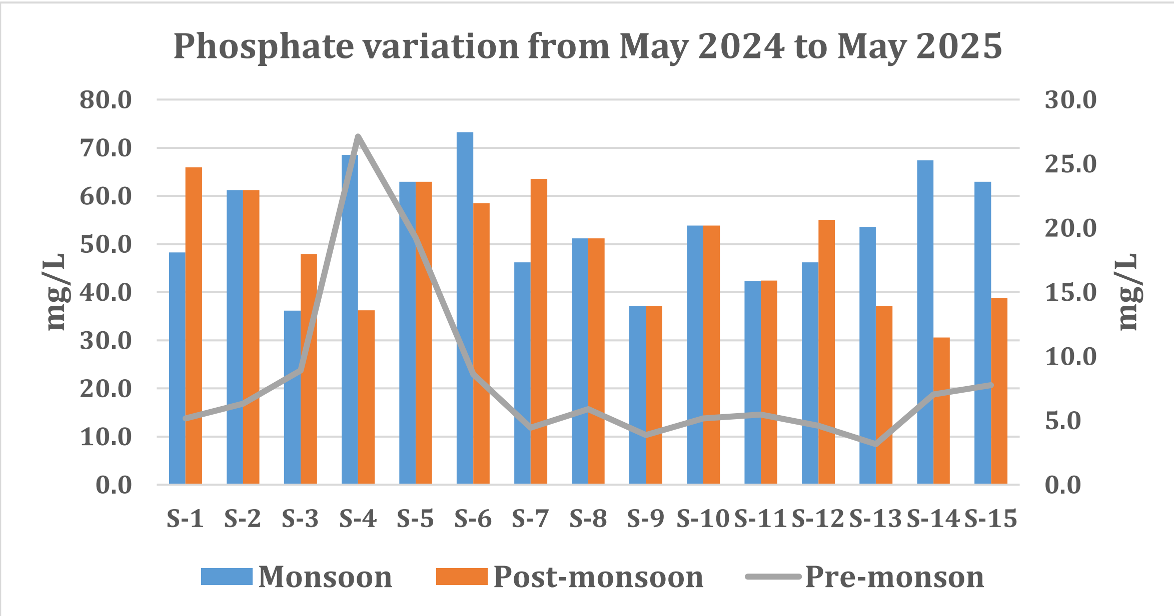


Figure 22 Seasonal variation Total Phosphorou sMay 2024 to May 2025

During Monsoon, the maximum value noted was 73.24 mg/L at (S-6) and the lowest was 36.18 mg/L at (S-3). In post-monsoon, the highest value was 65.90 mg/L at S-1 and 30.60 mg/L at S-14. In Pre-monsoon, the highest and the lowest values observed were 27.12 mg/L and 3.16 mg/L at S-4 and S-13 respectively.

Silicate

The total Silicate content at S-12 was highest during the Pre- monsoon during the study period. Seasonal observation revealed that the silicate values were in the range of 0.012 mg/L to 4.48 mg/L. The seasonal variation for the total silicates among stations is presented in Figure 23. During Monsoon, the maximum value noted was 0.058 mg/L at (S-15) and the lowest was 0.012 mg/L at (S-14). In post-monsoon, the highest and lowest value was 0.07 mg/L at S-15 and 30.01 mg/L at S-10. In Pre-monsoon, the highest and the lowest values observed were 4.48 mg/L and 1.02 mg/L at S-12 and S-13 respectively.

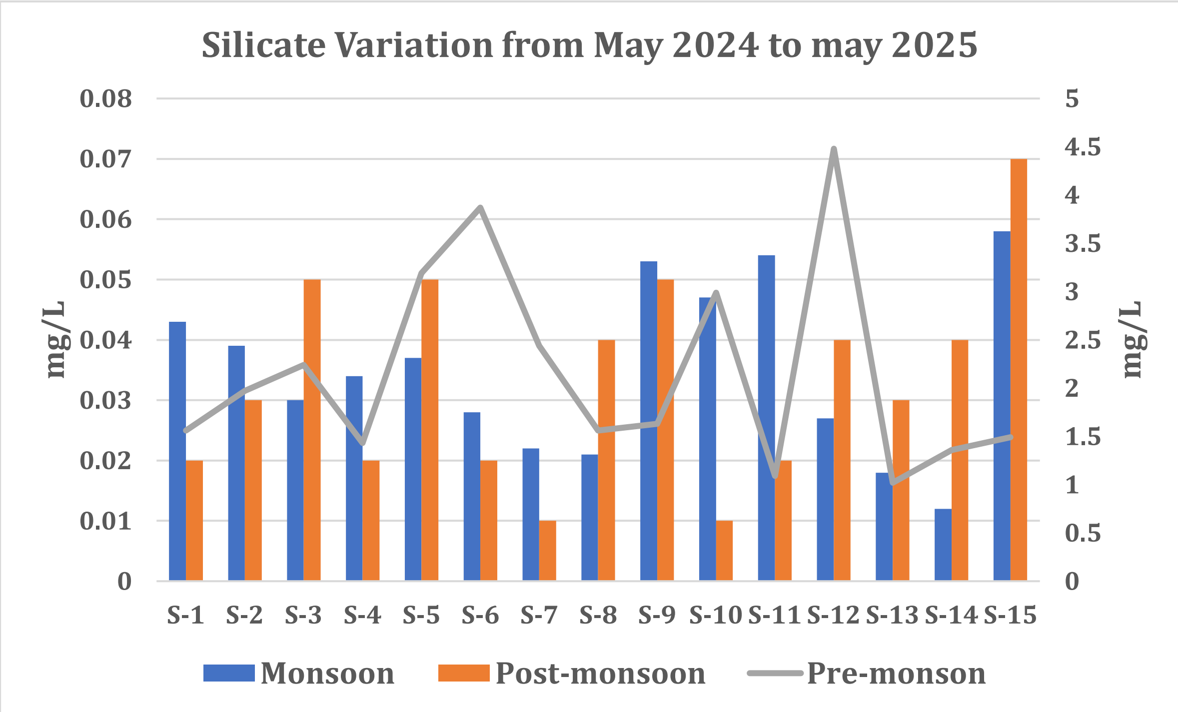


Figure 23. Seasonal variation of Silicate May 2024 to May 2025

4.1.2. Petroleum Hydrocarbon (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 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).

The PHs values were comparatively high at S-7 and S-8 during post-monsoon than the other seasons. The values for Petroleum Hydrocarbons (PHs) for the three-season varied from 0.19 µg/L to 70.80 µg/L (Figure 24). The PHs concentration in general, is at low level during monsoon and pre-monsoon. During monsoon, the highest PHs were observed at S-4 (10.10 µg/L) and lowest PHs were observed along S-5 (1.20 µg/L). Similarly in Pre-monsoon, the maximum PH content was recorded (8.3 µg/L) at S-4 and the minimum was (0.19 µg/L) at S-13. In post-monsoon, the highest PH value was observed at S-7 (70.80 µg/L) and the lowest PH was observed S-6 (2.50 µg/L).

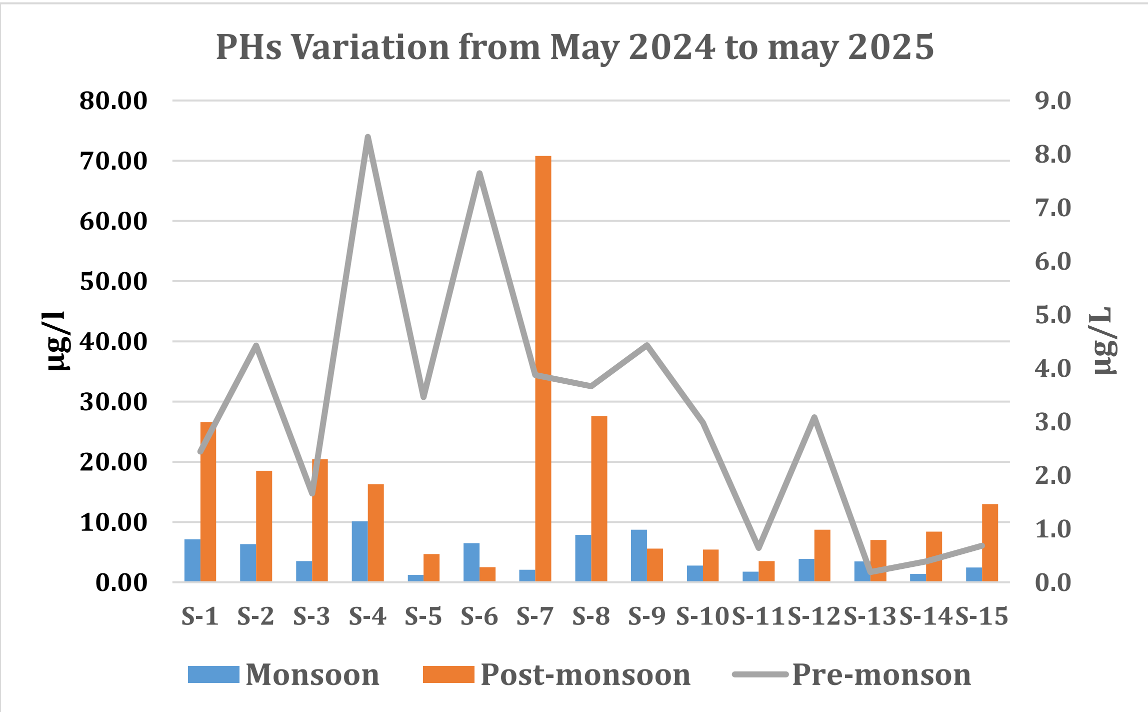


Figure 24 Seasonal Petroleum Hydrocarbon from May 2024 to May 2025

4.1.3 Sediment

Sediment texture

The sediment texture of DPA environment and its premises is presented in figure 25. The textural content mostly include sand , silt and clay. The percentage composition varieds from season to season. Through out the study period from May 2024 to may 2025 ,average sand percentage is during monsoon is more followed by pre-monsoon and Post-monsoon. The clay percentage occupies 2nd percentage composition and the average percentage is more in post and Pre-monsoon followed by monsoon. Average percentage of clay more in post-monsoon followed by pre-monsoon and monsoon.

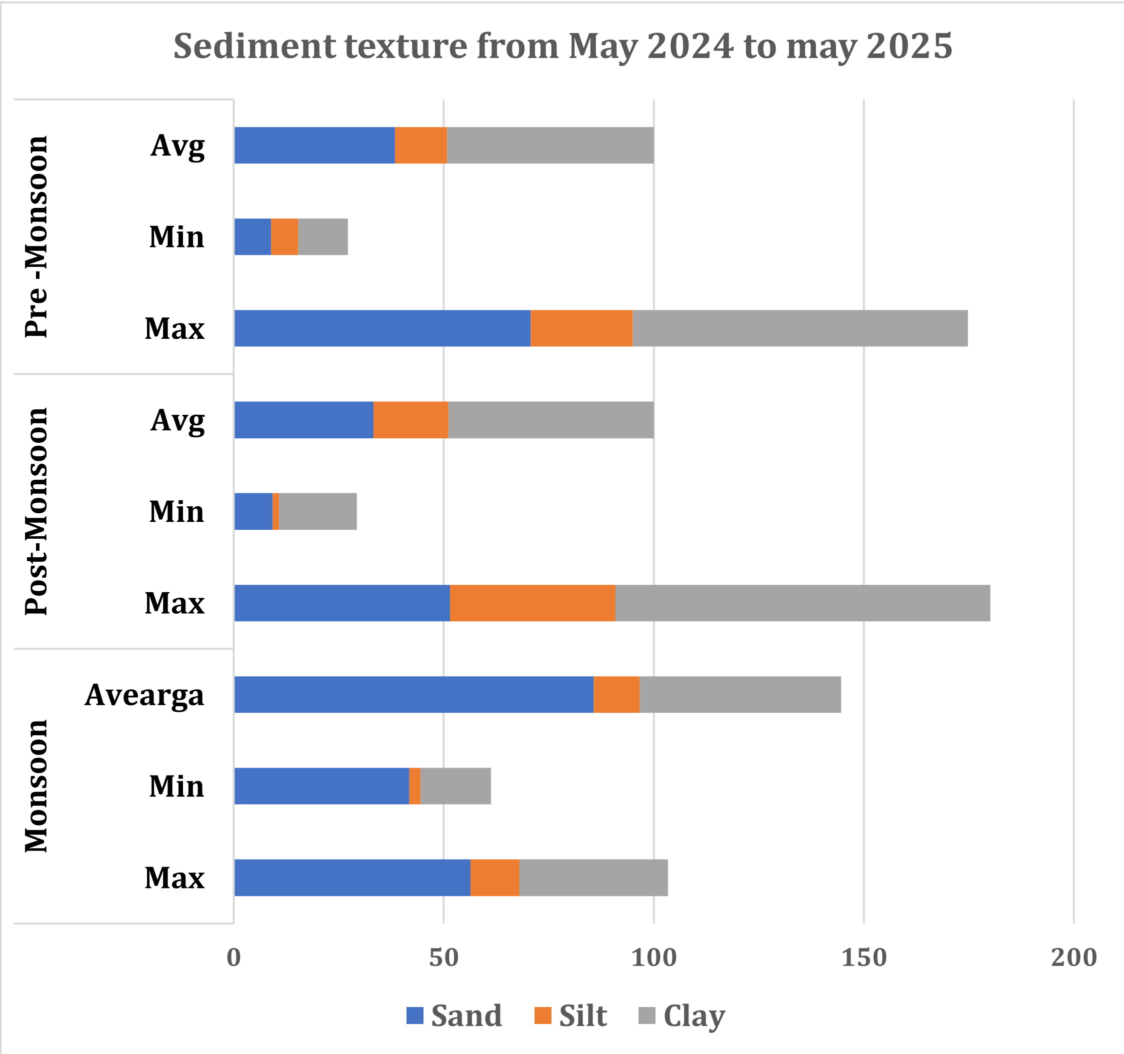


Figure 25. Soil textural chaacteristic from May 2024 to May 2025

4.1.4. Sediment total Organic Carbon (TOC)

The data on the total organic carbon of the sediment samples are presented (Figure 26). Among the station of DPA port area the maximum sediment carbon ranges from 1.2% to 3.2% and the minimum sediment carbon range was 0.5% to 2.4%. Station wise the highest sediment carbon was recorded at station S-12 during post-monsoon (3.2%), whereas lowest sediment carbon was recorded in station S-8 and S-9 during pre-monsoon (0.5%).

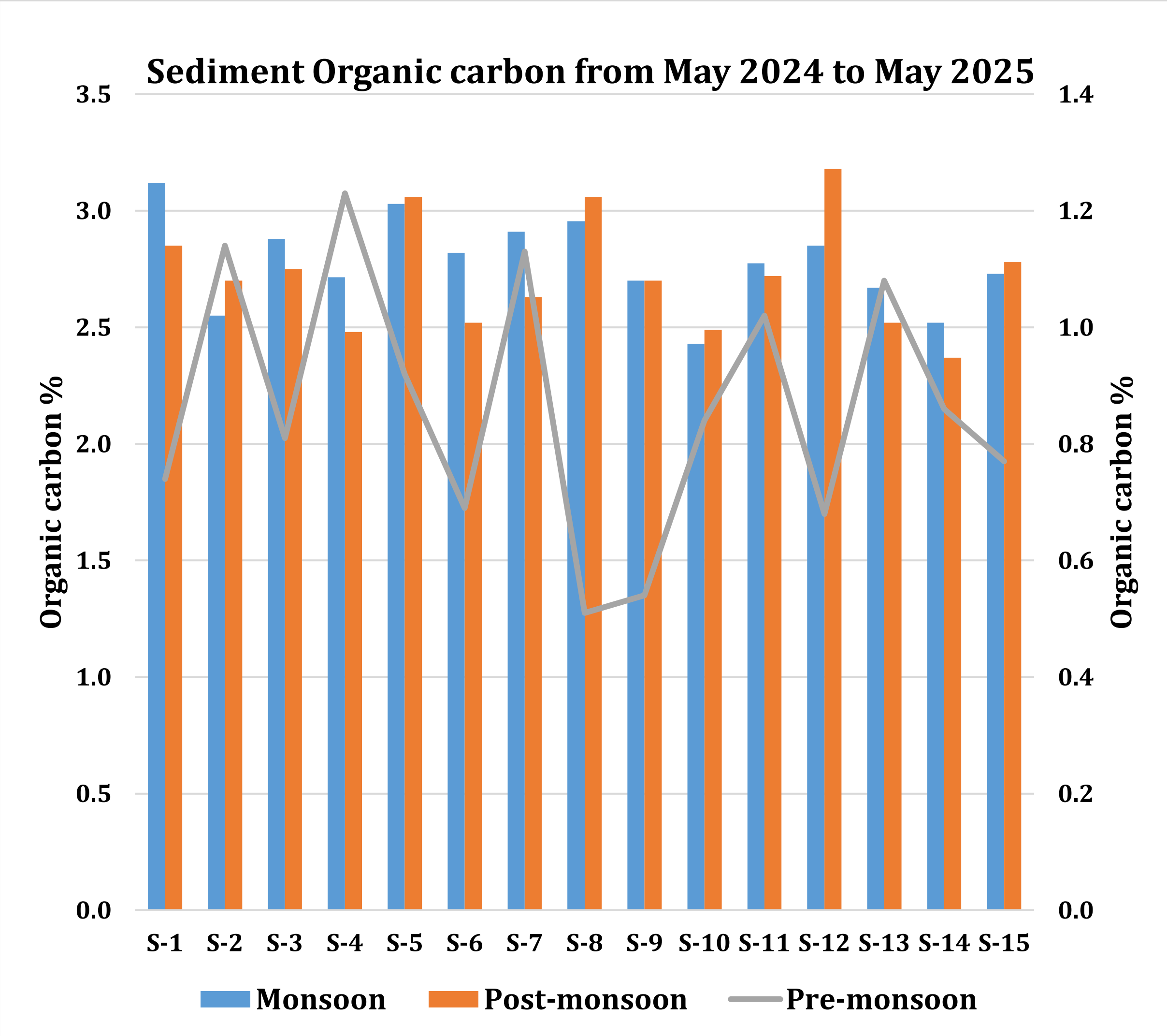


Figure 26. Sediment Organic carbon from May 2024 to May 2025

4.2. Biological characteristics water and Sediment

4.2.1. 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. . For the period of May 2024 to May 2025, the maximum Chlorophyll 'a' ranged from 0.0 mg/L to 2.98 mg/L inclusive of all the three seasons. The Chlorophyll 'a' value ranged from 0.12 mg/L to 2.98 mg/L during pre-monsoon while during monsoon, the range was recorded between 0.0 mg/L to 0.89 mg/L and during post monsoon, the range was found to be 0.04 mg/L to 0.65 mg/L. The seasonal variation of Chlorophyll 'a' among 15 stations is presented in Figure 27.

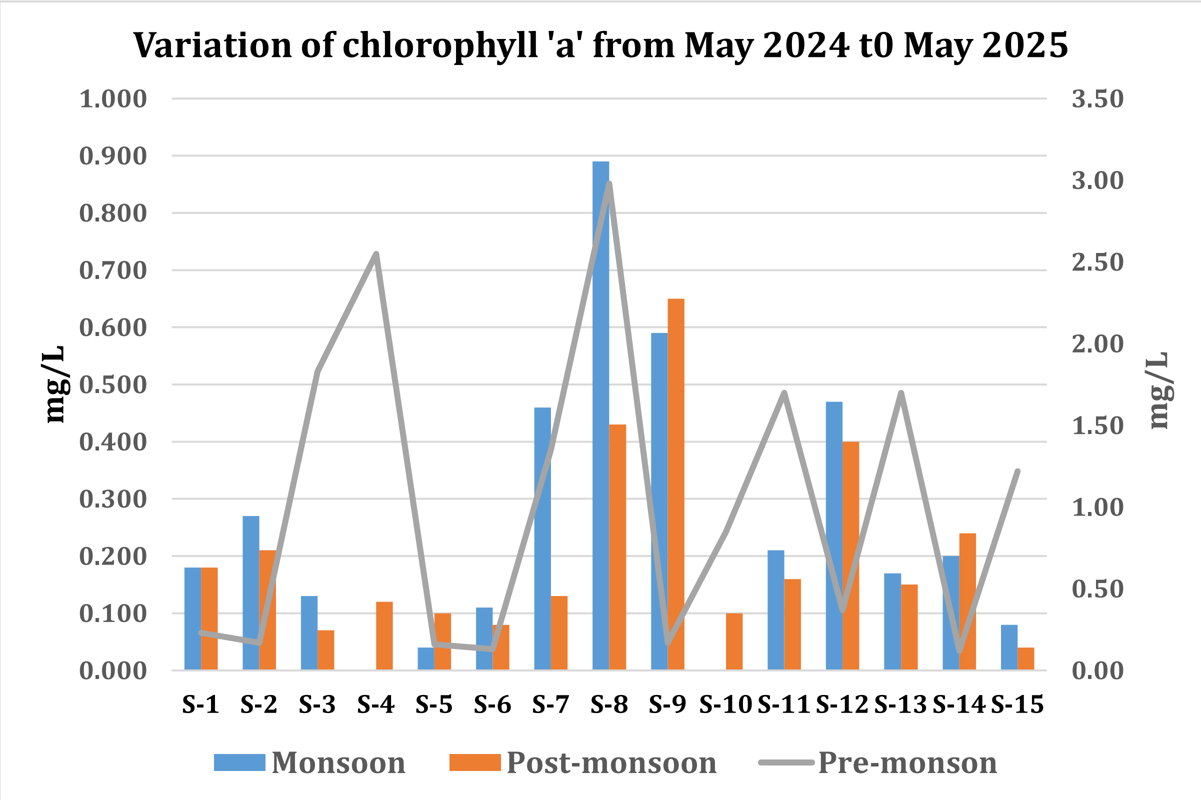


Figure 27. Concentration of Chlorophyl 'a' from May 2024 to May 2025

4.2.2. 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.

Generic Status

The phytoplankton genera for the period May 2024 to May 2025 varied from 8 to 29 number with average variation of 16-23 number. Highest genera was reported during post-monsoon followed by monsoon and pre monsoon(Figure 28).

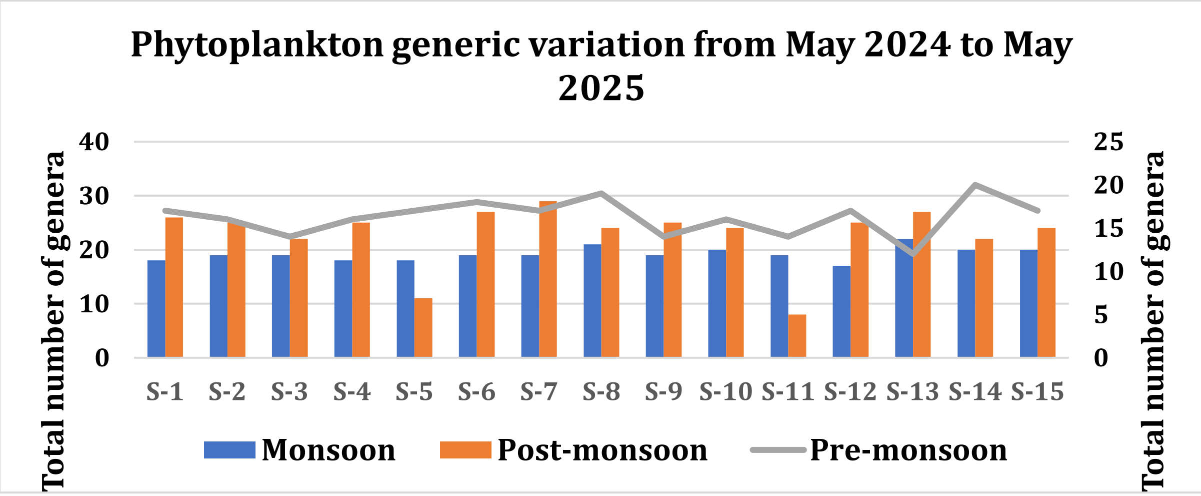


Figure 28. Seasonal variation of Phytoplankton genera from May-2024 to May2025

Percentage composition of phytoplankton

The percentage composition of different phytoplankton varied from 0.9% to 65.1% with average variation of 0.6% to 59.7% for the period May 2024 to May 2025. Four groups such as Pennales, Centrales, Dinophyceae , Cyanophyceae has been encounter during entire study period dominate by Pennales followed by Centrales and group Cyanophyceae represent less percentage of composition (Fig.29).

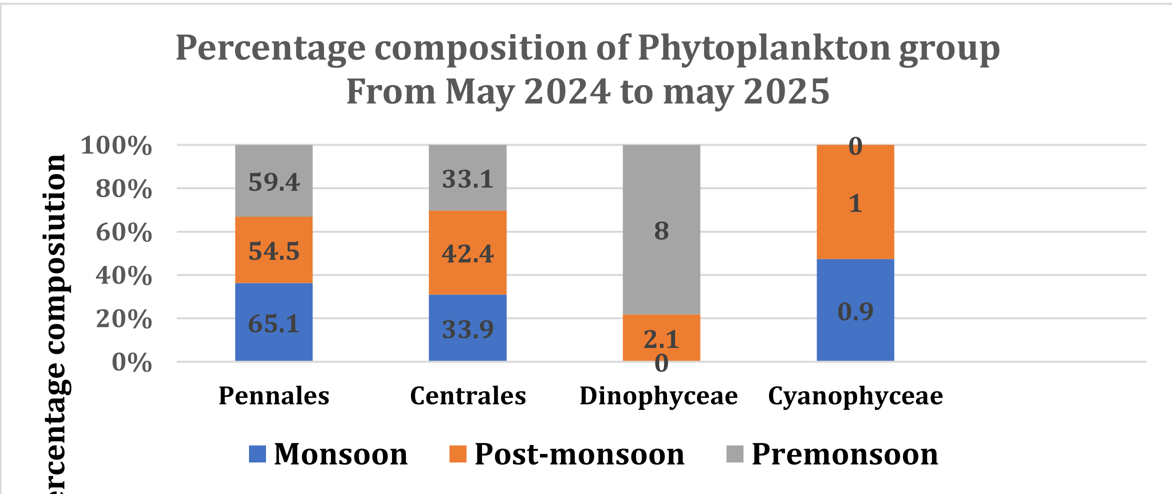


Figure 29 Percentage composition of different phytoplankton groupfrom May 2024 to May 2025

Percentage of occurrence

The percentage occurrence of phytoplankton for the period May 2024 to may 2025 was 13 to 100% . Highest percentage of occurrence was observed monsoon followed by post-monsoon and pre-monsoon. During monsoon 15 genera such as *Cheatoceros, Coscinodiscus, Dictylum, Eucampia, GyrosigmaMelosira, Navicula, Nitzschia, Odontella, Pleurosigma, Pseudonitzschia, Rhizosolenia, Synedra, Thalassionema, Thalassiothrix* represent 100% of occurrence. But in Post-monsoon and pre monsoon represent less number i.e 8 and 5 number of genera represent 100% of occurrence (Fig.30).

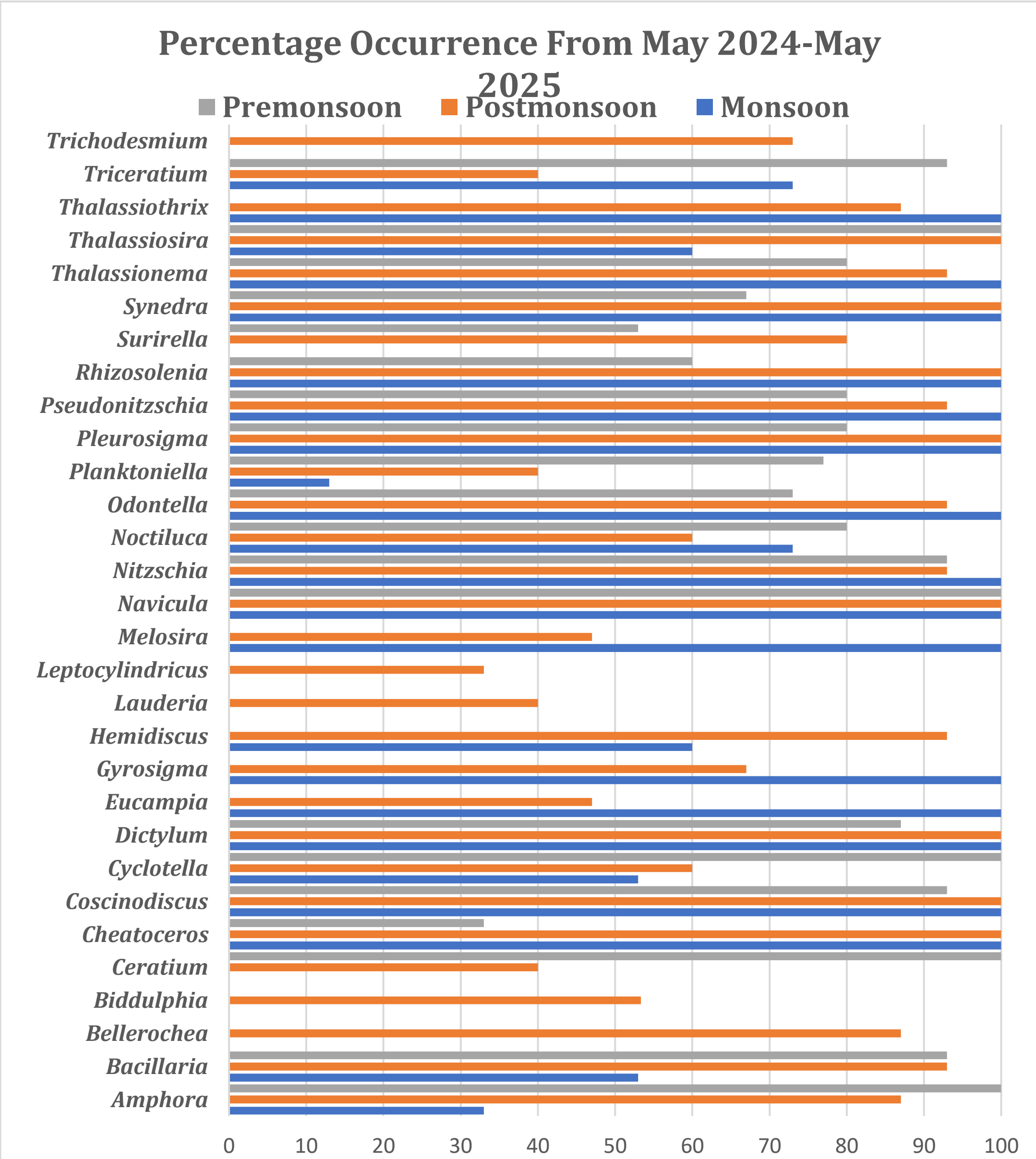


Figure 30. Percentage occurrence of phytoplankton genera from May 2024to May 2025

Phytoplankton density

The density of different phytoplankton group varied from 4000 No/L to 24320 No/L with average variation of 7,627 No/L to 24, 320. Highest phytoplankton density was observed in post-monsoon followed by Pre-monsoon and Monsoon (Fig 31).

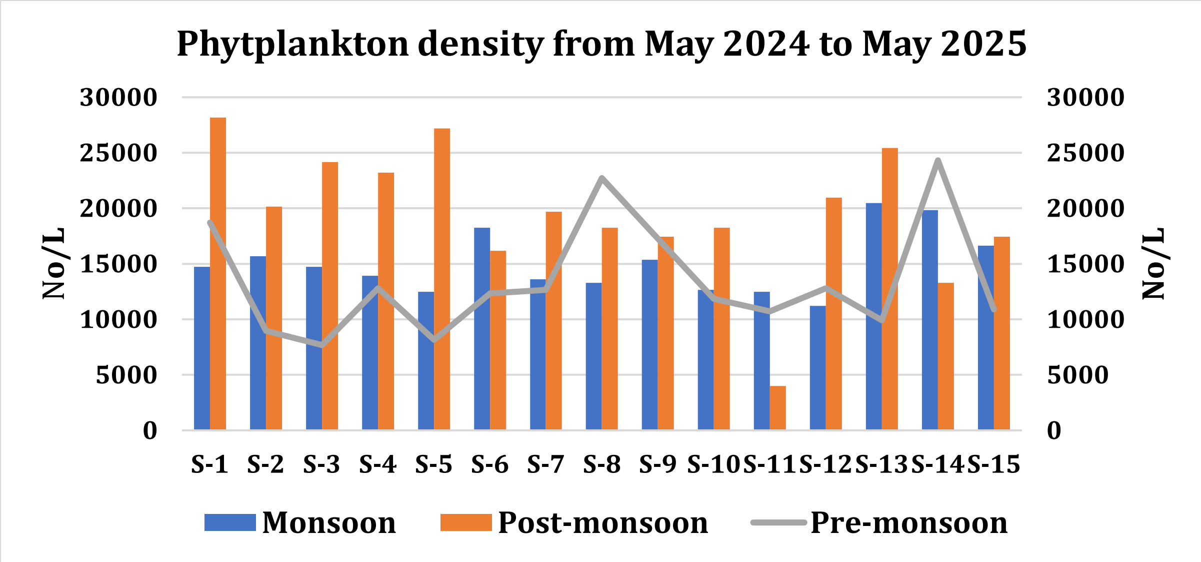
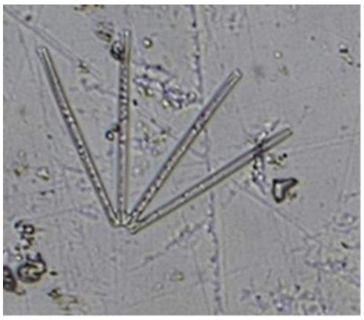
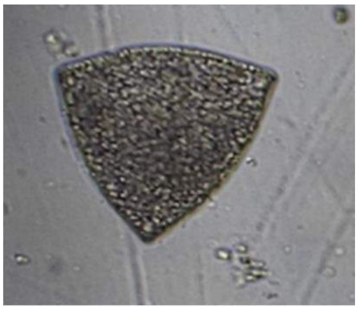


Figure 31. Seasonal variation Phytoplankton density during May 2024 to May 2025



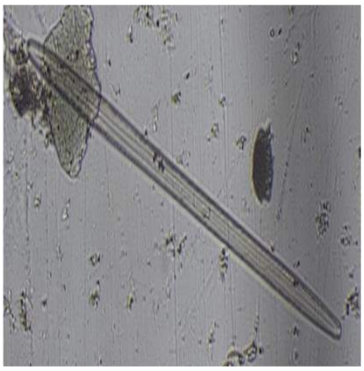
Thallasionema sp.

Coscinodiscuss sp.



Triceratium sp.

Pleurosigma sp.



Synedra sp.

Ceratium sp.

Plate 8: Phytoplankton of Deendayal Port Authority

4.2.3. 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 Post-monsoon 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).

Phylum and group status

The status of phylum and group of Zooplankton for the period 2024 to 2025 showed highest phylum and group during post-monsoon followed by pre-monsoon (Fig,32)

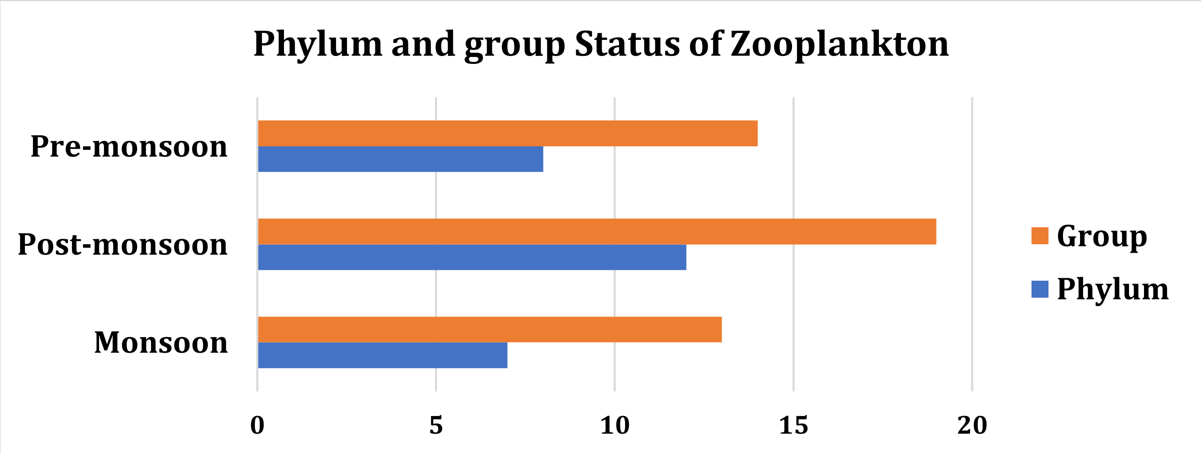


Figure 32. Status of Zooplanktonn and group and phylum from May 204 to May 2025

Generic Status

The generic status of Zooplankton from May 2024 to May 2025 varied from 13 to 37 in number with average variation of 16 to 32 in number. Highest number of genera was observed during Post- Monsoon followed by pre-monsoon and Monsoon (Fig.33)

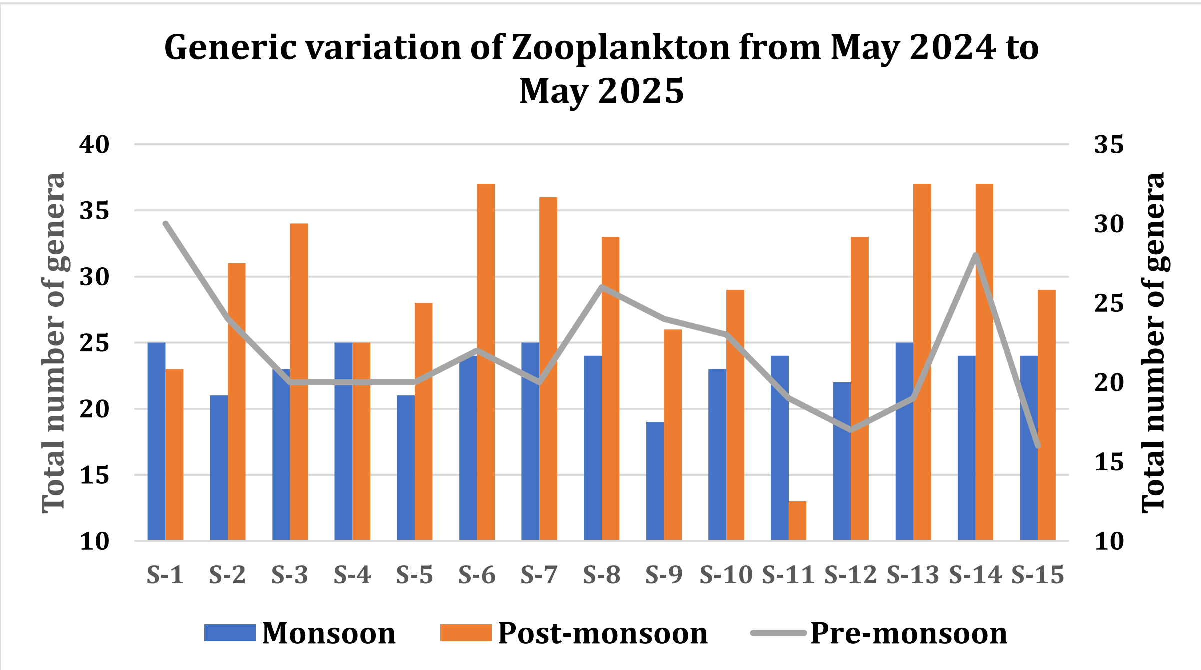


Figure 33. Generic Status of Zooplankton From May 2024 to May 2025

Percentage composition

The average maximum percentage composition of different zooplankton group varried from 26% to 31% with average variation of 29 %. Highest percentage of composition was contributed by *Copepoda-Calanoida* followed by Malacostraca and Tintinnida. Highest percentage of composition was observed in Post-monsoon and least percentage composition was observed in pre-monsoon (Fig.34).

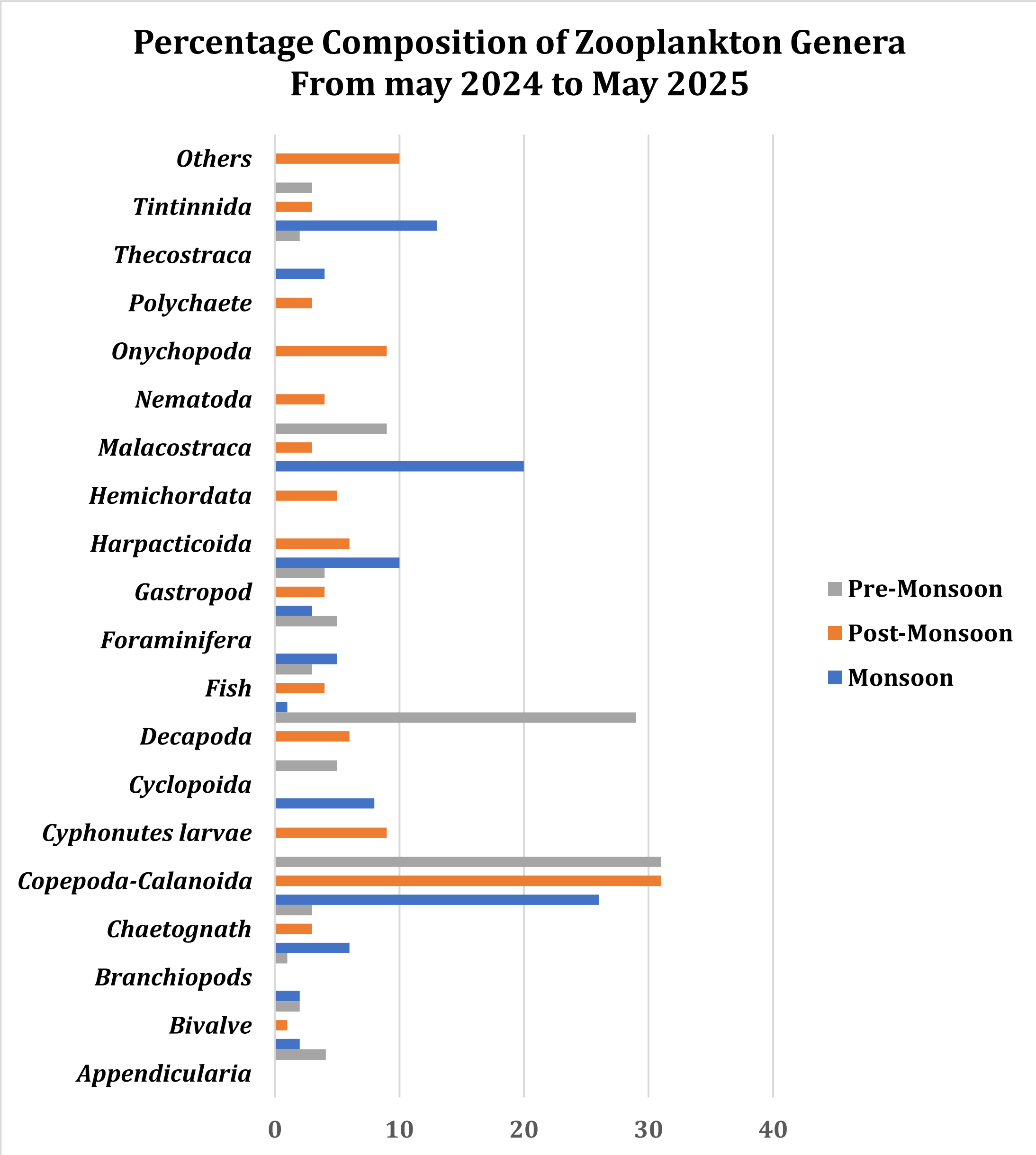


Figure 34. % Composition of Zooplankton Genera at DPA from May 2024 to May 2025

Percentage occurrence of zooplankton

The percentage occurrence of zooplankton from May 2024 to May 2025 was 7 to 100%. Highest percentage of occurrence was observed during monsoon i.e 12 genera such as Acartia, Acrocalanus, Bivalve larvae, Brachyuran larvae, Calanus, Cirripede nauplius, Codonellopsis, Eucalanus, Gastropod larvae,Globigerina, Microsetella, Tintinnopsis occurred 100% of occurrence. Similarly in Post monsoon 7 genera was found 100% of occurrence and during pre-monsoon. In Pre-monsoon least number of genera found 100% of occurrence where the genera Lucifer only found to be 100% of occurrence (Fig 35).

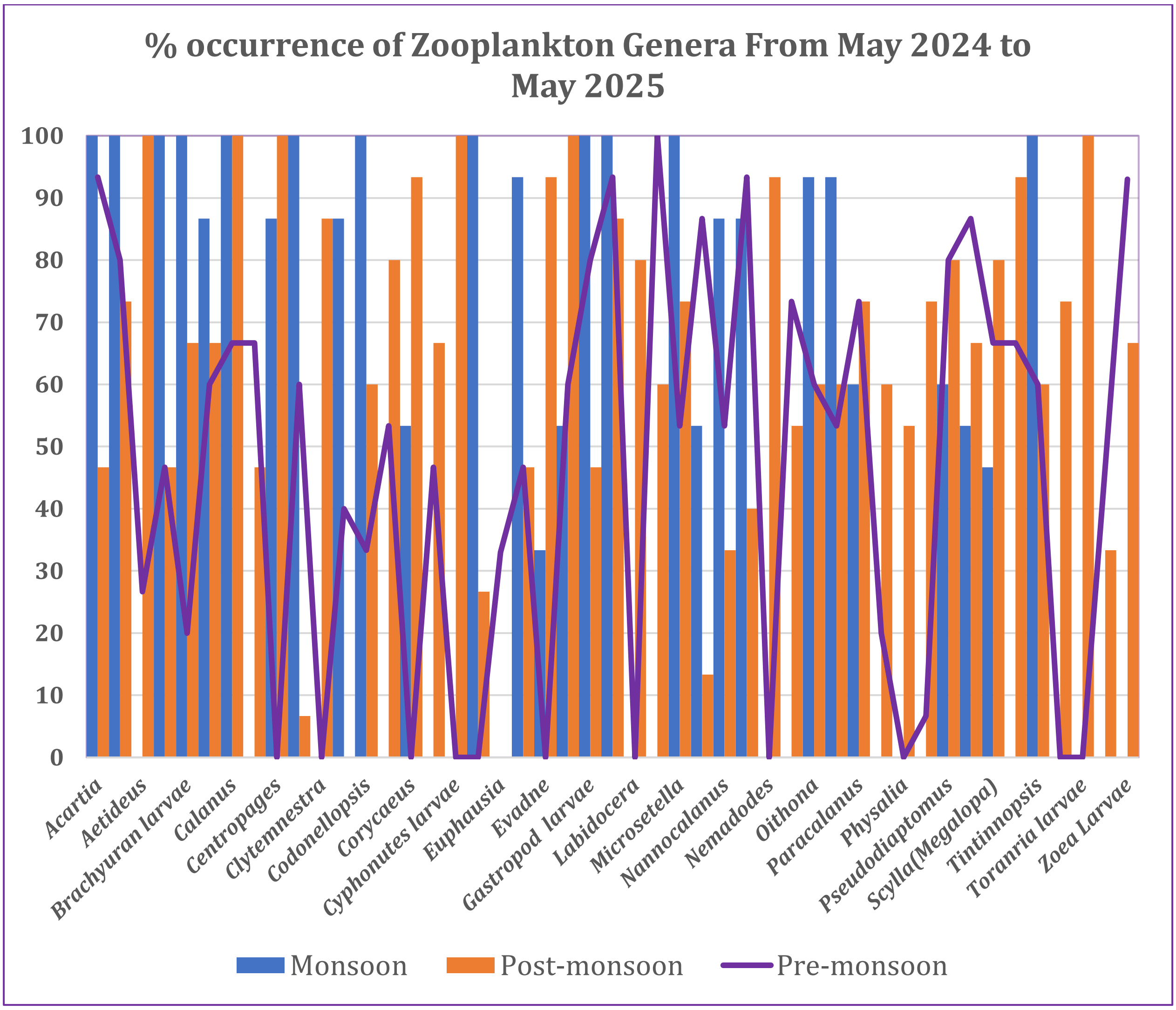


Figure 35. % Occurrence of Zooplankton Genera at DPA from May 2024 to May 2025

Density of zooplankton

The density of zooplankton from May 2024 to May 2025was 8,000 No/L to 20,000 No/L with average variation of 7,653 No/L to 17,660 No/ L. Highest Zooplankton density was observed in Post-mon soon followed by pre-monsoon and Monsoon (Fig.36).

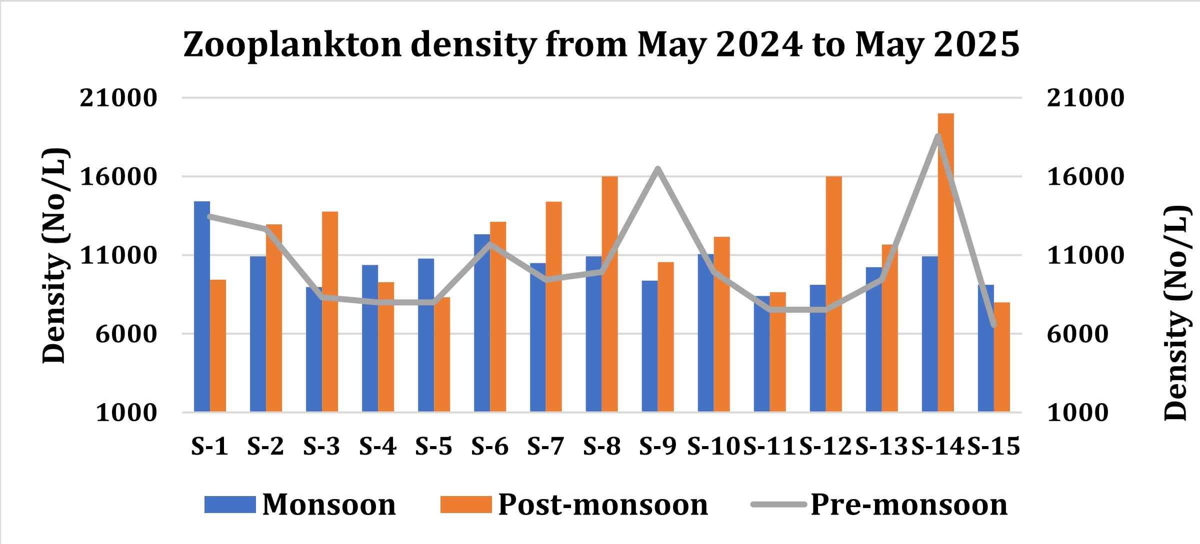
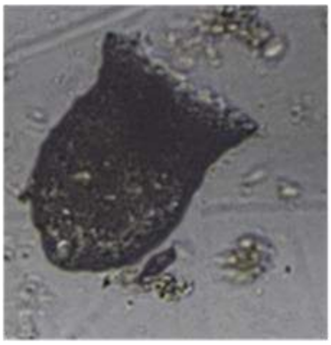
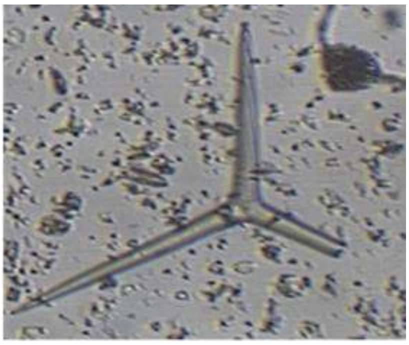


Figure 36. Density of Zooplankton in DPA form May 2024 to May 2025

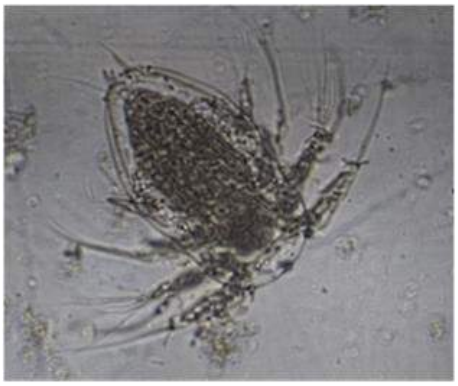
***Paracalanus** sp.*



Tintinnopsis sp.



Sponge spicule



Calanoida copipod

Microsetella sp.

Plate 9: Zooplankton of Deendayal Port Authority

4.2.4 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 survey of the intertidal Fauna of DPA Kandla area recorded the presence of 4 phyla (Arthropoda, Chordata, Mollusca). The faunal diversity was the highest for phylum Mollusca followed by Arthropoda and Chordata respectively (Fig.37).

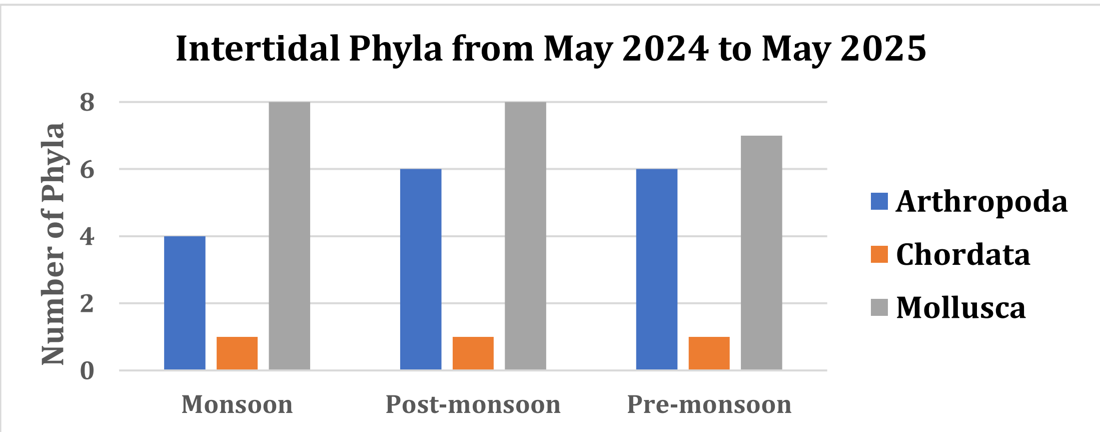


Figure 37. Intertidal faunal diversity in DPA from may 2024 to May 2025

Generic status

The generic status of intertidal fauna from May 2024 to May 2025 varied from 4 to 11 number with average variation of 4 to 10. Highest number of genera was observed during pre-monsoon followed by Post-monsoon and Monsoon (Fig.38)

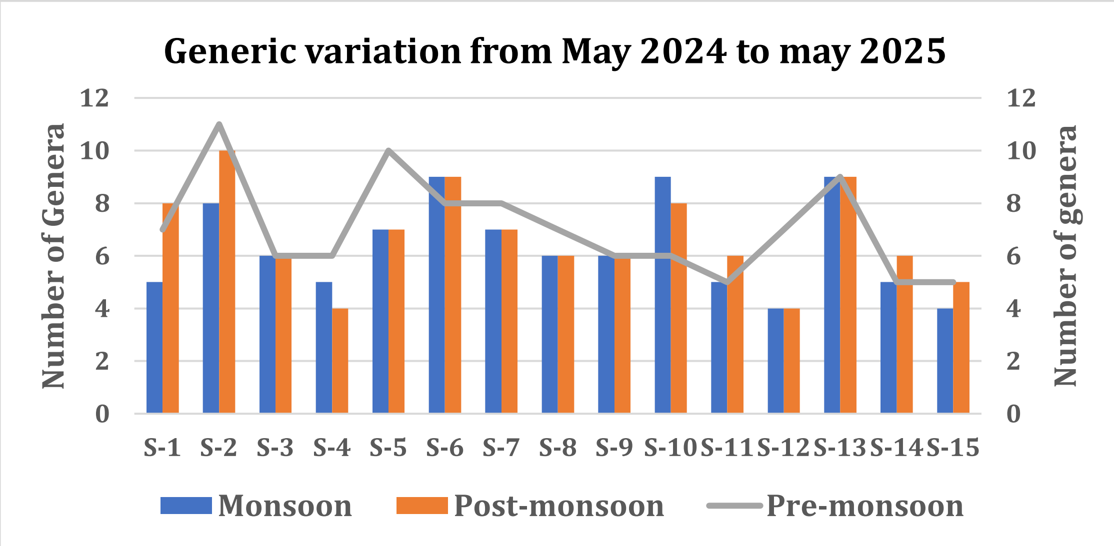


Figure 38. Generic Status of Intertidal Fauna in DPA from May 2024 to May 2025

Percentage composition of Intertidal Fauna

The percentage composition of Intertidal ranged from 0.2% to 245vwith average variation of 0.6% to 22% from May 2024 to May 2025.Highest organism contribute in pre-monsoon followed by followed by Monsoon and Post-Monsoon (Fig.39) .The organism such as *Austruca iranica*, *Austruca sindensis*, and *Austruca variegata* contribute highest percentage of composition.

Density variation of intertidal fauna

The density of Intertidal organism among different station was varied from 17No/m^2 to 133 No/m^2 with overall variation in 3 season was 18 No/m^2 to 97No/m^2 (fig 40). Monsoon contribute highest density of organism followed by Pre- and Post-Monsoon.

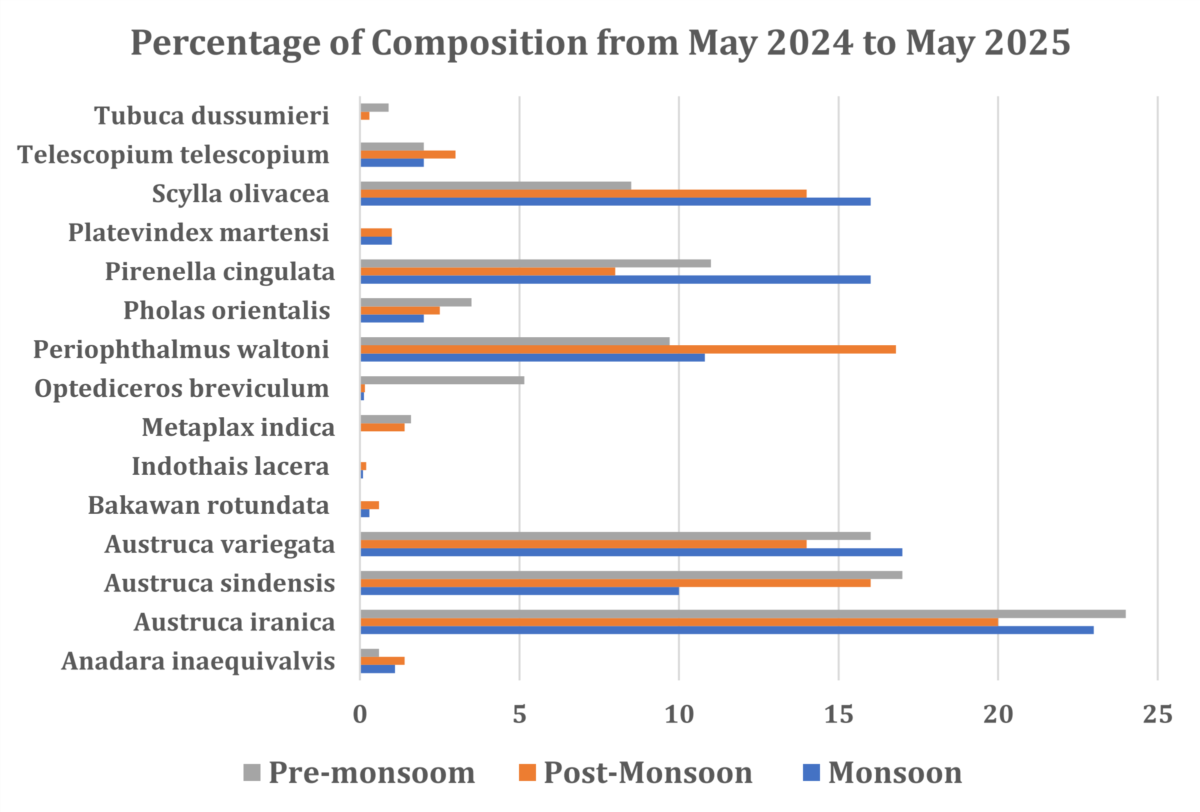


Figure 39.Percentage composition of Intertidal Fauna in DPA

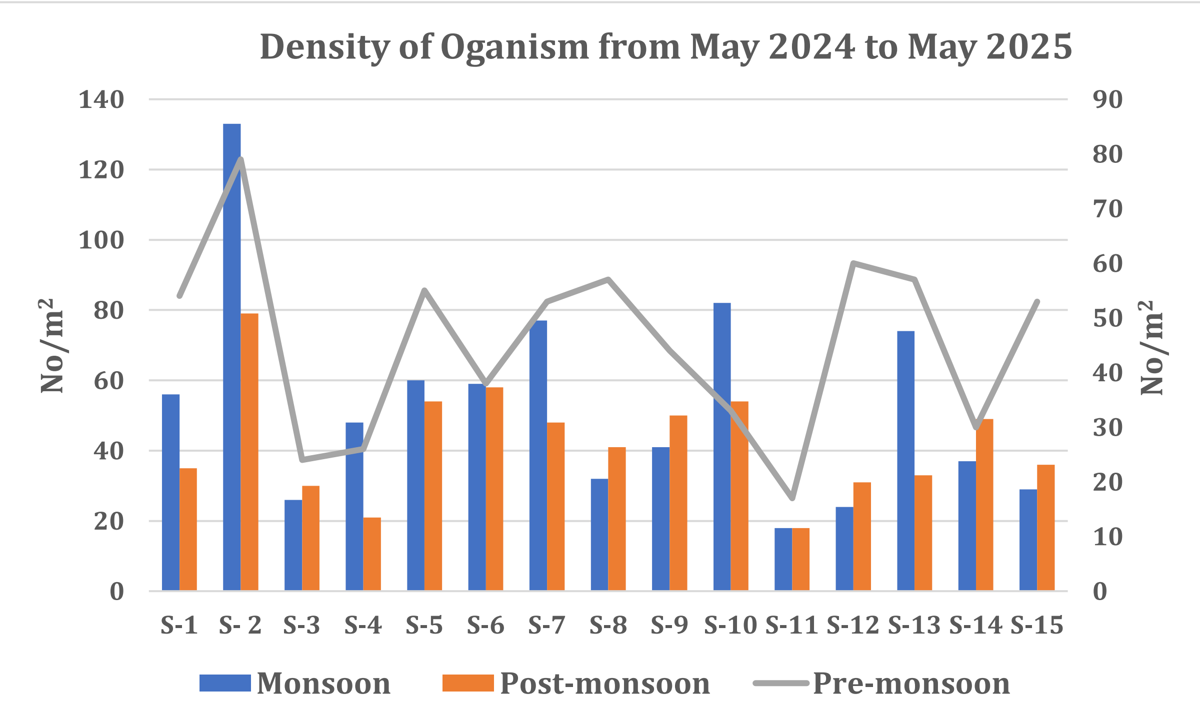


Figure 40. Density of Intertidal Fauna in DPA

4.2.5. 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 concentration. The oxygen deficiency may very well be the most widespread anthropogenically induced deleterious effect in me marine environment that causes localized mortality of benthic macrofauna.

Distribution and composition of subtidal macrobenthos

The number of macro benthic fauna of the various groups from the DPA port environment includes Annelida, Arthropoda, Mollusca and Nematoda. The number of various fauna from May 2024 to May 2025 raged from 1 to 11 with maximum contribution was during Post and pre-monsoon (Fig.41).

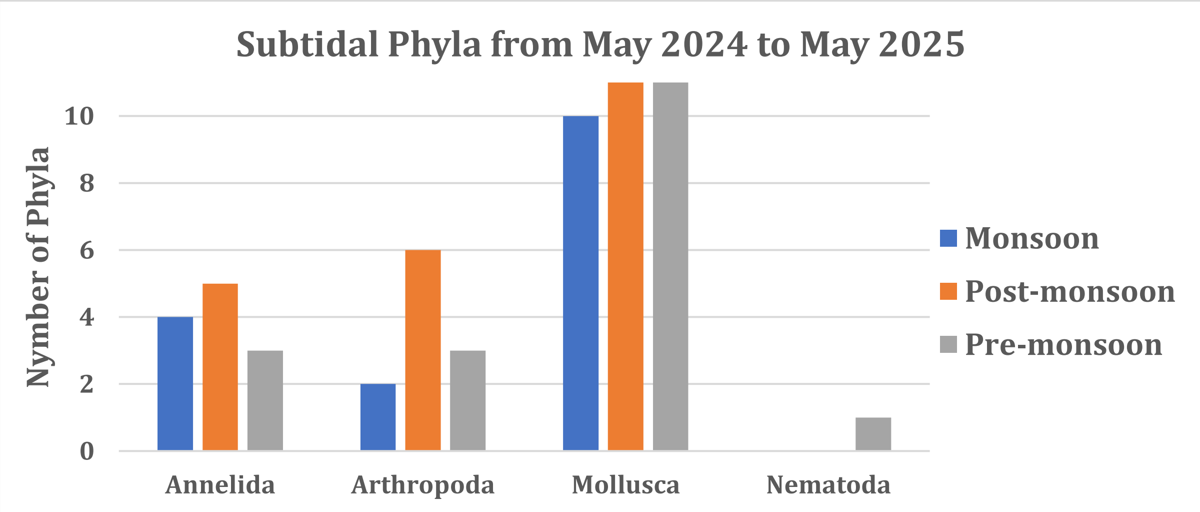


Figure 41. Distribution of Subtidal macrobenthos in DPA

Generic Status

The generic status of subtidal macrobenthos varied from 1 to 12 number with average variation of 2 to 10 number. Highest number of genera contributed during monsoon followed by pre-monsoon and Pre-monsoon (Fig.42).

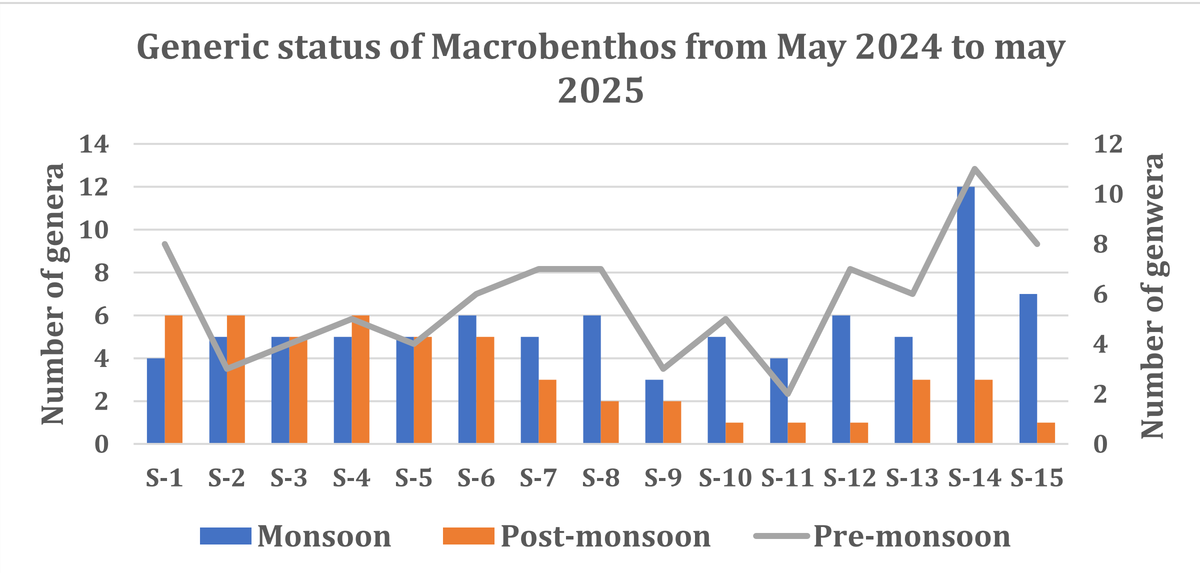


Figure 42. Generic status of Macrobenthos in DPA

Density of subtidal benthos

The average density and population of subtidal macrobenthos from May 2024 to May 2025 varied from 307 N0/m^2 to 507 No./m ^{2} and 12 to 20 in number (Fig.43)

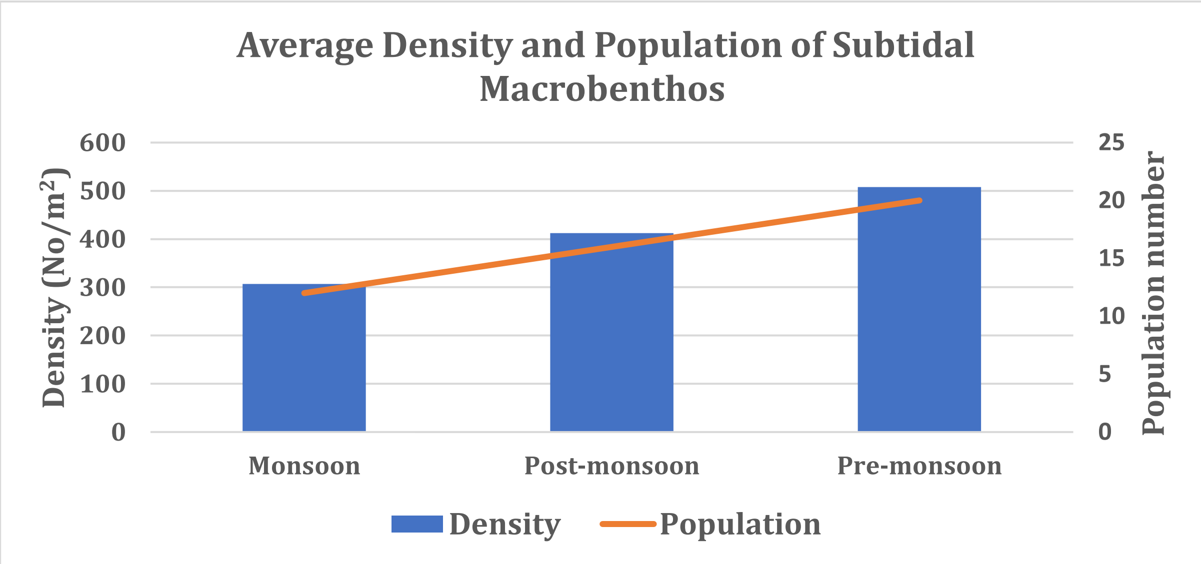


Figure 43 . Average Density of Subtidal macrobenthos in DPA

In station wise density of subtidal macrobenthos varied from 25 no/m^2 to 1150 no /m^2 with average variation of 100 no/m^2 to 754 no/m^2 . Highest dinsith was observed in Pre-monsoon and lowest was observed during post-monsoon (fig 44).

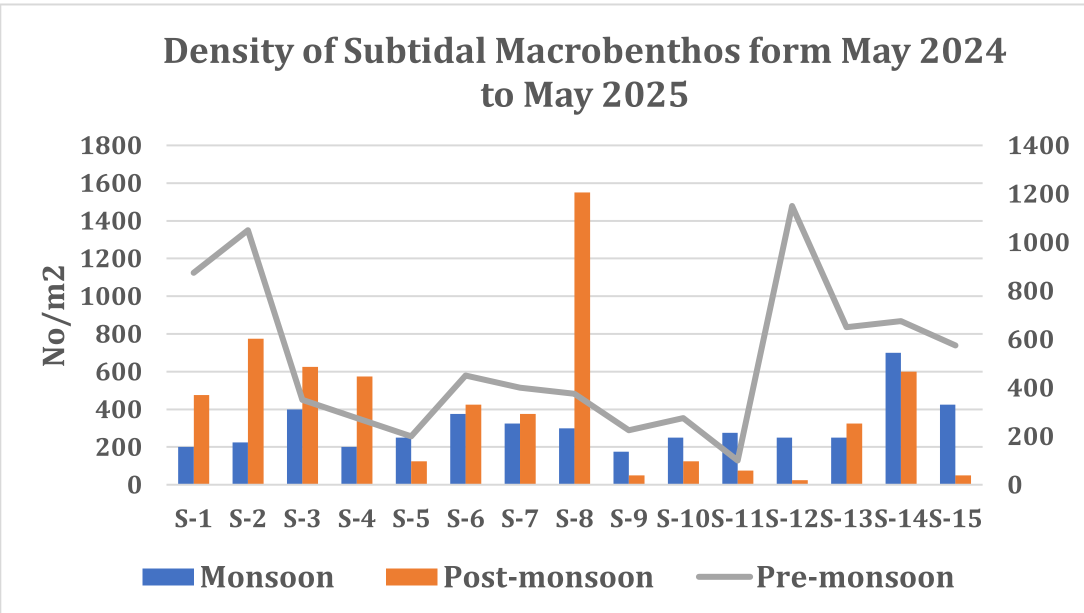


Figure 44 . Density of Subtidal Macrobenthos in DPA along different station

Percentage composition of Subtidal macrobenthos

The percentage composition of subtidal macrofauna varied from 0.4% to 31.8% with average variation of 1% to 26%.Highest percentage was contribution in Pre-monsoon ,followed by Post-monsoon and Monsoon (Fig 45).

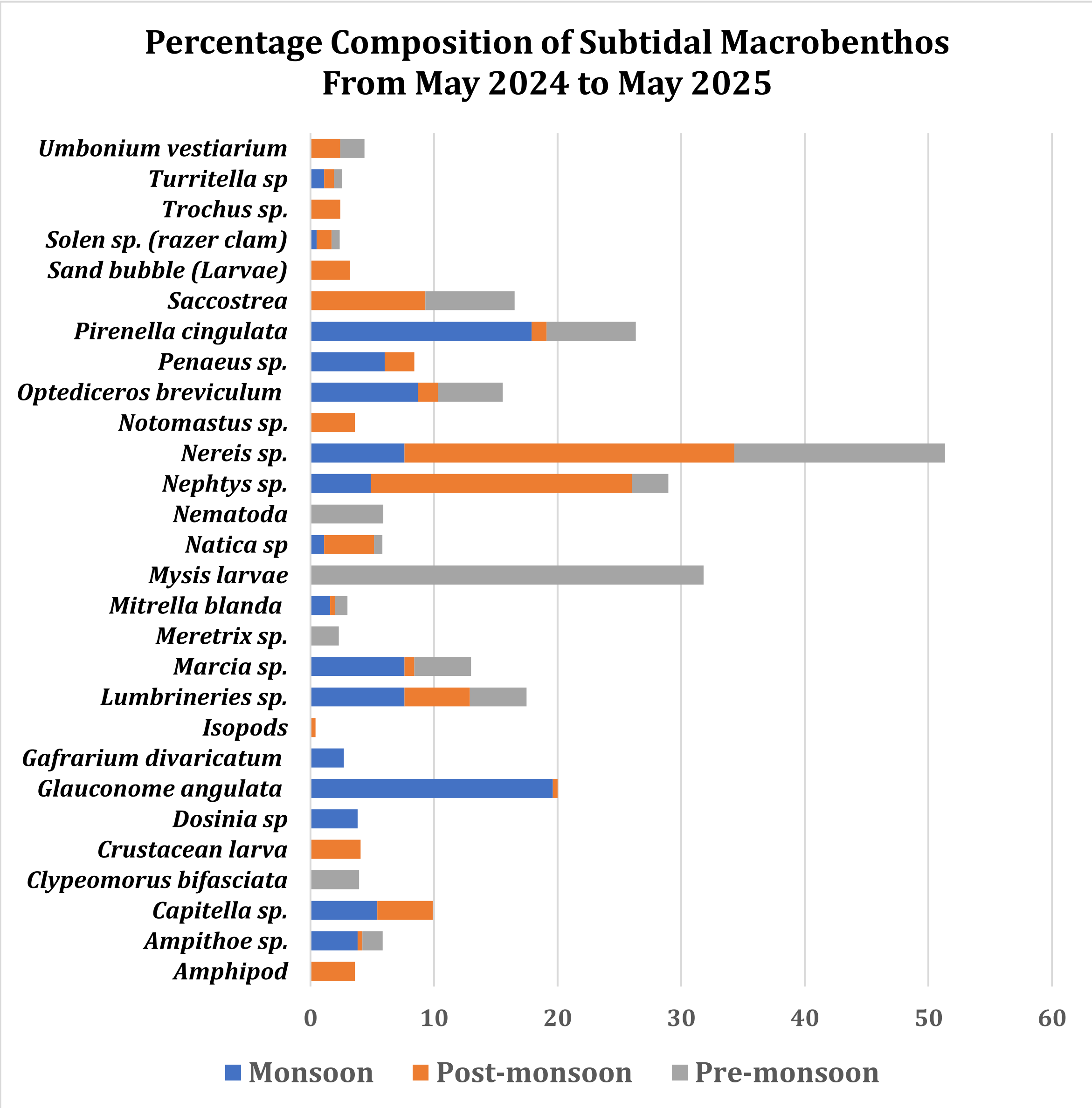


Figure 45. Percentage composition of Subtidal Macrobenthos in DPA

During the study period from May 2024 to May 2025 species such as *Mysis larvae, Nereis sp*, *Glauconome angulata* and *Pirenella cingulata* was dominated .

4.3. Mudflats

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 a direct indicator of mudflat productivity and blue carbon sequestration

4.3.1. Bulk density of the sediment

The sediment bulk density varied from 1.10 gm/cm^3 to 1.89 gm/cm3 with overall average variation of 1.21 gm/cm^3 to 1.68 gm/cm^3 (Fig.46). Highest bulk density was observed in Pre-monsoon followed by post-monsoon and post-monsoon. Among the station highest BD was observed in Pre-monsoon at S-14 (1.89 gm/cm^3) and lowest was observed at S-10 in Pre-monsoon (S-10).

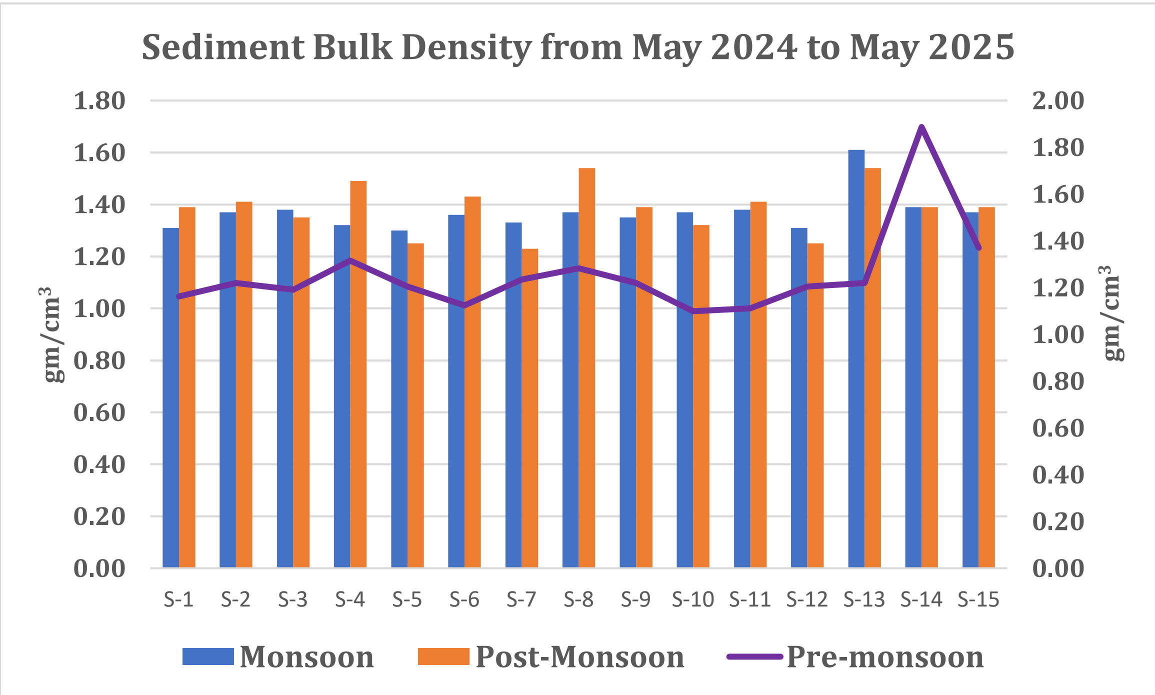


Figure 46. Seasonal variation of Sediment Bulk Density in DPA

4.3.2.Total Organic Carbon (TOC)

The sediment organic carbon of DPA varied from may 2024 to May 2025 was 0.5% to 3.2 % with average variation of 1.8% to 2.5%. Through out season the highest percentage of organic carbon was observed in post-monsoon followed by monsoon and pre-monsoon. Similarly lowest percentage of organic carbon was observed in pre-monsoon followed by equally percentage in monsoon and post-monsoon.

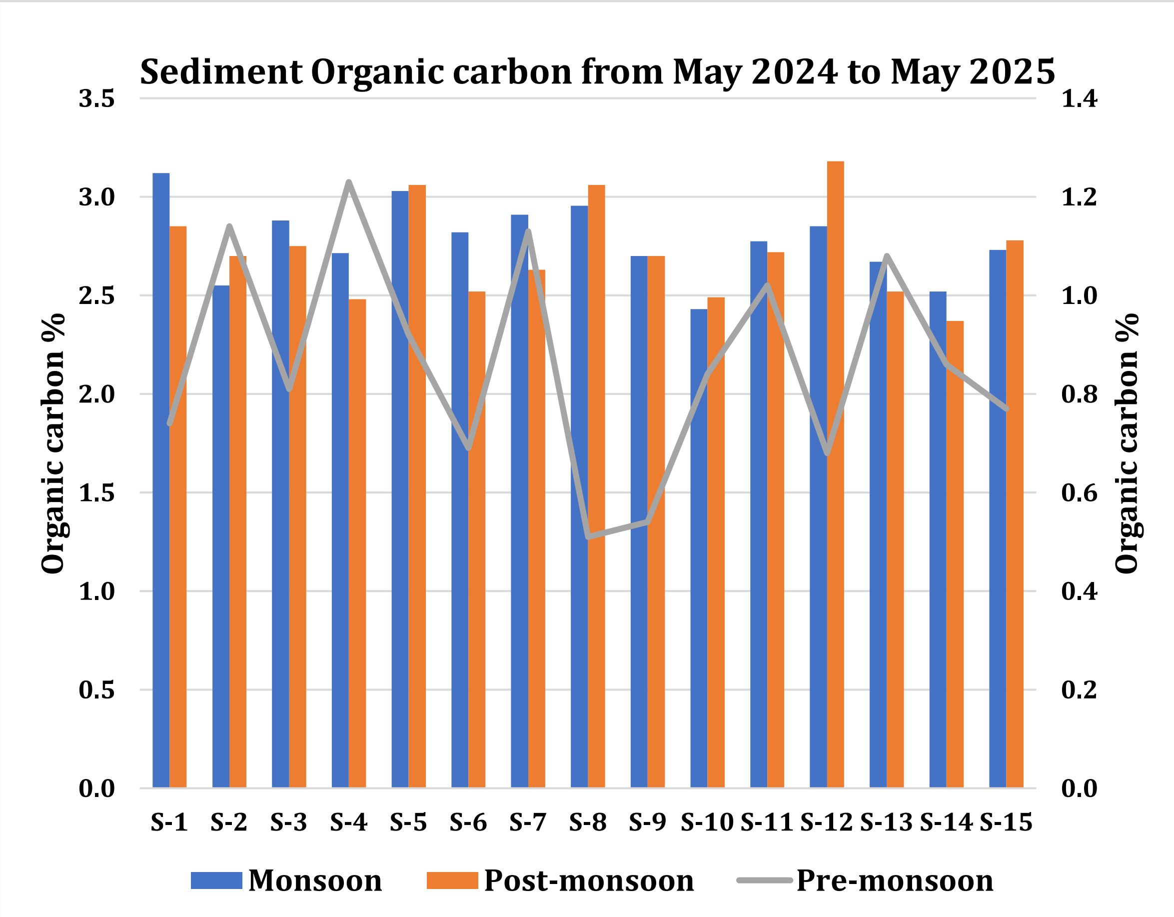


Figure 47. Seasonal variation Sediment Organic carbon in DPA

Among the station highest organic carbon percentage was contributed by S-12 during post monsoon and lowest percentage of organic carbon was observed during pre-monsoon at S-8.

4.4. Mangroves

Gujarat state has the longest coastline of India, with one of the rich coastal areas in terms of biodiversity, and major part of it is covered by mangroves. The mangrove cover in Gujarat ranks as the second largest in India, following the Sundarbans in West Bengal. Mangroves in Gujarat are distributed across four main regions: Kachchh, the Gulf of Kachchh, Saurashtra, and the Gulf of Khambhat including south Gujarat. Among these, Kachchh and the Gulf of Kachchh shows the major contribution of mangrove cover in Gujarat. Around 15 species of mangroves have been recorded across Gujarat's 13 coastal districts, though this number is subject to ongoing debate. However, Avicennia marina is the only species predominates in all the 13 coastal districts of Gujarat.

This unique ecosystem thrives in waterlogged, oxygen-deprived mud, typical of tropical and subtropical zones. The Kachchh coast is characterized by diverse habitats, including vast mudflats and small sandy beaches, shaped by extreme salinity, temperature variations, and tidal influences. These challenging conditions encourage mangrove species to adapt and flourish. Mangroves naturally enrich soil fertility by decomposing leaf litter and root systems, improving surrounding sediments. These ecosystems support a rich variety of flora and fauna, serving as essential breeding, nursery, and feeding sites for numerous marine and terrestrial species.

Despite their ecological significance, mangroves face persistent threats from human activities, such as deforestation, pollution, and climate change. Conservation strategies have been introduced to protect these invaluable ecosystems. The Gujarat Institute of Desert Ecology (GUIDE) has extensively studied and documented these ecosystems, providing insights into their vegetation, species diversity, ecological importance, and conservation status. Mangroves serve as critical habitats for marine and terrestrial wildlife, contribute to coastal protection, preserve biodiversity, and support local communities. The ongoing focus on research and preservation highlights the need for sustainable management practices to ensure their long-term survival. During the study period May 2024 to May 2024 4 species of mangrove such as *Avicenna marina* , *Aegiceras corniculatum* , *Ceriops tagal* and *Rhizophora mucronate* was observed (Plate 10).

4.4.1.Tree Density

Across three seasons of the study, monsoon 2024, post-monsoon 2024, and pre-monsoon 2025, a total of 15 mangrove sites in and around the Deendayal Port Authority (DPA) were assessed. During the monsoon 2024, the overall average tree density recorded was 2,189 trees/ha, with Tuna Creek exhibiting the highest mean density (2,535 trees/ha) and S-6 having the highest individual density (3,673 trees/ha). During post-monsoon 2024, the overall tree density recorded as 1,986 trees/ha, with Kharo Creek leading at 2,788 trees/ha and S-6 remaining the densest (3,156 trees/ha). During pre-monsoon 2025, the overall tree density recorded was 1,907 trees/ha and S-6 continued to show the highest density (3,113 trees/ha), however, major portion of S-11 was observed to go through extensive conversion into salt pans resulting the lowest density for the whole study period (872 trees/ha). The ongoing degradation highlights the pressing need for conservation measures to mitigate the impact of anthropogenic disturbances and preserve the ecological integrity of these mangrove ecosystems.

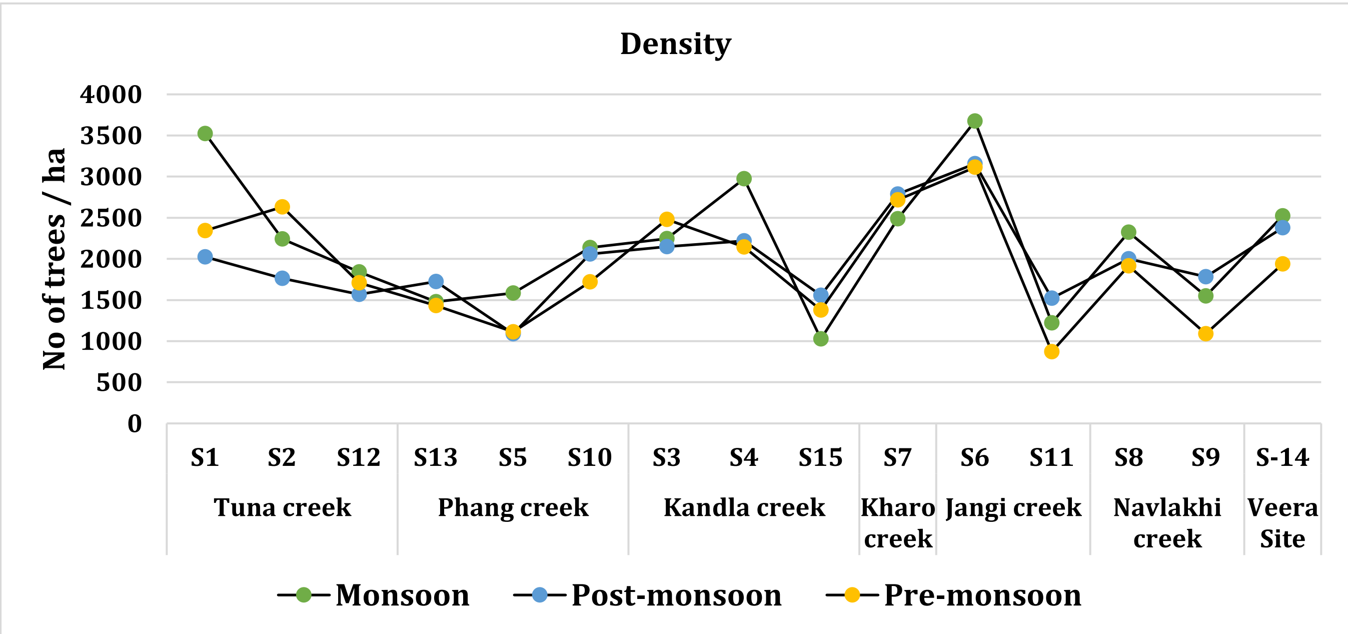


Figure 48. Average tree density during the three seasons study in 2024-2025

4.4.2.Tree Height

The study on mangrove tree height in the DPA Kandla region during 2024-25 revealed seasonal variations in growth. During the monsoon, of 2024, the overall average height of mangrove tree was recorded as 1.8 meters. The highest average was recorded at Veera coast (2 meters), followed by Tuna and Phang creeks (1.8 meters). Site-specific data showed the tallest trees at S-10 in Phang Creek (2.4 meters) and S-12 in Tuna Creek (2.3 meters). The height varied between 1.3 and 2.4 meters across the different locations. However, during the post-monsoon of 2024, the average height was recorded as 1.7 meters. Navlakhi Creek had the tallest mangroves reaching 3 meters while the overall average height was 2.2m. At S-10 in Phang Creek the average height of trees was 2.3 meters. The height of the plants recorded during this season ranged from 1.1 to 3 meters considering all the study stations. During the pre-monsoon of 2025, the average height was 1.6 meters, with Phang Creek recording the highest at 1.7 meters. Site-specific observations showed that S-10 in Phang Creek (2.2 meters) and S-2 in Tuna Creek (2.1 meters) were the maximum height of the plants. The height varied between 1 and 2.8 meters. Mangrove height is a key indicator of the health plants and the ecosystem. The taller trees provide greater protection against storm surges and coastal erosion.

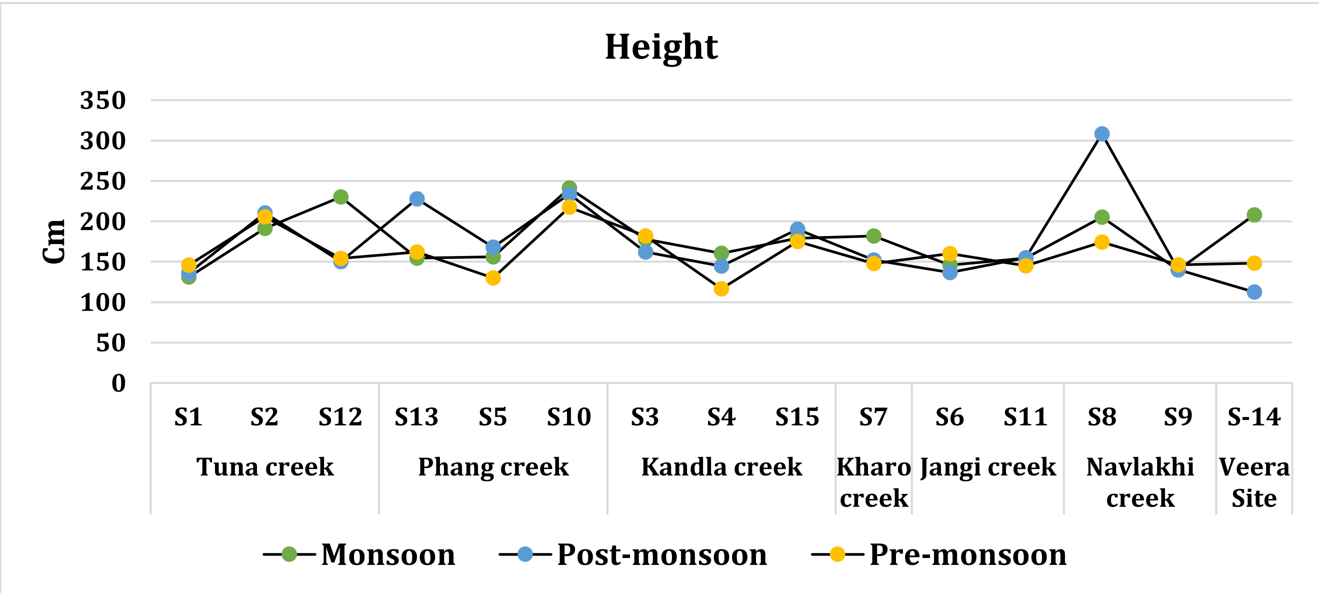


Figure 49. Average tree height during the three seasons study in 2024-2025

4.4.3.Canopy Crown Cover

During the monsoon, the average canopy cover across the mangrove study sites was 3.8 m^2. The highest average canopy cover was recorded at Navlakhi Creek (5.2 m^2), followed by Phang Creek (4.5 m^2). In station wise study, the highest canopy cover was recorded at S-10 (Phang Creek) and S-15 at Kandla Creek, while, S-1 at Tuna Creek, and S-4 at Kandla Creek showed comparatively lower average canopy cover. The post-monsoon survey of 2024 recorded an average canopy cover of 3.45 m^2. In this season the highest canopy cover was recorded at Navlakhi Creek (5.5 m^2), followed by Tuna Creek (3.8 m^2). In station wise observation, stations S-6 at Janghi Creek and S-4 at Kandla Creek recorded relatively lower canopy covers. During the pre-monsoon in 2025, average canopy cover was recorded as 2.25 m^2 across the mangrove study sites. The stations S-10 (4.9 m^2) at Phang Creek and S-15 (3.1 m^2) at Kandla Creek showed higher average canopy covers compared to other stations. However, stations S-4 (0.8 m^2) at Kandla Creek and S-7 (1.7 m^2) at Khari Creek recorded lower canopy covers. Such variations in canopy cover demonstrate how the local environmental factors shape the growth and progression of mangroves.

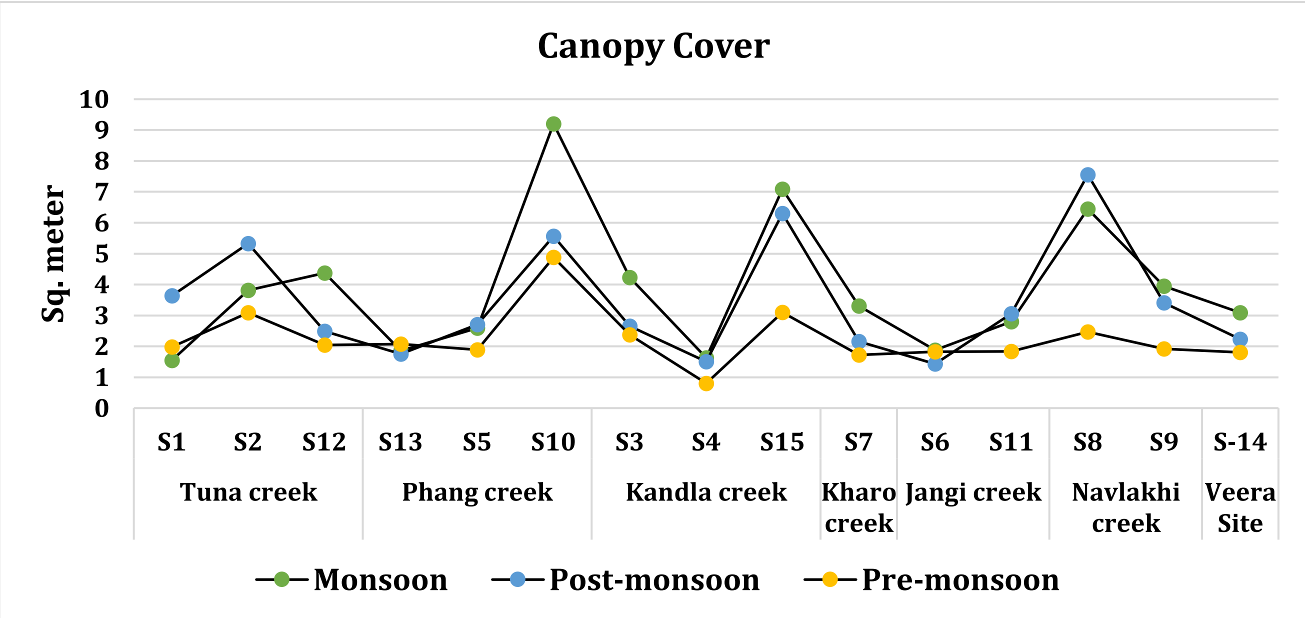


Figure 50. Average tree canopy during the three-season study during 2024-25

4.4.4.Basal Area (Girth)

During the monsoon of 2024, the average basal girth of the mangroves at the DPA sampling sites was reported to be 13 cm. The highest average basal girth was recorded at S-10 (22 cm) and S-8 (18 cm), located in Phang Creek and Navlakhi Creek respectively. The lowest average basal girth was reported at S-6 and S-9 (8 cm) in Janghi Creek and Navlakhi Creek, respectively. During the post-monsoon of 2024, the average basal girth recorded was 12 cm for all the sites while the highest average basal girth was 22cm observed at site S-10 in Phang Creek, followed by S-8 (20 cm) in Navlakhi Creek. In contrast, the lowest average basal girth 8 cm was noted at S-6 and S-14, situated in Janghi Creek and the Veera site respectively. During pre-monsoon of 2025, the average basal girth was recorded as 11 cm and the highest average basal girth were at S-10 (17 cm) in Phang Creek, followed by site S-15 (14 cm) in Kandla Creek. However, the lowest average basal girth was noted at site S-4 and site S-1, both measuring 8 cm, situated in Kandla Creek and Tuna Creek, respectively. Across the DPA Kandla region, Avicennia marina is the dominant species, recognized for its unique multiple-stem growth habit.

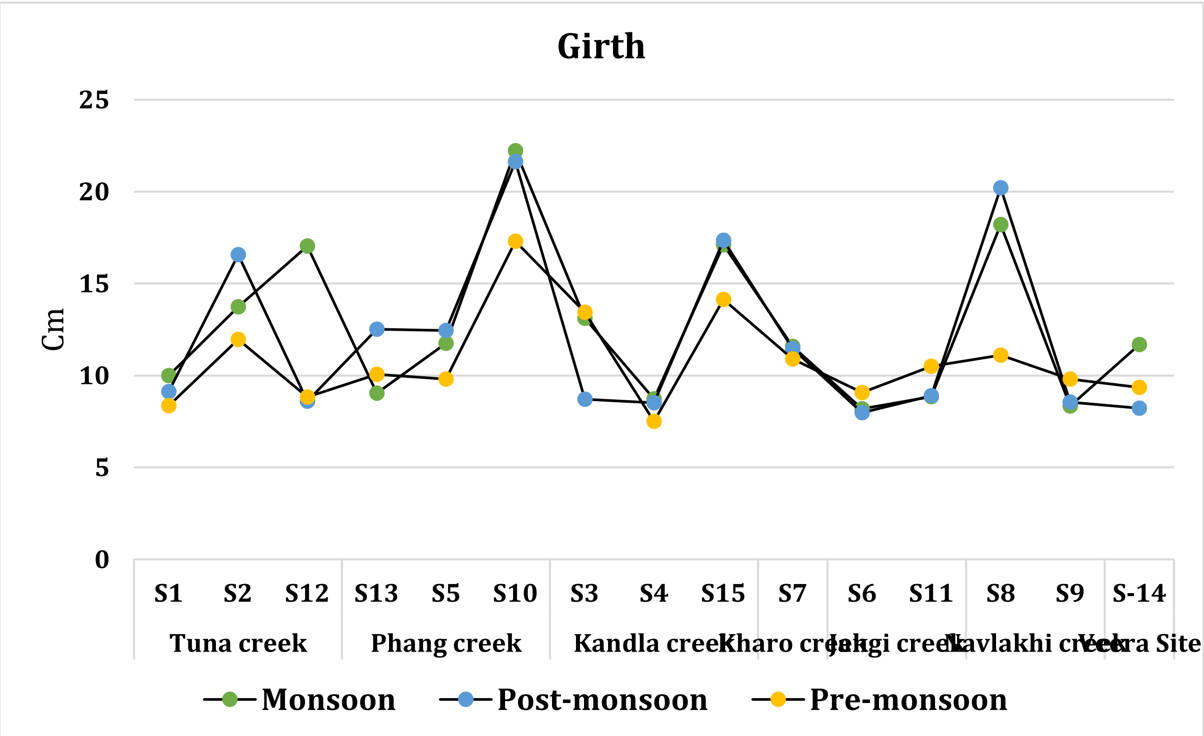


Figure 51. Average tree basal girth during three-season study during 2024-2025

4.4.5.Regeneration and Recruitment Class

During monsoon of 2024, the overall average regeneration class density was recorded as 29,692 plants/ha and the overall average recruitment class density was 5,308 plants/ha. In site-wise observations, the highest average regeneration class density was 73,000 plants/ha at S-8 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 S-7 located in the Kharo creek during this survey.

During the post-monsoon survey of 2024, the average density of the regeneration class was recorded as 24,467 plants/ha, while the average density of the recruitment class was noted as 4,785 plants/ha. The site-specific observations revealed that the highest average regeneration class density was at S-12, with 57,100 plants /ha, followed by S-1, which recorded 38,000 plants/ha, both situated in the Tuna Creek area. For the recruitment class, the maximum average density recorded was 10,725 plants per hectare at site S-12 in the Tuna Creek during the survey.

During the pre-monsoon survey of 2025, the average density of the regeneration class was observed at 23,100 plants /ha, while the average density of the recruitment class was3,819 plants/ha. In the station-specific observations the highest average regeneration class density was 46,000 plants/ha at S-11, followed by 36,700 plants/ha at S-3, situated in the Janghi Creek and Kandla Creek area respectively. For the recruitment class, the maximum average density recorded was 7,250 plants/ha at S-8 in the Navlakhi Creek during the survey.

The younger mangroves in these areas promise the future establishment of fully mature trees. These younger class mangroves play a vital role in stabilizing soil and capturing sediments, thereby preventing coastal erosion and maintaining the quality of nearby water systems

a **b**

c **d**

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

Plate 10. Mangrove Species of DPA Port Authority

4.5. 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 and Colmer, 2008). Halophytes are classified based on their growth conditions as obligate halophytes, facultative halophytes, and habitat-indifferent halophytes.

Percentage of Cover

In entire study period from May 2024 to May 2025 , highest percentage of cover contribute by the halophyte *Salicornia brachiate* (96% -100%) followed by *Sesuvium portulacastrum* (35-50%) , *Salvadora persica* (4% -60%) and *Aeluropus lagopoides* (7%-40%) in monsoon,Post-monsoon and Pre-monsoon. (Plate 11)

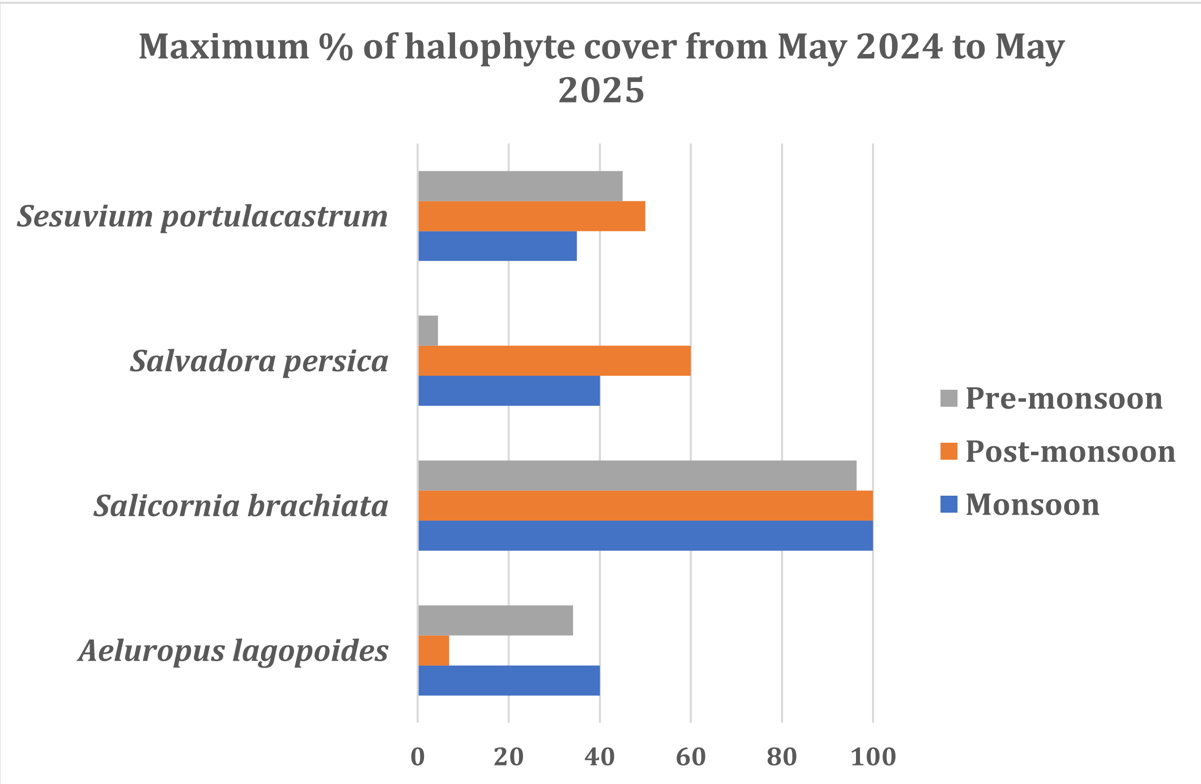
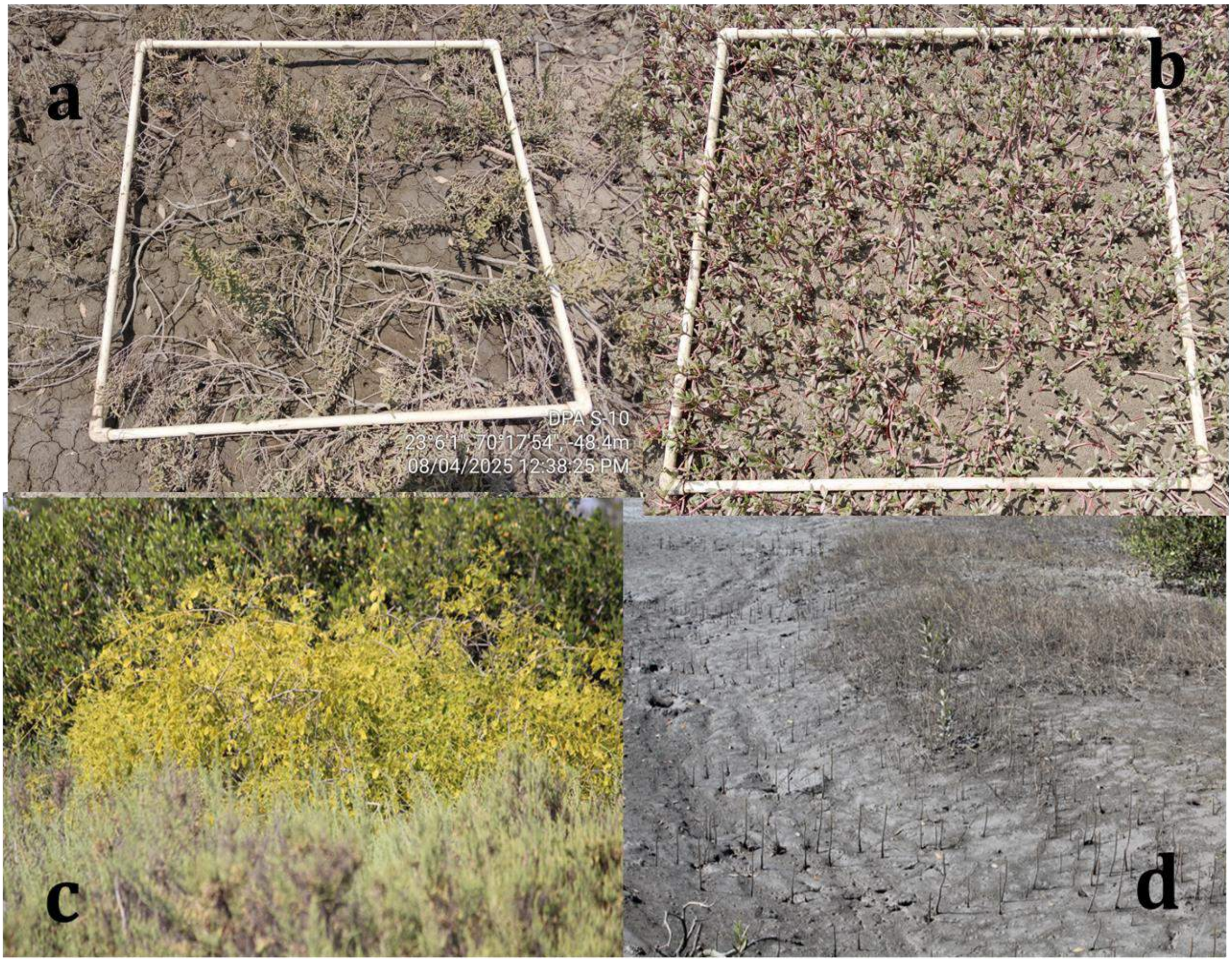


Figure 52. Maximum % cover of Halophytes in DPA and it periphery environment



a. Salicornia brachiata b. Aeluropus lagopoides c. Salvadora persica

d. Sesuvium portulacastrum

Plate 11: Halophyte species recorded along Deendayal Port Authority

4.6. Seaweeds &Seagrass

Both the seagrass and seaweed not observed entire study period from may 2024 to may 2025.

4.7.Marine fisheries

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 from May 2024-2025 , 0.5 kg to 5 kg of fish was catched in 1 km distance with 10 minutes and *Mugil cephalus* is only dominant species which is available in all the season (Plate12).

Plate 12 . Marine fisheries along DPA Jurisdiction

4.8.Reptiles

The saw-scaled viper *Echis carinatus sochureki* normally encountered during mangrove survey Monsoon and Post-monsoon at S-10 location

4.9.Marine mammals

Marine mammals was not observed in entire study period

4.10.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, Cox 2010, Grimmett et al. 2011). 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). Mangrove forest is an important habitat for many bird species and provide high quality habitat for birds because they contain relatively safe nesting and roosting sites, and abundant prey (Nisbet, 1968; van Balen, 1989). Mangrove habitats harbor much of the world's tropical biodiversity and 50% of the world's mangrove forests have been lost as a result of clearing and alteration of coastlines (Duke, 1992). With continuing degradation and destruction of mangroves, there is a critical need to understand the biodiversity of the mangrove ecosystems (Vannucci, 2002). Mangrove vegetation provide a complaint niche for the myriad resident as well as passage migrant aquatic birds, which utilize the system in varying degree from feeding, roosting and breeding (Oswin, 2002).

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).

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 2024-25. The entire survey was comprehensively carried out by boat survey and walking along the fixed sampling station, for documentation of avifauna. A total of 64 species (34 species terrestrial and 30 aquatic bird) representing 11 order, 26 families and 46 genera were recorded during the study period (Annexture 1, Plate 13). Scolopacidae (nine species) were the most dominant family in terms of species richness followed by Ardeidae and Laridae (eight species), whereas Columbidae and Accipitridae (five species), whereas others represent less species (Fig.53).

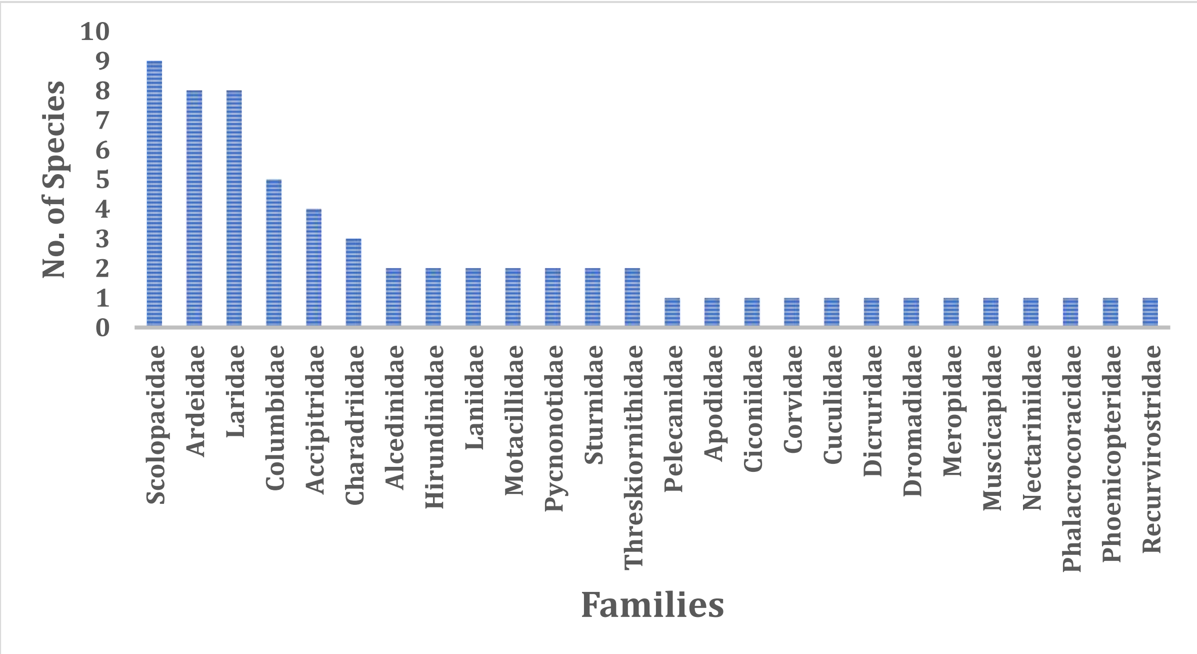


Figure 53. Distribution of families and species at the DPA , Kandla, India

Among the survey station, site 12 (55 species) were the most dominant with 41 genera and 24 families species richness followed by site 13 (53 species), sites 1, 2 and 7 have (47 species) and site 3 have 46 species and other sites have less species composition (Fig.54). The Shannon–Wiener diversity indices shows that site 13 (H=3.756), followed by site 12 (H=3.707), site 7 (H=3.642) and site 5 (H= 3.622), whereas others represent less diversity (Table 13). Based on the movement pattern 42 species (66%) of birds were residence, 18 (28%) are migratory and four (6%) species are regional migratory (Fig. 55).

Table 13. Site wise diversity indices recorded from DPA during 2024-25.

Sites	Taxa	Individuals	Simpson_1-D	Shannon_H	Evenness e^H/S	Margalef	Equitability_J
S-1	47	191	0.966	3.559	0.748	8.758	0.925
S-2	47	212	0.969	3.62	0.794	8.588	0.940
S-3	46	520	0.964	3.575	0.776	7.196	0.934
S-4	42	527	0.969	3.607	0.878	6.542	0.965
S-5	45	499	0.967	3.622	0.832	7.082	0.952
S-6	35	309	0.962	3.405	0.861	5.93	0.958
S-7	47	281	0.968	3.642	0.812	8.158	0.946
S-8	34	288	0.965	3.433	0.911	5.827	0.974
S-9	34	275	0.964	3.405	0.886	5.875	0.966
S-10	36	403	0.963	3.427	0.855	5.834	0.956
S-11	25	241	0.947	3.045	0.841	4.376	0.946
S-12	55	385	0.969	3.707	0.741	9.071	0.925
S-13	53	644	0.972	3.756	0.807	8.04	0.946
S-14	30	199	0.958	3.258	0.867	5.479	0.958
S-15	37	287	0.966	3.488	0.885	6.361	0.966

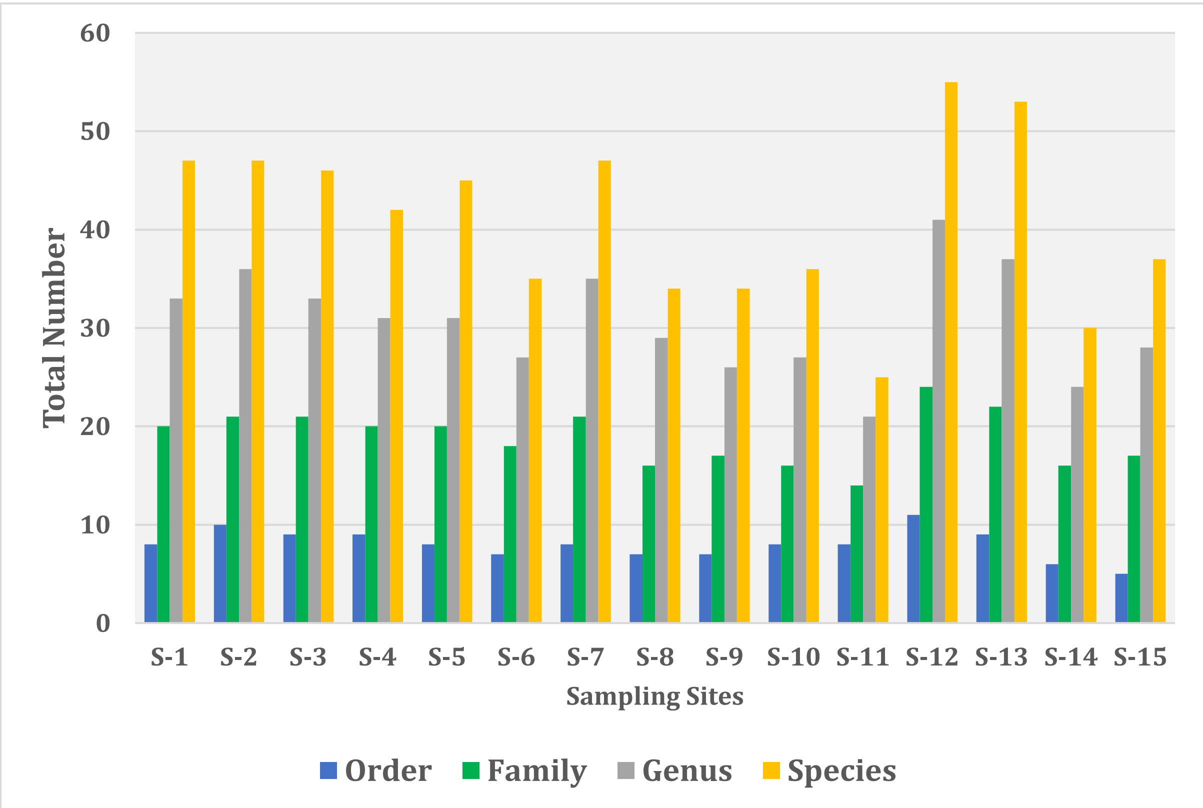


Figure 54. Station wise distribution of Avifauna from May 2024-May 2025 at DPA

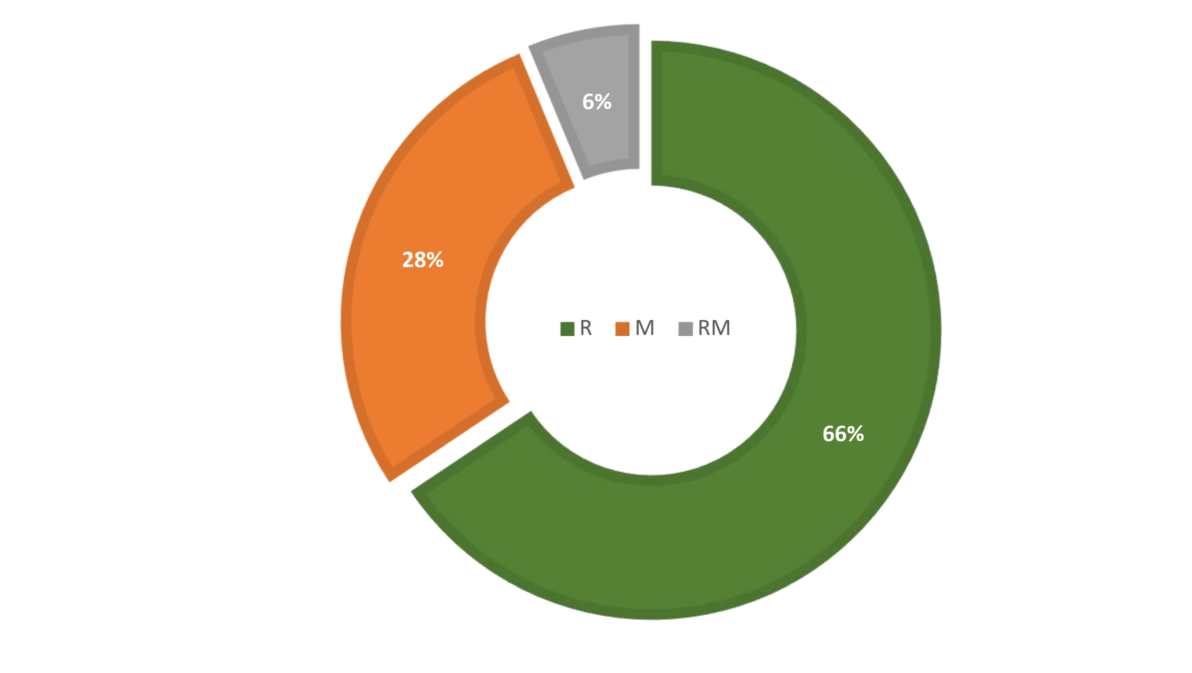


Figure 55. Behavioural status of avifauna from the DPA

Considering the abundance of the species during the study period, 34 taxa (53%) were recorded from terrestrial, 30 species (47%) from aquatic habitat. During the seasonal survey we have noted that, post monsoon season is most productive for avifauna in study area (Table.14)

Table.14. Season wise species recorded from study area

Sites	Monsoon	Post Monsoon	Pre-Monsoon	Overall
S-1	44	14	13	47
S-2	40	21	14	47
S-3	43	44	46	46
S-4	42	42	40	42
S-5	45	45	44	45
S-6	35	35	34	35
S-7	41	22	21	47
S-8	33	34	33	34
S-9	34	34	34	34
S-10	35	36	36	36
S-11	23	23	25	25
S-12	45	37	31	55
S-13	53	53	51	53
S-14	29	29	20	30
S-15	37	37	37	37
Total	**53**	**64**	**60**	**64**

Plate 13. Common and migratory birds from the Deendayal Port Authority, Kandla. (A) Western Reef Heron (*Egretta gularis*) (B) Black-headed Gull (*Chroicocephalus ridibundus*) (C) Eurasian curlew (*Numenius arquata*) (D) Grey Heron (*Ardea cinerea*) (E) Greater Flamigo (*Phoenicopterus roseus*) (F) Black-winged Stilt (*Himantopus himantopus*)

Based on the feeding guilds of recorded birds, it was found that carnivore, 20 species (31.35%) were insectivore, 17 species (26.56%) were piscivore were 14 species (21.88%) and 6 species of omnivores and others represents less (Fig 56).

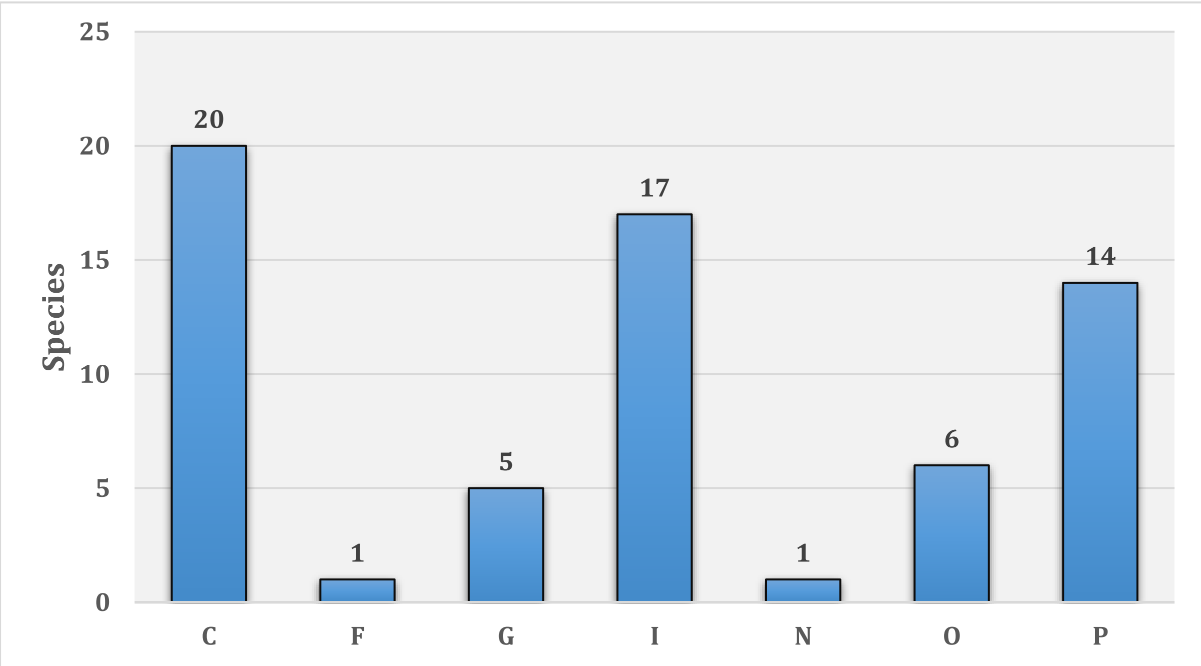


Figure 56. Status of foraging guild of avifauna recorded from Deendayal Port Authority, Kandla, India (C- Carnivore, F- Frugivore, G- Granivore, I- Insectivore, N- Nectarivore, O- Omnivore, P- Piscivore).

Among 64 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, four species (6.25%) River Tern *Sterna aurantia* (Gray, JE, 1831), Common Greenshank *Tringa nebularia* (Gunnerus, 1767), Black Kite *Milvus migrans* (Boddaert, 1783), Gull-billed Tern *Gelochelidon nilotica* (Gmelin, JF, 1789) and Shikra *Tachyspiza badia* (Gmelin, JF, 1788) were under the Schedule I, and species (90.63%) were under Schedule II categories of Wild Life (Protection) Act, 1972 (Fig 57) and the species rarefaction curve presented in figure 58.

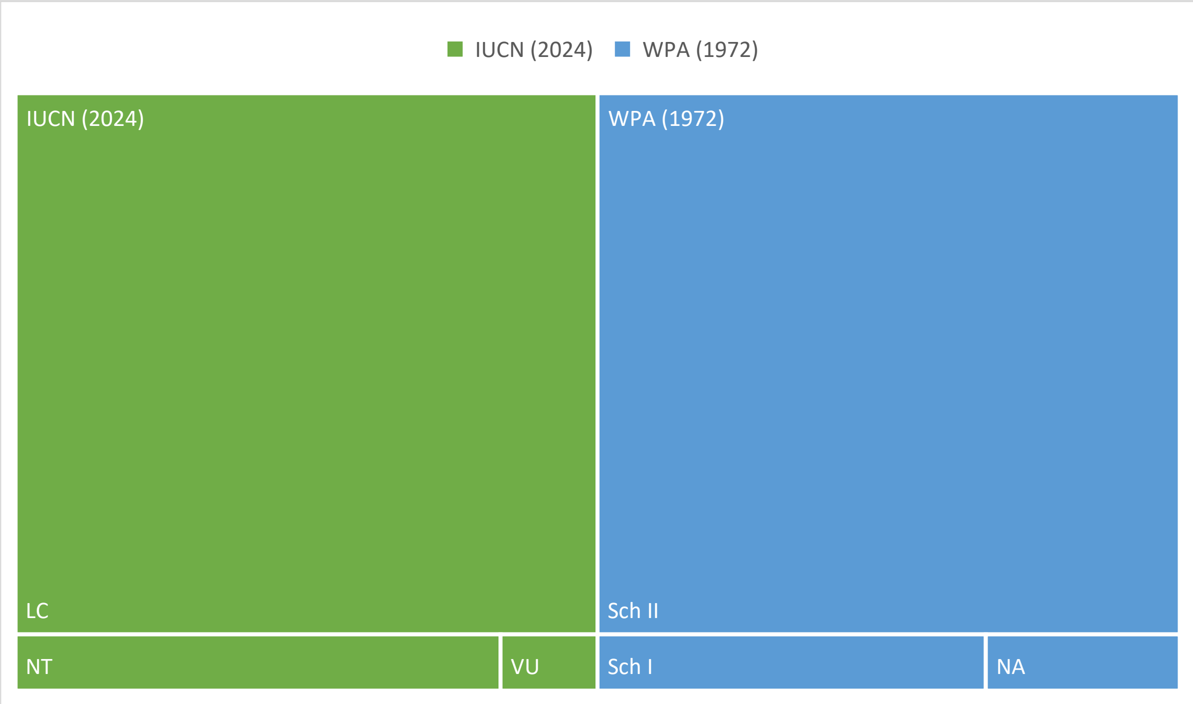


Figure 57. Status of threatened species recorded from Deendayal Port Authority, Kandla, India (Sch=Schedule, LC=Least Concerned, VU= Vulnerable, NT= Near Threatened).

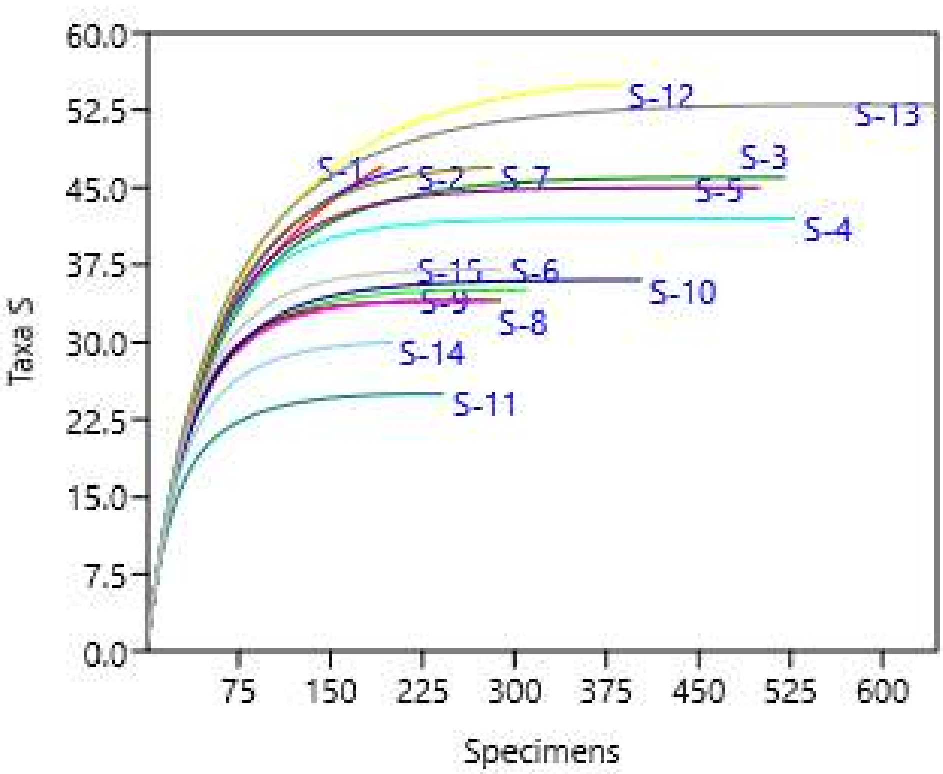


Figure 58. Species rarefaction curves of different sampling sites in study area.

5. Discussion

5.1.Physico-chemical status of Deendayal Port Authority Environment

Water quality of coastal water reveals the state of the overall environment. The quality of water determines the biological and other resources in the marine environment. However, water quality parameters in marine environment vary to a great extent, influenced by the climate,water currents and movements, input of pollutants in the form of effluent and sewage out fall and so on. The geophysical and geo-chemical factors such as shape and size of the coastal areas, prevailing currents, temperature, salinity, tidal impacts, directions of prevailing winds and influx of fresh water also influence the quality of water in the nearshore marine environment. The creeks and the intertidal zones are well known for the biodiversity and their role in the ecological services arewell documented. mangroves are now recognized as one of the most effective nature based solutions for climate change adaption and to reduce disaster risk (Sunkur, 2023). To assess the health of mangrove forest is inevitable in the monitoring programme in which extensive field survey is carried out to select the representative sites for data collection. The plant growth characteristics indicates the status of the mangrove cover for which the height,canopy dimension, Girth, as well as the number of different age groups of plants are considered. The DPA port and the influencing environment are surrounded by the mangroves and tidal flat with marshes are potential carbon stocks which are conserved and restored. Yet,the various human interventions due to the port related activities tendto impair the water and sediment quality which in turn affect the biological productivity. In this regard some of the most influencing physical and chemical water and sediment are considered for the seasonal study from the 15 selected sites. The plankton and benthic fauna diversity, Chlorophyll 'a' are also recognized as indicators of the health status of the environment (Adams,2002). The rate of variations in the different stress indicators in the water are followed in the monitoring process to evaluate the impacts that are likely to occur both in the near future as well as in the long term at the present rate of occurrence.

Temperature and pH

Water temperature in DPA port area generally varies in the range 12°C to 30.°C. However, the present study shows a increased range of water temperature in Kandla DPA port in previous year of 2023-2024. Water temperature Port region varies during monsoon, ranged from 23°C to 30°c to while in post monsoon observation, the value ranged from

12°c to 27°c to . However, in pre monsoon the values were noted in the range of 25°c to 29°C.The monsoon water temperature has been recorded as high (30°C). There is no vertical variation in temperature of marine water in Kandla Port area due to lack of thermal stratification in Creek (NIO,1998). This is because of the strong currents, high tidal impact and low depth of the harbour areas. The currents influence vertical mixing and restrict the stratification of water layer in the harbour area. High temperature during pre- monsoon attributed to high rate of evaporation and less rain fall.

pH

The pH of seawater of DPA Port area varied in the range of 7.3 to 8.5. Generally, the pH of seawater is controlled by Carbonate and biocarbonate system and falls in the narrow range of (0.2-0.3). pH was alkaline during summer and showed downward pattern up to monsoon and remained alkaline during postmonsoon, (Vajravelu et.al 2018). Changes in pH will depend on the factor like the removal of CO2 by photosynthesis through bicarbonate degradation, fresh water influx, reduction in salinity and temperature and decomposition of organic matter (Rajasegar et al., 2002).

Salinity

As temperature influences the salinity of marine water in the tropics, water in DPA region has higher salinity in the range of 36ppt 47ppt during 2023-2024 but at present the salinity ranged 32ppt to 42 ppt which is quite lower in previous year . Highest salinity observed during monsoon and Post-monsoon (42ppt) at station S-8. The higher salinity towards open sea regions around S-8 due fresh ingress of seawater in gulf region and localized effects of seepage of high saline (brine) water from salt marshes and saltpans of salt industries (Zingde& Anand ,1996). Hundreds of salt industries in and around Kandla Port use seawater with salinity in the range of 35 to 50 ppt. They release 'bittern' remains of salt after manufacturing, which has salinity as high as 250 ppt in Kandla Creek, thereby increasing the salinity in isolated regions of port areas (Chhaya, & Chhaya, 1997). Lack of fresh water from catchments coupled with higher evaporation is the cause of higher salinity in Kandla Port area. In the Little Gulf of Kuchchh water salinity has been recorded as high as 50 ppt (NIO,1998).

Dissolved oxygen

DO is consumed in marine ecosystem by the respiration and decaying organic matter in the water column. Loads of high organic matters may deplete the DO to its minimum level, which can be detrimental for the aquatic life. A severe depletion of DO may lead to 'Eutrophication' in an aquatic system. However, no such event has been reported in Kandla port region so far. DO in marine water of DPA region has been found in the range of 2.9 mg/l to 8.2 mg/l for in 3 seasons May 2024 to May 2025. The current range of dissolved oxygen in the marine water of Kandla Port region conforms to the designated best use for Salt pans, Shell fishing, Mariculture and Ecologically Sensitive Zone. For ecologically sensitive zone not less than 3.5mg/l at any time in a year (or 5.0 mg/l at 60 percent saturation level) of DO is essential for the protection of aquatic life. But in presentation observation less content of do in monsoon at S-7 might be due certain nutrient load from mangrove environment.

Total Suspended Solids

Suspended solids in Deendayal port area varied in the range 205 mg/l to 729 mg/l. Generally, the suspended solids in the Deendayal region are high and vary to a great extent from the inner port region to the out harbour region and further towards outer Gulf..The higher value of suspended solids and their variations across the stations in the inner Gulf including Kandla Port regions results from the dispersion of sediment loads due to strong currents and tidal influence Zingde& Anand (1996).

Turbidity

The Kandla Port areas fall under inner Gulf of Kuchch, there is a high turbulence in the· Creek, due to strong an ocean currents and tidal influence. Therefore, the turbidity of tropical seas is higher than other tropical and subtropical seas. The marine water turbidity is expressed in Nephelo Turbidity Unit (NTU). Water turbidity in DPA Port region has been recorded in the range of 16 NTU to 489 NTU. 2023-2024 at present 2024-2025 the turbidity 20 NTU to 489 NTU. Generally, water turbidity is high due to high organic load of mud and silt. (Omprakash, 1997) Higher turbidity of marine water at the DPA Port regions may also be associated with the washed sediment from mangrove environment and partially dredging activities, which is done on a regular basis along the Kandla Creek.

Nutrients

Nutrients in marine water such as Nitrate and Nitrite ,Phosphate and silicate are very crucial for the marine life. Their increase in concentration enhances the primary productivity in marine water. Nonetheless, excessive concentration sometimes can be detrimental to the aquatic life especially in creeks, estuaries and bays where there is a restricted water exchange. These increased nutrients lead to an excessive growth of algae resulting in eutrophication in some extreme cases (NIO,1998). During the period of May 2024 to May 2025 covering 3 season with respect to nutrient concentation it was observed that the concentration were with in permissible limit to marine life expect phosphate concentration which is quite higher from 3.16mg/l to 73.24mg/l which might be due to handling of cargo in port area ,input of sewage and industrial effluent to creek environment

Petroleum Hydrocarbon (PHs)

Petroleum hydrocarbons in the water column of Deendayal port area have been found in the range of 0.3 µg/l to 85.8µg/l for the period 2023 and 2024. For the period may 2024 to May 2025 the PHs ranged from 0.19 µg/l to 70.80 µg/l. High range of petroleum hydrocarbon results from the spills and leakage during the handling of crude petroleum products at the Port especially at oil terminals (NIO,2002).

5.2.Biological status of Deendayal Port Authority Environment

Biological resources of a marine area reflect the overall environment of the region in question. The coastal areas especially bays, creeks and estuaries are rich in biota and are habitat of many marine species. Usually, ports are also built in these areas for their geographical advantages. The port and harbour activities in these locations disturb the habitat of many marine biota. However, in the process many habitats are also created for marine biota. The Gulf of Kachchh is an example of such habitat and has been considered to be rich in biodiversity. Kandla port has been built right in the gulf and has been serving this region nearly seventy years.

Chlorophyll ‘a’ Phytoplankton and Zooplankton

In general the basic parameters of marine biota like Chlorophyll ‘a’ and Phytoplankton are observed to be moderate in their values but similar to those prevailing along the coastal waters of India (NIO,2002). During the period May 2024 to May 2025 the Chlorophyll 'a' concentration 0.04 mg/l to 2.89mg/l which is quite satisfactory for port environment.

The index value of both phytoplankton and Zooplankton of 3 season shows moderate environmental status (Fig.59).

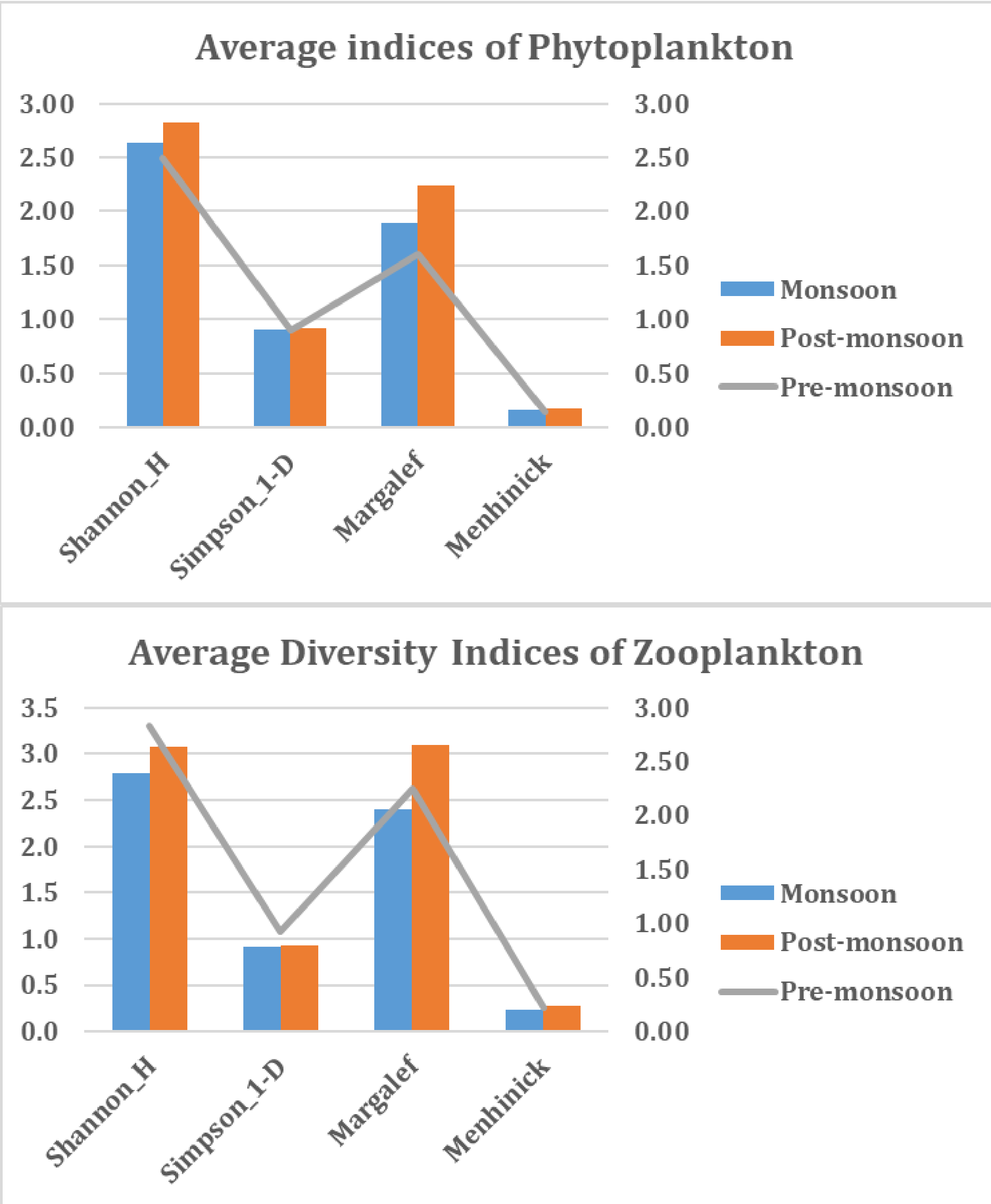


Figure 59 Diversity indices of Phytoplankton and Zooplankton

As per Shannon Wiener's rules the aquatic environment i.e both soil and water classified as very goodwhen 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 DPA port and its periphery environment has been influenced by contaminants deposited from industries and the cargo movements. Accordingly, species diversity decreases at sites with poor water quality. As deduced from the Shannon diversity index values between 3-4 overall 3 season representing the moderate quality of environmental status dominated by the few genera such as Coscinodiscus sp. and Synedra sp,and copepod sp. A community dominated by relatively few species indicates environmental stress (Plafkin et al., 1989). According to Staub et. al (1970) species diversity index value between 3.0 to 4.5 represents slightly polluted and the lightly polluted environment, the index value characterizes 2.0-3.0, similarly, moderately polluted environment shows index value of 1.0-2.0 and finally, the heavily polluted environment index value is 0.0-1.0. While considering the overall index values it is inferred that the study sites can be included under the category of lightly polluted environment.Natural geographical processes such as strong currents and higher tidal influence have been responsible for the high turbidity and suspended solids which in turn reduce the light penetration thereby reducing the growth of Plankton and primary productivity.

Intertidal Fauna

Macrofaunal communities did not show much spatial and temporal variation in their components at 15 sampling locations. The distribution of intertidal Fauna seems to be entirely governed by the environmental parameters like Physico-chemical and biological characteristics of the ambient milieu. Generally, intertidal Fauna on the Kachchh coast scope a harsher environment with relatively high salinity, wide temperature fluctuations, seasonal fluctuation of different hydrological parameters and a high sedimentation rate. The water suspended solids (SS) were generally found due to the dispersion of fine sediment from the bed and the intertidal mudflats due to tidal movements at the mouth of the Kachchh coast (Kandla).

An earlier study by Saravanakumar et al. (2007) revealed the presence of five intertidal Fauna in the mangrove environments along the Kachchh coast, with a diversity index such as Shannon_H, Simpson_1-D, Margalef and Menhinick ranging from 1.84 to 2.45 in 2023 to 2024 at present from may 2024 to may 2025 it is 0.77 to 1.66. The species composition and diversity indices reported during 2018-2019, 2019-2020, 2020-21, and 2021-2022 2022-2023 and 2023 to 2024 did not vary significantly in the DPA port environment. It was understood that the intertidal fauna community in the Kachchh mangrove had not varied much in terms of its species diversity. An earlier study by Saravanakumar et al. (2007) revealed the presence of five intertidal Fauna in the mangrove environments along the Kachchh, with a diversity index ranging from 1.84 to2.45. During the 2023 to 2024 average Shannon diversity indices varied from 1.51 to 1.6 similarly the Margalef and Simpson indices ranged from 1.43 to 1.5 and 0.7 to 0.73 and similar patter the index value also run parallelly (Fig. 57). According to Magurran (1991), the Shannon diversity index of >3.0 indicates a healthy coastal environment. However, diversity indices around the DPA coastal environment were <2.0, indicating that the lower moderate faunal diversity.In the present observation, the species composition of the benthic macrofauna showed dominance in the Phyla Molluscs, Arthropoda, Annelida, Nematoda, Nemertea and Chordata. Previously, Ansari et al. (1986), Mohammed (1995) and Kumar (2001) recorded the presence of the Molluscs, Arthropoda, Annelida, and Chordata in various parts of Indian coastal waters.

Subtidal Fauna

The Shannon diversity indices ranged from 0.65 to 1.77, similarly Margalef and Simpson indices ranged from 0.75 to 2.18, 0.35 to 0.80 during 2023 -2024 . The results obtained from this study represent and the indices such Shannon_H,Simpson_1-D, Margalef, and Menhinick reflect similar moderate to lower environmental status for the period 2024-2025 (Fig.61). There is a need for an in-depth study of Fauna and their interactions in mangrove ecosystems. Also, practices directed at managing mangrove resources should go hand in hand with conservation strategies.Mahapatro et al. (2011) documented the macrofaunal diversity in Bhitarkanika (Odisha coast) mangroves, and the diversity ranged from 1870 No/m2. Ramakrishna et al. (2011) recorded the population structure and density of macrofaunal from the Andaman and Nicobar Islands and documented diversity from 1015 No/m2 in the. In the Gulf of Katchh, Saravanakumar et al. (2007) documented that from 1999 to 2000.

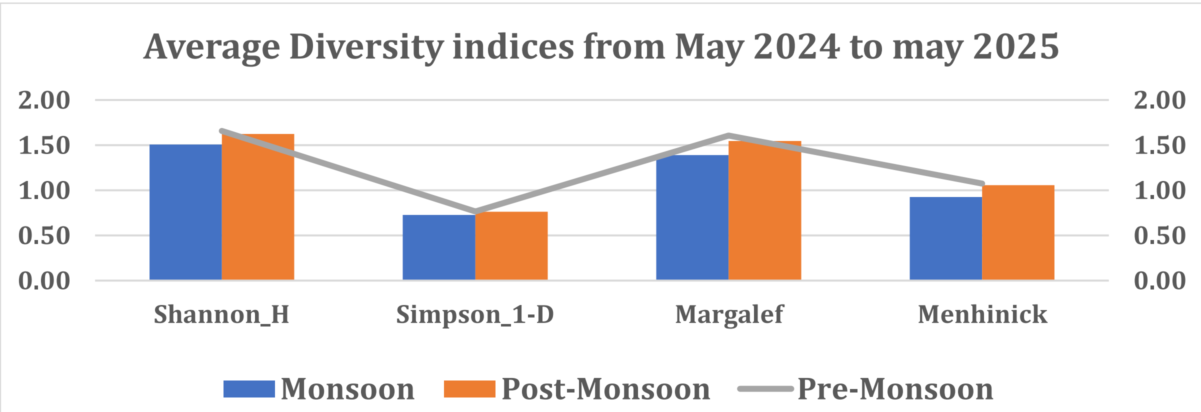


Figure 60. Average diversity indices of intertidal fauna of DPA

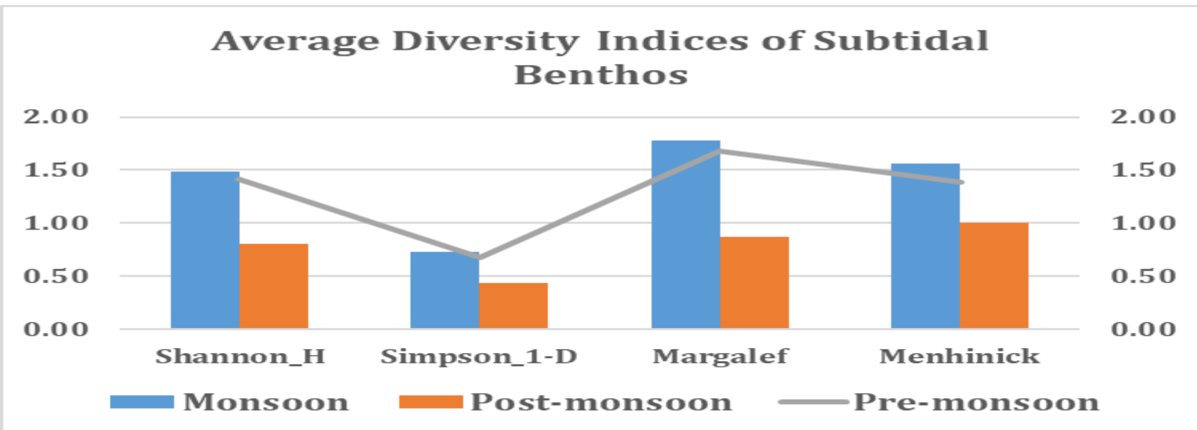


Figure 61 Average diversity indices of Subtidal fauna of DPA

6. Impact identification and Evaluation

The Deendayal Port, Kandla, in Kachchh district is surrounded by a large number of port associated industries and salt pans and salt processing industries. There are a number of minor and creeks that are connected to the Gulf of Kachchh. The DPA has been the prominent industrial and transport facility primarily associated with the inter connected creek environment which influences the open oceanic zone. The adjacent marine zone is well known for the multitude of the biological resources however, the very sensitive ecosystems like coral reefs, sea grass meadows and salt marshes are not found within the 10 km radius of the DPA port Jurisdiction, and the direct impacts are not experienced.

The general consequences of the port associated activities, particularly on the free-floating microscopic animals and plants, the macrofauna inhabiting the sub-tidal and Intertidal habitats and the birds have been well known, in this respect it is imperative to analyze the major impacts and to put forth effective mitigation measures.

Routine dredging Impact

- Dredging and dredge spoil disposal activities for port development and maintenance can induce short and long-term impacts on aquatic systems, namely degradation of marine resources such as fisheries and other aquatic biota.
- Dredging activities often disturb sediments reducing visibility and transparency of water.
- Dredging activities potentially affect not only the site itself, but also the surrounding areas, through a large number of impact factors such as turbidity, sedimentation, resuspension and release of contaminants which can be within the site or to the nearby area on a temporary or over a long period.
- **Impact on Air quality of the Port premises**
- Emissions from burning waste materials and the escaping dust particles due to handling of fine-particulate materials such as fertilizers and minerals causing air pollution in port areas.

Impact on Avifauna

Impact-I Location of the Deendayal port site in the close vicinity of the ecologically sensitive terrestrial ecosystem (migratory route, breeding and nesting sites of avifauna) may impact the overall biodiversity values due to the project associated activities such as A. Habitat degradation due to pollution

B. Loss of habitat and population of faunal groups

C. Overall impact on biodiversity of the protected area

Evaluation: The Deendayal SEZ project site located in the mid of the Deendayal Port area surrounded by port associated industrial sectors, predominately salt industries. There is no any ecologically sensitive ecosystem (Protected Areas) located within 10 km radius of the project site. Due to the prevailing land use no impact on protected areas was foreseen. Further the study area also not reported any migratory route of major animal groups, nesting and breeding sites of avifauna.

Impact on threatened flora and Fauna – Inter-tidal coastal habitat.

Impact 2: Direct loss of inter-tidal habitat like mangrove and saltpan will impact the threatened floral and faunal species existing within it due to; Loss of inter-tidal habitat (mangrove) and degradation due to project associated activities will overall population status of threatened aquatic avifauna.

Evaluation: As per land use land cover study, the project area dominated by intertidal habitats like, Mangrove, creeks and salt pans. The study area reported total 5261 birds belong to 64 species (Annexure 1). However, this list includes 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, four species (6.25%) River Tern *Sterna aurantia* (Gray, JE, 1831), Common Greenshank *Tringa nebularia* (Gunnerus, 1767), Black Kite *Milvus migrans* (Boddaert, 1783), Gull-billed Tern *Gelochelidon nilotica* (Gmelin, JF, 1789) and Shikra *Tachyspiza badia* (Gmelin, JF, 1788) were under the Schedule I of Wildlife Protection Act, 1972 (amendment 2022).Since the study area beyond 5 km supports large extent of similar (Inland wetlands and Salt pans) habitat types and supports large number of aquatic birds, the overall impact on few aquatic threatened avifauna reported in the study area would be minimal (Annexure 1). In spite of that, implementing, proper mangrove plantation activity can take care of this minimal impact. Further, no endangered aquatic birds reported in the study area.

7. Mitigation

Adopting mitigation techniques for reducing the carbon concentration in the atmosphere through green belt/plantation, conservation of water and energy in the agriculture and several production sectors have been very much familiar. Various other considerations to control air and water quality in the port and influencing environment have been suggested and implemented in many states. Depending on the physical and chemical characteristics of the dredged material, disposal may be confined, unconfined or treated prior to release in open water, along the shoreline, or on land. Ultimately, EMMP acts as a comprehensive manual for environmental protection, reduction in carbon (GHG) emission and finally it helps in converting major ports into "Green Ports". The ultimate goal of a Green Port Plan program is to achieve long-term environmental, societal and economic benefits through resource conservation, waste reduction and pollution prevention. The Green Port Program unifies the Port's environmental sustainability goals (in many key areas) by way of setting measurable goals and evaluating progress in each area on an annual basis.

Pollution control

The major health impacts of pollution from ports are related to the gaseous and particulate emissions arising from the combustion of petroleum products and coal leading to various respiratory tract diseases, cardiovascular disease, lung cancer and also climate change related issues. Petroleum contamination is a very common problem these days arising from leaking tanks, oil spill, and gas into the surrounding water and soil and takes long time for reclamation by bioagents or physical and chemical treatments. A process called thermal soil remediation helps in the remediation of contaminated soil which can be reclaimed and reused by this method.

The possible soil contamination due to spillage of oil residues, petroleum products, cement, paint, plastics, non -degradable solids etc. are to be handled effectively by scrupulous preventive management guidelines. The laborer and officials should be aware of the extent of damage they can bring on the ecosystem and in turn to human as well through the process of biomagnification through the marine food chain. In this regard any potentially contaminated soils from construction activities must be handled, transported and disposed off in accordance with the Environmental Management Act (EMA) and its Regulations of Government of India.

Afforestation

The port authority should take up plantation of various kinds according to the space, soil types and water availability. Also, it is utmost necessary to carry out promotion compensatory mangrove and associated vegetation plantation along the shoreline at the suitable tidal level with the common species. The development such green belts surrounding the whole project area will enhance the integrity of the ecosystem and provide ecological and economic services at large on a long and regular basis. The plantation needs to be carried out with higher density of seedlings to realize high survival rates and growth performance considering the past experiences in the coast and the type of natural stands existing along the shores of the creek system as well.

Mangrove plantation

The Green Port Program is an umbrella program designed to achieve the Port's environmental sustainability goals by adopting appropriate afforestation programs to develop large green belt areas at all prospective locations. The afforestation would not only contribute to the aesthetics but also would serve as a 'sink' for the pollutants released from the station and would thereby protect the quality of ecology and environment in and around the projects. Green belt will help in supporting the biological diversity, controls soil moisture, erosion control and coastal protection, increase the rate of ground water recharge and act as carbon sink to reduce climate change. Green cover interventions capture the fugitive, attenuate the noise, subside the particulate matter in the air and reduce the temperature in the surroundings. The mangrove plantation is expected to support the avifauna diversity of the local environment. It is recommended that construction activities to be restricted during the non-migratory season of the birds (November – February) to avoid disturbance to the migratory species as the Kachchh wetlands serve as major wintering grounds, located in the major central Asia fly way. Since the intertidal zone of the creeks comprising the mangroves and salt pan habitats support many benthic fauna including finfishes and shell fishes, aquatic and terrestrial migratory birds, the protection of these productive environments is very much essential for the restoration of the biodiversity and the livelihood of the fishermen. The above suggested mangrove plantation needs to be monitored for the next five years till it attains maturity and later on evaluation of the ecosystem and economic services rejoiced by the community in view of the evolving climate change related issues. The monitoring of the mangrove and coastal zone should include the study of species composition, population characteristics, growth rate of plants, abundance of the flora and fauna in order to estimate the diversity and health status at every season of the entire environment.

Soil erosion control

Shore line substratum erosion is a major threat to the intertidal habitats in DPA port jurisdiction. Often the rate of erosion is severe in the port environment due to the continuous vessel movement and the churning effect induced hydrological regime and other natural causes. During the present study it was noticed that few creeks stretch in Kandla are susceptible to erosion due to high water currents and tides. The dual purpose of controlling erosion and promoting intertidal biodiversity could be best achieved by installation of artificial reef structures, limestone rocks, laterite, cement and granite as well as bio reefs. Artificial coastal structures are cheap and installation is easy and adaptable and for better results it can be supplemented with the addition of a substrate that will support marine organisms as that of the natural intertidal and sub tidal environment. The structural diversity of the artificial reef will determine the diversity of marine organisms utilizing the created habitat. Artificial reefs once built will last for decades and would enrich marine biodiversity in a short period of time by providing ideal habitat for sessile and free-living benthic organisms and their larvae. Natural materials such as dead shells can be used for building artificial reefs and are environment-friendly. Reef balls are another form of artificial reef increasingly used in western countries to create sustainable marine reef habitat which may be easily attempted at Deendayal port Areas. Both reef balls and artificial reefs being inexpensive and locally available, can be built in different creek systems of the port jurisdiction. Application of coir mats are also suitable to control the shoreline erosion in the mangrove patches and open shore in conjunction with the rocky and cement structures.

Phosphate mitigation

- Optimizing fertilizer and detergent application in the households and industries
- Creating awareness among the stakeholders
- Planting perennial crops or crop rotation to avoid bare fields, which experience higher erosion and phosphate runoff.
- Planting trees and shrubs around fields to absorb excess nutrients.
- Restricting runoff from livestock rearing areas and maintaining treatment systems for sewage
- Bioremediation methods to be adopted for the removal phosphorous in agriculture and waste water.
- The most reliable and most frequently applied removal process is chemical phosphorus precipitation by addition of metal salts. Dissolved phosphorus is converted to solids which are removed from the waste water together with the sludge.
- The decay of the organic material produced by photosynthesis under aerobic conditions again results mainly in mineral phosphorus compounds in the sediments with low availability. Under anaerobic conditions decomposition process results in the release of phosphorus in dissolved and therefore easily accessible form.
- By precipitation with calcium cations manifold reactions are known, which are hard to predict. High phosphorus removal efficiency can be achieved at pH-controlled crystallisation of calcium hydroxyapatite which has a very low solubility product.

8. Conservation and Management Plan

Conservation of biodiversity is considered as the key component for administration of natural assets. Biodiversity is an all-encompassing concept that describes the magnitude of ecological diversity addressing the wide range of life associated with different types ecosystems. Biodiversity conservation is the protection and management of the biotic ad abiotic resources for sustainable development and existence and preservation of the diverse species, Sustainable utilization of species in the ecosystem along with the maintenance of the life-supporting systems are essential for the functioning of the various ecological processes. It is an integral part of any commercial activity and infrastructure development in the marine environment. Emphasis is given towards the reinstatement of the physical, chemical and biological characteristics of the coastal ecosystem which are much complex and vulnerable on which the human is highly dependent. Management of the marine biodiversity is the prime concern in the development of Ports and harbors which occupy the fragile continental shelf which is highly productive and harbors numerous living resources. Hence Environmental Management Plan (EMP) is considered as an important component in any developmental activity with sustainable management goals which are to be fulfilled within a time frame. Thus, EMP aims to suggest concrete measures that would mitigate the impacts paving way for maintaining the integrity of the project environment.

Development of ports involves effective management plan towards environmental wellbeing that guarantees both sustainable port growth and a healthy ecosystem functioning in its vicinity. There is a need for innovative solutions for port development which are in harmony with the ecosystem and which are robust or adaptable under change. The recent trends like growth of global trade, increasing vessel movements and size, modernize port facilities, driving urgent investments in ports have been found negatively impact water quality and marine flora and fauna. This simultaneously calls for sustainable and inclusive development which ensures productive nature of its marine environment.

The port authorities mandate to their activities environmentally sustainable and benign need to understand the marine ecological setting of their ports including water quality, biotic components and the factors that impact them. In spite of all the pressures, the ecosystem continues to deliver many services which are often intangible. In order to maintain these services intact, it is imperative that different biotic and abiotic components of the port environment are to be sustainably managed in the long run.

Accordingly, Deendayal Port has initiated several environmental management measures as mandated by the MoEF &CC from time to time with the purpose of maintaining and preserving its terrestrial and coastal environmental integrity.

The following measures have been taken by the port authorities:

Ongoing Environment Management Measures by DPA

A holistic and comprehensive study on the marine ecology of the port including different marine faunal and floral components and preparation of a management plan based on the results obtained has been initiated as per the specific condition No. xviii of the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016. The results of the seasonal observations on the environmental characteristics and biodiversity of the intertidal zones have been compiled along with the conservation plan recommendation for three consecutive years (2017 to 2021). Mangrove plantation has been carried out to the tune of 900 ha in Sat Saida Island, 150 ha in Nakti creek, 450 ha in Kantiyajal by Deendayal Port. The black mangrove Avicennia marina was used in these plantation activities as this species is more suitable to the existing environmental condition of this coast.

Based on the information gathered through the seasonal studies on the different biotopes and the biodiversity along with the mangrove, macrofauna, plankton density and diversity, productivity of mudflat and avifauna for the period 2018-2022 within the limits of the Deendayal port, it is evident that the impact is insignificant since management action plans are showing positive responses to a large extent in spite of the climate change induced impacts on the marine ecosystem. This project aims to draw a holistic management framework for conserving the Marine Biodiversity and Ecology of the DPA port marine environment which include many biotopes such as mangroves, intertidal and subtidal realms, mudflats and salt marshes, each serving as an abode for a variety of fauna and flora. Given the economic importance of DPA port and the increasing national and global demand for sustainability, it is planned to study the marine ecology of this port seasonally, with the long term objective of rendering the port existence and operations environmentally sustainable. The proceeding section outlines management initiatives to be undertaken by the port authorities for holistic management of marine biodiversity within the port limits envisaging several facilities will be built within port premises in the future.

Intertidal and Subtidal Biodiversity Management

The intertidal zone constitutes the coastal environment where land and sea meet, i.e., the area between extreme high-water springs (EHWSs) and extreme low water springs (ELWSs). The subtidal zone lies below the lowest water level beyond the intertidal zone. Both these zones provide habitats for various marine fauna and flora and needs to be managed effectively for the overall wellbeing of the ecosystem. In addition, intertidal zone biodiversity index did not vary very much in the recent years but the population density has not increased and remained stable. The intertidal zone may be susceptible to natural and anthropogenic pressures such as soil erosion, industrial pollution, continuous dredging and sedimentation. Hence, interventions are required to mitigate or support the natural recovery of the fauna in the bottom sediment. The sedentary benthic species produce a large number of their larva as an adaptation for their survival which get attached to the mangrove surfaces and metamorphose into adults and also serve as food for several fishes and shellfishes. Hence, soil erosion control interventions could help to improve the restoration of many benthos and plankton productivity. In the DPA vicinity, intertidal and subtidal zones are mostly dominated by clayey substratum admixed with silt and there are no rocky or sandy shores. The intertidal belts of the study area support many biological elements indicating the overall health of the ecosystem.

Mangrove Management

The mangrove cover in the vicinity of DPA is 23.967km^2 encompassing the major and minor creek systems within its limit of which the port infrastructure occupies only ~1% of the total area. Establishment of facilities is a continuous process and the expansion of infrastructure over the coming years will bring remarkable changes in the landscape and seascape in and around the port area. Mangrove environment will continue to be stable and balanced if there are no external stressors such as change in hydrology, elevation and slope, soil and water salinity and pH, soil texture and wave energy are maintained in a natural condition without wide fluctuations. In addition, human centered stress factors such as resource collection, camel grazing, tree felling and other habitat modification activities are to be minimized. Generally, micro-topography controls the distribution and well-being of mangroves, and physical processes play a dominant role in the formation and their functioning through reproduction, seed germination and establishment of young plants. The mangrove forests undergo self-repair over a period of time, provided that the normal tidal hydrology is not disrupted and the availability of water borne seeds are not blocked. Regular monitoring of mangrove hydrology through simple scientific methods will go a long way in maintaining ecosystem balance. The natural regeneration capacity of the stand is to be assessed by quantifying the degree and extent of the entrance of younger classes such as saplings into the mature tree category. The ratio between these different size classes will indicate the dynamic state of the mangrove forest. Only if the natural seedling recruitment is not occurring does the system requires an assisted recovery by plantation and physical amendments. The present study displays that natural regeneration in the studied mangrove formations is expected, as indicated by the entry of younger classes into adult categories. In addition to *A. marina,* three species namely, *Rhizophora mucronata, Ceriops tagal* and *Aegiceras corniculatum*, have been recorded sporadically within DPA limits. It is strongly recommended that in all the future plantation efforts, these additional species also could be selected at appropriate locations and tidal levels.

Conservation of Island

Islands support a rich marine fauna, flora and avifauna diversity and deserve special conservation efforts. Land cover classification of Sat Saida Island using GIS tool revealed sparse and dense mangroves, mudflats and halophytic vegetation other than mangroves are other prominent land cover categories. Though equipped with all the features to support a dense mangrove formation, the Sat Saida Island has sparse and scrubby plants confined mostly to creek banks. Different elevation features of the Island render the reduced flooding rate at the interior regions results in sparse and open mangrove formations. This Island could be an ideal site for mangrove plantations while implementing plantation activities, other mangrove restoration and rehabilitation activities with biophysical amendments such as desilting the existing the minor creeks could help to increase the mangrove cover in this Island. These physical activities in the mangrove lined minor creeks will increase tidal flooding and hydro-period and convert sparse to dense mangroves in due course of time. The Deendayal port authority has already carried out 1400 ha of mangrove plantation since 2006 with good success rate in various locations and additional 100 ha is in progress.

Management plan to improve the water quality in the port area

- The drains and outfall should be cleaned regularly to avoid anaerobic decomposition and also for proper flow of water/wastewater. This will also enable the characterization of wastewater and calculation of waste load.
- Domestic and canteen wastewater should be discharged only after proper treatment.
- The solid waste generated from the canteen and other diffused sources should be collected and disposed properly for which modern purification system should be established.
- The discharge of oil waste into the sea from the following main sources should be controlled
    1. Discharge of oil waste from liquid chemical corridor area. This liquid waste is generated during tanker cleaning, and oil spills during filling operations,
    2. Oil spills at berth during unloading operations.
    3. Tanker ballast discharge from ships.
- Bulk material should not be disposed into the sea. All drains and roads should be cleaned before the rainy season to avoid runoff from land to sea carrying a myriad

of pollutants, including chemicals that may be impose oily discharges in and around the port.

Management plan for marine fisheries

Regular dredging activities in the Port area can impact marine fauna and the flora particularly the phytoplankton and seaweeds. The fishes and other fishery resources such as shrimps and crabs are distracted through noise and vibration levels, water quality and habitat loss along with food sources. Generally, fishes in the water column are free swimming in nature, they tend to avoid the turbid areas and move to safer zones. Once the turbidity increase becomes reversed due to sedimentation and dispersion by current and wave influences, the fishes are expected to occupy the area. Hence, there will be virtually no impact on fish due to dredging in the long term. The dredging is usually carried out on the main channel of the creeks, the impact on the fishes are minimum during the dredging phase. The most important potential impact would be the rise in suspended solid load, which hinders the photosynthesis of the producer communities, especially the phytoplankton and affects the pelagic food chain. The high turbidity due to heavy suspended solids load during dredging and reclamation can result in the clogging of the gills of the filter feeding organisms, thereby causing asphyxiation.

Co-Management with the Community

Management program for mangroves is feasible in the case of Deendayal Port Authority since all the mangrove formations are under its legal control and hence any management program could be implemented without any sectoral conflicts with forest or any other government departments. It was proven in many instances that involving the stakeholder communities in the surrounding villages will yield better results in mangrove management. Though the population in the port surroundings has different livelihood activities, fishermen community could be targeted to involve in community-based mangrove management.

The fishermen in the villages such as Vera, Khari Rohar, and Tuna close to the port could be involved by forming “Samithies” for the conservation of mangroves with possible funding resources. The communities are expected to involve in the plantation and management activities for which awareness campaign and interactive sessions are to be conducted time to time and the feedback and experiences are to be recorded and duly acknowledged. The community’s resource dependency, perception about the conservation of mangroves and associated flora and fauna and their level of involvement in such resource management activities are to be assessed before forming such a community-based organization. They could be assigned the specific task of conserving the mangroves by involving them in plantation/restoration activities, physical protection and other conservation measures. This could be taken up as part of the port's CSR activity.

Mannagement plan for Avifauna

1. Direct and indirect impact on ecologically sensitive ecosystems

The Deendayal SEZ project site is located in the mid of the Deendayal Port area surrounded by port associated industrial sectors and salt industries. Since there are no Protected Areas located within 10 km radius of the SEZ site, impacts on sensitive ecosystem was not visualized.

2. Loss of Inter-tidal habitats - Coastal

- The project proponent (Deendayal Port Authority) should take up compensatory mangrove plantation in and around the project area
- The plantation needs to be carried out with fourfold density of seedlings compared to the natural mangrove density of the Kandla creek area and to maintain the density at the required level
- This mangrove plantation expected to support mangrove associated bird species and thereby enhance the avifauna diversity of the local environment
- Since the intertidal (mangrove and creeks) and salt pan habitats supports few thousands of aquatic and migratory species, the project proponent should plan the establishment /construction activities (if any) should be planned non migratory season (November – February) to avoid the disturbance to the migratory species.
- The above suggested mangrove plantation needs to be monitored at least for the next five years till it attains maturity with the expert team to understand the growth rate and enhancement and assemblage of associated faunal species.
- Since the area located in the Intertidal habitat and adjacent areas supports thousands of aquatic avifauna, the project proponent (Deendayal Port authority) should take up long-term (five years) Ecological Monitoring Program of the creek, mangrove and salt pan habitats to assess the change in avifaunal diversity due the any developmental activities take place in the future project.

Phosphorus management

Anthropogenic inputs of nitrogen (N) and phosphorus (P) from agriculture, aquaculture, wastewater treatment, urban runoff, and burning of fossil fuels, are now reported to exceed the natural inputs worldwide (CENR, 2000, NRC, 2000). The nutrient enrichment has led to deadly blooms of phytoplankton and seaweeds, coral reef deterioration and altered ecosystem functioning. As marine ecosystems continue to experience land use change, rising sea levels, altered weather patterns, and global warming, the threat of nutrient enrichment is predicted to intensify.

It is understood that mangrove wetlands can alleviate nutrient pollution through rapid nutrient uptake, long-term burial, or denitrification, thus protecting surrounding marine waters and organisms (Valiela and Cole, 2002). However, coastal wetlands themselves are still vulnerable to the impacts of nutrient enrichment. In this circumstance studies have reported that due to high rates of nutrient uptake and denitrification, nutrient enrichment can have direct and indirect impacts on mangrove trees (Kaplan et al., 1979; Seitzinger, 1988).

The blue-green algae (Cyanobacteria) blooms are predominantly), tend to grow in high density under situations of low ratios of nitrogen to phosphorus. numerous long-term studies have pointed out that reducing inputs of a single nutrient: phosphorus could control the incidence of algal bloom and also by introduction of iron, alum, or other compounds to sequester phosphorus in sediments. This management is possible in inland water bodies.

In creeks and coastal environments, the water is dynamic in nature mitigation measures are in general impractical. It is recommended that it is necessary to identify the possible primary sources of input and to control awarenessdrive are to be implemented to the concerned community, industries and the government bodies.The influx of sewage ,land run off from the cropland and the industries are major sources of phosphorus/phophates into aquatic systems. Traditional wastewater treatment methods do not fully remove phosphates, leading to their accumulation even though modern filtration technologies can effectively eliminate phosphates which are expensive. Many countries have imposed strict regulations on the use of phosphate-containing detergents and implemented laws to reduce phosphate pollution.

Phosphates are salts of phosphoric acid formed with the reactions of metals and there is dihydrogen phosphate that dissolves in water while the hydrogen phosphate is less dissolution in water. In water, phosphorus exists in the form of inorganic, organic, and organo-mineral compounds and is also part of the cells of aquatic organisms. Notably, inorganic compounds have the highest bioavailability. Today, phosphates in marine and freshwater systems present a significant environmental challenge. Human waste is a natural source of phosphorus. In this context it is understood that improper sewage treatment could lead to higher level of phosphate-phosphorus in the coastal water bodies. These effluents contain biological phosphorus as well as phosphate components from detergents, food products, etc. When phosphorus and nitrogen levels in water become excessive, microorganisms receive more nutrients, leading to rapid reproduction. This process, known as eutrophication, reduces oxygen levels, kills fish, and makes water treatment more complex due to the increased biomass.

Petroleum hydrocarbon Management

Increasing petroleum consumption and a rise in incidental oil spillages have become global concerns due to their persistent nature and toxicity to aquatic and terrestrial living organisms. Various physicochemical and biological treatment strategies have been studied to tackle them and their impact on environment. Combinations of biological, chemical, and eco-toxicological techniques are used for this process while monitoring the efficacy of bacterial products and nutrient amendments to stimulate the biotransformation of contaminated soil. One of such approaches in this regard in the marine environment is the use of microbial processes due to their being "green" and also apparent low cost and high effectiveness. Different hydrocarbon removal levels were observed with bacterial augmentation (*Beta proteobacterium* and *Rhodococcus ruber*), exhibiting a total petroleum hydrocarbon (TPH) reduction of 61%, which was further improved to a 73% reduction using bacterial augmentation combined with nutrient amendment (nitrogen, potassium, and phosphorus). Mixed bacterial consortia isolated from the hydrocarbon-contaminated soil samples were used

Chemical treatments suggest agents like dispersants, solidifiers, and chemical oxidants are the remediations are grouped. The surfactants present in dispersants help to break down oil slicks into smaller droplets,then undergo rapid dilution by transferring it into the water and are degradable. This method makes oil spills less harmful for living organisms and the marine life. Nokomis 3-F4, Slickgone NS,Finasol OSR 52, SPC 1000™, Neon AB3000, ZI-400, Corexit 9500, Corexit 8667, and Saf-Ron Gold are some of the examples of chemical dispersants.

Bioremediation is a cost-efficient method used for the treatment of petroleum consisting of biodegradable hydrocarbons and indigenous microbes. Biological techniques are more economical and proficient than physicochemical techniques.. Three distinctive approaches are adopted in the context of bioremediation, namely, bioaugmentation, biostimulation and bioventilation. Bioaugmentation is used to enhance the performance of the microbial population through the addition of bacterial with specific catabolic activities, strains or enrichment consortia to increase the rate of contaminant degradation.Many microorganisms are responsible for increasing the surface area of the substrate by excreting emulsifiers including *Bacillus licheniformis, Pseudomonas putida, Bacillus cereus, Pseudomonas aeruginosa, Bacillus subtilis,* and *Bacillus laterosporus* are well known for degradation of oil pollutants. The water should maintained be suitable for the normal growth of the oil degrading microbes so that by natural processes by itself the PHCs will be degraded under with time.The biodegradation rates are improved by the biosurfactant's addition which increases the elimination and solubility of these pollutants.

It is recommended that proper measures should be taken to avoid the introduction of petroleum related products from the ports, during the loading and unloading of consignments , navigation channel maintenance and such activities.

9. Summary and Conclusion

The physico-chemical characteristics during the entire year was dynamic with respect to sptio-temporal situation in the gulf environment. The phytoplankton genera for the period May 2024 to May 2025 varied from 8 to 29 number with an average of 16-23. The highest number of genera was reported during post-monsoon which is followed by monsoon and pre monsoon. The Zooplankton for the period 2024 to 2025 showed high number of representatives of phylum and group during post-monsoon followed by pre-monsoon than the monsoon period.

It is imperative to create strong baseline data on the marine environment in the port vicinity in tune with the spatial extent of developmental activities. Continuous marine ecological monitoring study since May 2017 focused on the biological diversity and productivity of the mudflats. Based on the detailed investigations of marine ecological components and the possible impacts of the DPA port environment, it could be concluded that the effects on the various biotic components are minimal and confined to high activity areas only with limited impacts on the surroundings. From the results of the studies conducted by GUIDE, 2017 to 2024, it was inferred that there was no significant variation with respect 2024 to 2025 on the taxa/genera/species composition as well as fauna and plankton community, eventhough the values of and in term of phosphate and petroleum hydrocarbon compounds were slightly increased. The mangrove tree category density has shown higher values in all the sampling locations in the Deendayal port Authority and its creek environments.

In this respect it is recommended that In addition to the monitoring of the biological parameters, of the water and sediment in the creeks, petroleum hydrocarbons and phosphate level in the port environment to be assessed intensively in future in order to sort out the more effective management plans in the mangroves and the encompassing creek environment nearer to the Deendayal Port Authority .

Knowledge of marine species diversity is incomplete, however, studies have highlighted an increase in the rate of decline in the population density of many vulnerable species with space and time due to several reasons including habitat destruction and alterations and the related stresses. The biodiversity of the coastal zone has been explored more extensively than the deep offshore areas due to the accessibility for sampling. These areas are considered to be highly productive due their shallow and dynamic nature suitable for the growth of the flora , phytoplankton, seaweeds and sea grasses. The, bio-geochemically more active zone provides all the major,minor and trace elements for the floating micro flora as well as the macroscopic algae and sea grasses that flourishes in the nearshore environments. The abiotic physical and chemical parameters of the water in all the study sites are found to be within the optimum level during the seasonal assessment. The prevailing higher turbidity of the water due to the high tidal currents inhibits the primary productivity of the phytoplankton and the benthic algae and seagrass. However, there exists several diatoms which have higher adaptive features to survive under such circumstances as evidenced from the present study. There are indicator species to assess the biodiversity status of ecosystems, the keystone species, such as the coral reefs, sea grasses and macro algae which are specific for the benthic habitat. These groups of plants and the fauna require clear water, optimum temperature aided through the high rate of light penetration through the water column. The absence of the seaweeds and seagrass beds could be well correlated with the relatively high level of suspended particles in the water in the selected study sites. The sediment entire creek environment bottom substratum is dominated by fine clay which holds organic and inorganic elements and acts as a sink for essential nutrient elements for the multitude of micro algae which are the primary source for the pelagic and benthic food chain, including the fin fishes and shell fishes in the creek as well as the nearby oceanic zone. The concentration of petroleum hydrocarbon at some locations is higher than the admissible level in the coastal waters. This chemical compound is highly hydrophobic in nature and tends to attach to the surface film of the water. Though the degradation is a slow process it has been distributed to longer distances and tends to settle down as tarballs. Also, the residues if such particles persist for longer duration, affects the pelagic communities and ultimately the fishes and higher vertebrates. In the Kandla adjacent creek complex such incidents have not been reported and fishing is a regular activity in the mangrove environment by the fishermen who have a valid registration from the port Authority.

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

Sl. No.	Order, Family, Common & Scientific Name	MS	FS	IUCN 2024	WPA, 1972	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
10	Black-headed Gull *Chroicocephalus ridibundus* (Linnaeus, 1766)	M	O	LC	Schedule II	A
11	Brown-headed Gull *Chroicocephalus brunnicephalus* (Jerdon, 1840)	M	P	LC	Schedule II	A
12	Gull-billed Tern *Gelochelidon nilotica* (Gmelin, JF, 1789)	M	P	LC	Schedule I	A
4	**Recurvirostridae**					
13	Black Winged Stilt *Himantopus himantopus* (Linnaeus, 1758)	R	C	LC	Schedule II	A
5	**Scolopacidae**					
14	Black-tailed Godwit *Limosa limosa* (Linnaeus, 1758)	M	O	NT	Schedule II	T
15	Common Greenshank *Tringa nebularia* (Gunnerus, 1767)	M	I	LC	Schedule I	T
16	Common Redshank *Tringa tetanus* (Linnaeus, 1758)	M	I	LC	Schedule II	A
17	Common Sandpiper *Actitis hypoleucos* (Linnaeus, 1758)	M	I	LC	Schedule II	A
18	Eurasian curlew *Numenius arquata* (Linnaeus, 1758)	M	C	NT	Schedule II	A

19	Green Sandpiper *Tringa ochropus* Linnaeus, 1758	M	I	LC	Schedule II	T
20	Marsh Sandpiper *Tringa stagnatilis* (Bechstein, 1803)	M	C	LC	Schedule II	T
21	Temminck's stint *Calidris temminckii* (Leisler, 1812)	M	C	LC	Schedule II	T
22	Whimbrel *Numenius phaeopus* (Linnaeus, 1758)	M	P	LC	Schedule II	A
B	**COLUMBIFORMES**					
6	**Columbidae**					
23	Blue Rock Pigeon *Columba livia* (Gmelin, JF, 1789)	R	G	LC	NA	T
24	Spotted Dove *Spilopelia chinensis* (Scopoli, 1786)	R	G	LC	Schedule II	T
25	Eurasian Collared Dove *Streptopelia decaocto* (Frivaldszky, 1838)	R	G	LC	Schedule II	T
26	Laughing Dove *Spilopelia senegalensis* (Linnaeus, 1766)	R	G	LC	Schedule II	T
27	Red Collared Dove *Streptopelia tranquebarica* (Hermann, 1804)	R	G	LC	Schedule II	T
C	**CORACIIFORMES**					
7	**Alcedinidae**					
28	Common Kingfisher *Alcedo atthis* (Linnaeus, 1758)	R	P	LC	Schedule II	A
29	White-throated Kingfisher *Halcyon smyrnensis* (Linnaeus, 1758)	R	C	LC	Schedule II	T
8	**Meropidae**					
30	Green Bee-eater *Merops orientalis* Latham, 1801	R	I	LC	Schedule II	T
D	**PELECANIFORMES**					
9	**Pelecanidae**					
31	Great White Pelican *Pelecanus onocrotalus* Linnaeus, 1758	M	P	LC	Schedule II	A
10	**Ardeidae**					
32	Cattle Egret *Bubulcus ibis* (Linnaeus, 1758)	R	C	LC	Schedule II	T
33	Great Egret *Ardea alba* (Linnaeus, 1758)	R	P	LC	Schedule II	A
34	Indian Pond Heron *Ardeola grayii* (Sykes, 1832)	R	C	LC	Schedule II	A
35	Intermediate Egret *Ardea intermedia* (Wagler, 1829)	R	P	LC	Schedule II	A
36	Little Egret *Egretta garzetta* (Linnaeus, 1766)	R	C	LC	Schedule II	A
37	Grey Heron *Ardea cinerea* Linnaeus, 1758	R	P	LC	Schedule II	T
38	Western Reef Heron *Egretta gularis* (Bosc, 1792)	RM	P	LC	Schedule II	A

39	Purple Heron *Ardea purpurea* Linnaeus, 1766	R	C	LC	Schedule II	A
11	**Threskiornithidae**					
40	Black Headed Ibis *Threskiornis melanocephalus* (Latham, 1790)	R	C	NT	Schedule II	A
41	Glossy Ibis *Plegadis falcinellus* (Linnaeus, 1766)	R	C	NT	Schedule II	T
E	**CICONIIFORMES**					
12	**Ciconiidae**					
42	Painted Stork *Mycteria leucocephala* (Pennant, 1769)	R	C	NT	Schedule II	A
F	**PHOENICOPTERIFORMES**					
13	**Phoenicopteridae**					
43	Greater Flamingo *Phoenicopterus roseus* Pallas, 1811	RM	C	LC	Schedule II	A
G	**PASSERIFORMES**					
14	**Corvidae**					
44	House Crow *Corvus splendens* (Vieillot, 1817)	R	O	LC	NA	T
15	**Dicruridae**					
45	Black Drongo *Dicrurus macrocercus* Vieillot, 1817	R	I	LC	Schedule II	T
16	**Hirundinidae**					
46	Barn Swallow *Hirundo rustica* (Linnaeus, 1758)	RM	I	LC	Schedule II	T
47	Wire-tailed Swallow *Hirundo smithii* Leach, 1818	R	I	LC	Schedule II	T
17	**Laniidae**					
48	Bay-backed Shrike *Lanius vittatus* Valenciennes, 1826	R	I	LC	Schedule II	T
49	Brown shrike *Lanius cristatus* Linnaeus, 1758	R	I	LC	Schedule II	T
18	**Motacillidae**					
50	White Wagtail *Motacilla alba* Linnaeus, 1758	M	I	LC	Schedule II	T
51	Yellow Wagtail *Motacilla flava* Linnaeus, 1758	M	I	LC	Schedule II	T
19	**Muscicapidae**					
52	Oriental Magpie Robin *Copsychus saularis* (Linnaeus, 1758)	R	I	LC	Schedule II	T
20	**Nectariniidae**					

53	Purple Sunbird *Cinnyris asiaticus* (Latham, 1790)	R	N	LC	Schedule II	T
21	**Pycnonotidae**					
54	White Eared Bulbul *Pycnonotus leucotis* (Gould, 1836)	R	O	LC	Schedule II	T
55	Red-vented Bulbul *Pycnonotus cafer* (Linnaeus, 1766)	R	O	LC	Schedule II	T
22	**Sturnidae**					
56	Common Myna *Acridotheres tristis* (Linnaeus, 1766)	R	O	LC	Schedule II	T
57	Brahminy Starling *Sturnia pagodarum* (Gmelin, JF, 1789)	R	I	LC	Schedule II	T
H	**SULIFORMES**					
23	**Phalacrocoracidae**					
58	Little Cormorant *Microcarbo niger* (Vieillot, 1817)	R	P	LC	Schedule II	A
I	**Apodiformes**					
24	**Apodidae**					
59	House Swift *Apus nipalensis* (Hodgson, 1837)	R	I	LC	Schedule II	
J	**ACCIPITRIFORMES**					
25	**Accipitridae**					
60	Black-winged Kite *Elanus caeruleus* (Desfontaines, 1789)	R	C	LC	Schedule I	T
61	Black Kite *Milvus migrans* (Boddaert, 1783)	R	C	LC	Schedule II	T
62	Oriental Honey Buzzard *Pernis ptilorhynchus* (Temminck, 1821)	R	C	LC	Schedule II	T
63	Shikra *Tachyspiza badia* (Gmelin, JF, 1788)	R	C	LC	Schedule I	T
K	**CUCULIFORMES**					
26	**Cuculidae**					
64	Asian Koel *Eudynamys scolopaceus* (Linnaeus, 1758)	R	F	LC	Schedule II	T

Note: FG- Feeding Guild, C- Carnivore, F- Frugivore, G- Granivore, I- Insectivore, N- Nectarivore, O- Omnivore, P- Piscivore; MS-Migratory Status, R- Resident, M- Migratory, RM- Resident Migrant; IUCN- International Union for Conservation of Nature, LC- Least Concern, NT- Near Threatened, VU- Vulnerable


Annexure–E

DEENDAYAL PORT AUTHORITY

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

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

www.deendayalport.gov.in

CivilEng./Pipeline/4811/Aug.ofLiquidCargoHand.Cap.EnvCRZCle./28 Dated24/06/2025

To,
Mecon Limited
(A Govt, of India Enterprise)
Doranda Main Road,
Vivekanand Chowk, Shayamli Colony,
Doranda, Ranchi Jharkhand 834002
E-mail: suvamoyadak@gmail.com

Sub: **Preparation of Site Specific Conservation Plan & wildlife management plan for implementation of stipulated condition of Environment & CRZ clearance for DPAs three project**

Ref.:
1. Your offer vide letter no. 24-25/1020/C/TC/000213 dated 13/03/2025
2. Yours Revised offer letter submitted by Mecon vide letter 24-25/1020/C/TC/000213/R dated 20/03/2025.
3. Your Email dated 23/04/2025.

Sir,

The proposal submitted by MECON Limited ,Ranchi for the subject work vide above referred letters/Emails (**copy Attached-Annexure A**) for the work "**Preparation of Site Specific Conservation Plan & wildlife management plan for implementation of stipulated condition of Environment & CRZ clearance for DPAs three project**" amounting to **Rs. 1,48,18,000.00/- plus applicable GST (Rs One crore forty-eight lakhs and eighteen thousand + GST Only**) for the scope of work, time period, including all terms & conditions mentioned in the proposal, has been accepted by the Competent Authority of DPA.

1. **Brief Scope of Work**

   Preparation of site specific conservation plan & wildlife management plan for implementation of the stipulated conditions of EC&CRZ Clearance for DPAs below mentioned three projects :

   1. Augmentation of liquid cargo handling capacity from 8 MMTPA to 23.8 MMTPA through modernization of existing pipeline network at oil jetty area DPA
   2. Setting up of RoRo/Ropax facilities at Muldwarka Port
   3. Setting up of RoRo/Ropax facilities at Pipavav

The brief scope of service of for preparation of wildlife conservation plan for each of the three projects shall be as mentioned below

A. Carry out a rapid reconnaissance survey of the "Study Area" which shall comprise of the actual "Project Area" and the "Buffer Zone" (10 km radius area around the Project Area) of a single season to augment / validate the information available in the EIA/EMP Reports on whose basis the three projects have been granted Environmental Clearance

B. Carry out inventorization of flora & fauna including Rare, Endangered and Threatened (RET) species duly authenticated by the Chief Wildlife Warden, Gujarat clearly indicating the Schedule of the Wildlife (Protection) Amendment Act, 2022 in which each animal is listed. Separate lists shall be prepared for the Project Area and the Buffer Zone

C. Collection of information on man-animal conflict and damage to crops and / or livestock caused by wild animals in the study area through focussed group discussions with the relevant stakeholders such as Forest Department officials and/or frontline staffs, villages, different officials to review man-animal conflict and depredation caused by wild animals in study area

D. Review and analyse data if any available with the forest department on fatal & non-fatal attacks on human beings and livestock & crop damage, animal kills. due to various reasons in consultation with local forest department

E. To review the extent of biotic pressure by villages in study area on forest growth. This shall cover livestock population in the study area, villages, dependency on forest for grazing, study of no. of families dependent on Non-Timber Forest Produce (NTFP) collection and its impact on wildlife

F. Preparation of Site-Specific Wildlife Conservation Plan for Schedule-I Fauna as per The Wildlife (Protection) Amendment Act, 2022 as advised by Gujarat State Forest Department. The same shall cover management measures to be implemented in the Project Area (if possible) and in the Buffer Zone. Implementation Responsibility (DPA or Gujarat State Forest Department), Implementation Physical and Financial Progress Schedule, Budget Allocation. and protocol

G. To submit the prepared Site-Specific Wildlife Conservation Plan and Management Plan to DPA for soliciting comments/suggestions and approval on the same.

H. Preparation of map showing location of National Parks, Sanctuaries, Biosphere Reserves, Ramsar Sites & their Eco Sensitive Zones (ESZs), Habitat for Schedule I Fauna, Habitat for Migratory Birds, Wildlife Corridors, if any, within 10 km from the project boundary.

I. Approval of the Site Specific Wildlife Conservation Plan by the Chief Wildlife Warden, Gujarat shall be obtained by
   a. Follow up with concerned Deputy Conservator of Forests (DCF) for early recommendation of the plan and onward moment to the Conservator of Forests (CF)
   b. Follow up with concerned o/o Conservator of Forests to for early. Recommendation the proposal and forwarding the same to the concerned APCCF/RCCF
   c. Follow up with Regional Conservator of Forests to recommend the proposal and forwarding the same to the PCCF (Wildlife)/Chief Wildlife Warden (CWLW)
   d. Assist DPA in presentation (if any required) before the PCCF (Wildlife)/Chief Wildlife Warden (CWLW), Gujarat Forest Department
   e. Assist DPA in incorporating comments/ suggestions of the PCCF (Wildlife)/Chief Wildlife Warden (CWLW), Gujarat Forest Department and obtaining early approval on the same.

2. <u>Obligation of DPA</u>

1. Assistance regarding the statutory clearances from authorities concerned to be rendered by DPA for field visits/plantation activities
2. Payment of all statutory fees

3. Time Schedule

1. Zero date shall be considered as the date of receipt of order/LOI and acceptance of same by MECON

2. MECON shall depute concerned personnel to the site(s) within three weeks of receipt of Work Order for collection of basic data / information and holding Kick-off meeting with DPA Officials

3. Initial Draft Site Specific Wildlife Conservation Plan for any of the three projects shall be submitted to DPA for their Comments / Observations within 3 months of receipt of work order

4. Initial Draft Site Specific Wildlife Conservation Plan for any of the 2nd project shall be submitted to DPA for their Comments / Observations 10 days after submission of the Initial Draft Site Specific Wildlife Conservation Plan for the 1st project

5. Initial Draft Site Specific Wildlife Conservation Plan for the 3rd project shall be submitted to DPA for their Comments / Observations 10 days after submission of the Initial Draft Site Specific Wildlife Conservation Plan for the 2nd project

6. Final Site-Specific Wildlife Conservation Plan and Management Plan shall be submitted to the concerned Dy. Conservator of Forests (DCF) within one week of receipt of DPA's comment/ observations on the draft site-specific wildlife conservation plans

7. Approval of the Site-Specific Wildlife Conservation Plan and Management Plan from the concerned DCFs after incorporation of recommendation is expected to be obtained within One Month after Submission of the Final Site-Specific Wildlife Conservation Plan and Management Plan

8. The Revised Site-Specific Wildlife Conservation Plan and Management Plan incorporating the concerned DCF's comments shall be submitted to the Principal Chief Conservator of Forests (Wildlife) / Chief Wildlife Warden, Gujarat within one (1) week of receipt of the concerned DCF's Approval of the Site-Specific Wildlife Conservation Plan and Management Plan

9. It is expected that the entire work of obtaining Approvals of the Principal Chief Conservator of Forests (Wildlife) / Chief Wildlife Warden, Gujarat shall be completed within 6 (six) months of receipt of the Work Order

4. Terms and Mode of Payment:

(The amount is to be paid against cost of the each individual project mentioned in the proposal)

1. 20% of fee Shall be paid upon deputation of MECON personal to the site for the first initial visit

2. 15% of fee on Submission of Initial Draft Site Specific Wildlife Conservation Plan to DPA for their Comments/Observations

3. 25% of fee on submission of Final Site-Specific Wildlife Conservation Plan and Management Plan to the concerned Dy. Conservator of Forests (DCF)

4. 25% of fee on Approval of Site-Specific Wildlife Conservation Plan and Management Plan by the concerned Dy. Conservator of Forests (DCF)

5. 10% of the fee on submission of the Revised Site-Specific Wildlife Conservation Plan and Management Plan incorporating the concerned DCF's comments to the Principal Chief Conservator of Forests (Wildlife) /Chief Wildlife Warden, Gujarat

6. 5% of fee after Approval of the Site-Specific Wildlife Conservation Plan and Management Plan by the Principal Chief Conservator of Forests (Wildlife)/Chief Wildlife Warden, Gujarat

5. Kindly sent the acceptance of this work order & start the work w.e.f 01/07/2025.

Thanking you

Yours faithfully,

24/6/25

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

Annexure–F

Inception Report

On

Greenbelt Development in Deendayal Port Authority (DPA) and its surrounding areas (Phase-III) along with two years maintenance

Submitted to

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

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

Prepared by

Gujarat Institute of Desert Ecology
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E-mail: desert_ecology@yahoo.com
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Inception Report

on

Greenbelt Development in Deendayal Port Authority (DPA) and its surrounding areas (Phase-III) along with two years maintenance

Co-ordinator
Dr. V. Vijay Kumar, *Director*

Principal Investigator
Dr. Jayesh B. Bhatt, *Scientist*

Co-Principal Investigator
Mr. Bhagirath Paradva, *Project Fellow*
Mr. Rakesh Popatani, *Project Fellow*

Team Member
Mr. Vivek Chauhan, *Junior Research Fellow*

Submitted by

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Content

Introduction

A greenbelt is a designated area of undeveloped, wild, or agricultural land surrounding urban areas, intended to limit urban sprawl, protect natural environments, improve air quality, and promote biodiversity. Greenbelt development involves creating and maintaining these areas, often through strategic planting of trees, shrubs, or other vegetation to form natural barriers between urban and rural landscapes.

Thus, greenbelt offers a number of benefits for population. Vegetation absorbs various pollutants from the environment and thus help in effective pollution control. However, economic development like industrialization, mining, infrastructural development, etc. have exerted pressure and led to reduction and fragmentation of natural vegetation cover day-by day across the globe. Industrial and infra-structural developmental activities are likely to pollute the environment with varying magnitudes. Nevertheless, the pre-eminence of resistance of each of the organisms helps themselves to overcome the hazards caused by such pollutants.

Therefore, the general concept of greenbelt has evolved to develop vegetation or green spaces alongside of industries, mines, thermal power stations, roadsides, and other developmental unit is an effective measure to rejuvenate the environment through vital vegetation cover that safeguard the health of human and other living organisms. Greenbelts in and around urban and industrial areas are important to the ecological health of any given region.

Rationale

GUIDE team visited the proposed Greenbelt development site at Kandla port with the officials from Kandla Port as part of site selection. Based on the field observation and its landscape, environment and ecology of the area, suitable plant species were identified to improve the local environment and for the Greenbelt development at the port area.

Project Site

Based on observation made by the GUIDE team and officials from Deendayal Port Authority, a site at Road Over Bridge (RoB) to oil jetty road and Gopalpuri The area proposed for green development of Deendayal Port is barren land without any vegetation. The soil of the area is black muddy and is high saline soil with saline ground water. The area is very dry and hot during the summer.

Scope of Work

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

1. Inventories the suitable sites for greenbelt development in and around the Deendayal Port at Kandla.
2. Carryout Soil and Moisture Conservation (SMC) and management of the plantation sites.
3. Identify suitable plant species as per site scenario for the greenbelt plantation and plantation of plant saplings (5000 plants-suitable to the area & 200 plants at Gopalpuri-fruit bearing/medicinal/air purifying) including maintenance of the same for 1st year, along with maintenance, management and monitoring of plantation including drip/tanker water supply for a further period of 2 years.
4. Adopting plantation technique and soil/manure amendments.
5. Regular monitoring (survival and growth) of the plantation.

Approach and Methodology for Greenbelt Development

Following steps have been adopted for greenbelt development:

1. **Planning Phase**:

- Involves site selection, environmental assessments, and choosing appropriate plant species based on local ecosystems.
- DPA officials and environmental experts collaborate to design sustainable spaces that support biodiversity and recreation.
- Selecting native trees/suitable to the condition and local environment to ensure ecological compatibility and resilience.

2. **Implementation Phase**:

- Includes land preparation (clearing and levelling), planting trees and shrubs, and constructing pathways or recreational facilities.
- Sustainable practices are prioritized to minimize environmental disruption.

3. Maintenance Phase:

- Focuses on long-term care such as watering, pruning, pest control, and replanting.
- Regular monitoring ensures the health of vegetation and ecosystems.
- Community involvement and education are key to sustaining the greenbelt

Plantation techniques:

- Site development for a plantation includes clearance for weeds and it involves, bush cutting, soil and moisture conservation works and marking of pits for planting of saplings, etc.
- After clearing the land sites for pits, plantation have been marked on ground using a measuring tape to ensure the desired spacing.
- Pits of the size 45 cm x 45 cm and 45 cm depth have been dug for tree plantation. Pits have been deep enough to ensure that the roots of the plants do not curl up once the planting material is placed in it.
- Since the soil is highly saline, a fertile soil around 06 dumpers have been added for better survival.
- Charcoal have been added for better moisture conservation and survival.
- The pit has been filled a little above the ground level so that after the earth settles the upper surface of the pit is at same level as that of ground thus avoiding any water logging.
- The plantation has been carried out in two phases (1st in Gopalpuri-200 plants & 2nd Road Over Bridge (RoB)-Oil jetty road side-5000 plants)

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

Management and Monitoring of Greenbelt: The plantation within the identified site will be managed and monitored for a minimum period of two years after the plantation. The management of plantation includes watering at regular intervals, during summer and winter periods and if required even during monsoon with dry spells.

Fig. Map of Plantation Area at Gopalpuri

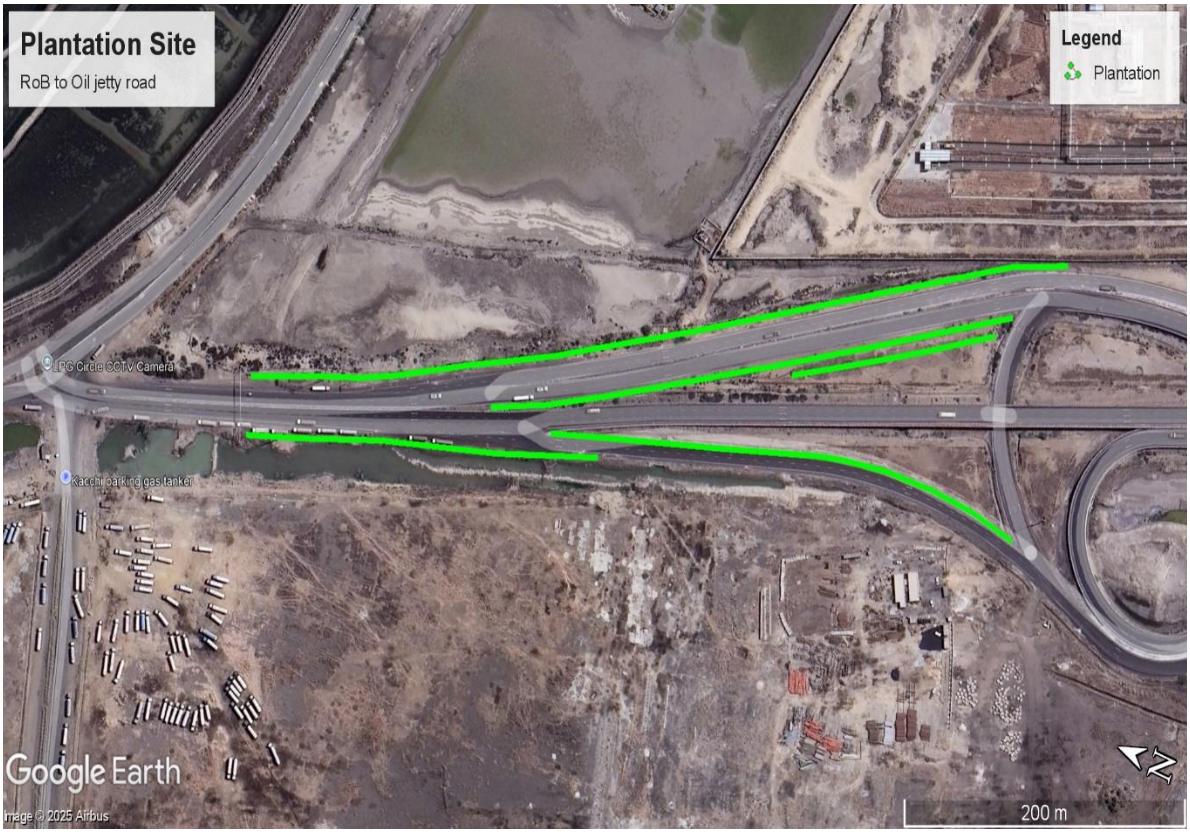

Fig. Map of Plantation Area RoB to Oil Jetty Road

Fig. Digging Out Trench for Plantation

Fig. Transportation of Plants to Site

Fig. Fertile Soil for Better Survival of Plants

Fig. Fertile Soil Filling to the pits

Fig. Addition of Charcoal for moisture conservation

Fig. Regular Watering of the Plants by Tanker

Annexure I

List of Plants for Plantation at site for Greenbelt Development
Site: Gopalpuri

Sr. No	Scientific name	Local name	No. of plants
Fruit Plants			
1	*Achras sapotta*	Chiku	3
2	*Citrus limonum*	Limbu	3
3	*Citrus medica*	Bijora	3
4	*Cocos nucifera*	Nariyel	3
5	*Eugenia jambolana*	Jambu	3
6	*Ficus carica*	Anjir	3
7	*Morus indica*	Shetur	5
8	*Phyllanthus emblica*	Amla	3
9	*Psidium guajava*	Jamfal	3
10	*Punica granatum*	Dadam	3
11	*Terminalia catappa*	Badam	5
12	*Pithecellobium dulce*	Gorsamli	3
13	*Tamarindus indica*	Khatiamli	5
14	*Carissa carandas*	Karmda	5
15	*Moringa oleifera*	Mitho sargavo	5
16	*Limonia acidissima*	Kothi	3
Medicinal Plant			
17	*Murraya koenigii*	Mitho limdo	5
18	*Plumbago zeylanica*	Chitrak	5
19	*Vitex negundo*	Nagod	8
20	*Nyctanthes arbor-tristis*	Parijat	8
21	*Justicia adhatoda*	Ardusi	5
22	*Butea monosperma*	Khakharo	5
23	*Hibiscus rosa-sinensis*	Jasud	5
24	*Bauhinia variegata*	Kanchnar	5
25	*Terminalia arjuna*	Arjun	5
26	*Azadirachta indica*	Limdo	5
27	*Ficus racemosa*	Umaro	5
28	*Aegle marmelos*	Bili	5
Air purifying plant			
29	*Cestrum diurnum*	Divsno raja	5
30	*Nerium odorum*	Karen	8
31	*Plumeria rubra*	Khadchampo	8
32	*Thespesia lampas*	Parspipalo	8
33	*Alstonia scholaris*	Saptaparni	8
34	*Plumeria rubra*	Kadam	5

Sr. No	Scientific name	Local name	No. of plants
35	*Ficus elastica*	Rabarplant	3
36	*Livistona chinensis*	Fenpalm	3
37	*Polyalthia longifolia*	Asopalav	8
38	*Roystonea regia*	Roayalpalm	2
39	*Pongamia glabra*	Karanj	8
40	*Delonix regia*	Gulmhor	5
41	*Ficus benjamina*	Ficus	5

Site: RoB to Oil Jetty Road

Sr. No.	Scientific Name	Local Name	No. of plants
1	*Conocarpus lancifolius*	*Conocarpus*	1700
2	*Peltophorum pterocarpum*	Peltophorum	660
3	*Millettia pinnata*	Karanj	660
4	*Delonix regia*	Gulmahor	660
5	*Tabubia rosea*	Tabubia	660
6	*Senna siamea*	*Kasid*	660

Annexure–G

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

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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
Post Box No. 50, Gandhidham-Kachchh
Email: seplkpt@gmail.com,
www.deendayalport.gov.in

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No: EG/WK/4783/VII/ **Date: 4 /~~09~~ 10/2024**

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.

04/10/24

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

Annexure–H

CE

May posted in Civil Engineering Deptt/ Chairman's office, after observance & due formalities there.

25/8/2025

Date: 25th August

To,

The Secretary,
Deendayal Port Authority,
Gandhidham, Kutch

Subject: Duty Report for the post of Chief-Manager (Environment & Safety) on contractual basis at DPA – reg.

Sir,

I Dr. Utkarsh S. Mukkannawar, have been selected and offered the position of Chief Manager (Environment & Safety) on contractual basis under professional functionaries category vide Letter No. GA/PS/4292(PF)/2025/1347 with effective from 12th August'2025.

As per terms clause no 19, I "have to report for medical examination before the Chief Medical Officer, DPA at Gopalpuri Hospital……"

Accordingly, I hereby submit and enclose my medical examination Report as clinically healthy and "FIT to Join".

Further, I hereby submit my duty report today i.e., 25th August 2025 (FN) along with duly signed acceptance copy of Offer Letter, the original copy of the medical report enclosing clinical documents and two passport size photos for your kind perusal.

Thanking you,

Yours faithfully,

25/08/25

Dr. Utkarsh Mukkannawar
Mob: 9822077507

CE

May be posted in Civil Engineering Department, after due observance of formalities as per T&C of engagement, under intimation to GAD please.

Sd/- 10/9/2025

Secretary.

Date: 10th September 2025

To,

The Secretary,

Deendayal Port Authority,

Gandhidham, Kutch

Subject: Duty Report for the Port of Manager (Environment & Safety) on contractual basis at DPA – reg.

Sir,

I Ms. Neha Chandrashekhar Dekate, have been selected and offered the position of Manager (Environment & Safety) on contractual basis under professional functionaries' category vide letter no. GA/PS/4292 (PF)/2025/1349 with effective from 12th August'2025.

As per clause no. 19, "I have to report for medical examination before the Chief Medical Officer, DPA at Gopalpuri Hospital……. "

Accordingly, I hereby submit and enclose my medical examination report as clinically healthy and "FIT to Join".

Further, I hereby submit my duty report today i,e. 10th September 2025 (FN) along with duly signed acceptance copy of Offer letter, the original copy of the medical report enclosing clinical documents and two passport size photos for your kind perusal.

Thanking you,

Yours faithfully,

Neha Dekate

Ms. Neha Dekate

Mob: 9096069665

CE/Sr AS

May be posted in Environment Cell of Civil Engineering Deptt, subject to observance of due formalities as per terms & conditions of engagement in DPA on contract, Please.

3/9/2025

Secretary

To,

The Secretary

Administrative Building

Deendayal Port Authority

Date: 03/09/2025

SUBJECT: Duty Report for Contractual Engagement as Manager – Environment & Safety in Deendayal Port Authority (DPA)

Ref.: DPA letter GA/PS/4292(PF)/2025/1348 dated 12/08/2025

Sir,

With reference to the above referred letter dated 12/08/2025 I am hereby pleased to submit my Duty Report and I confirm to join the organization with effect from today i.e.03/09/2025.

Thanking You

Yours Faithfully

Rajeshwari Sharma

Annexure –II

Monitoring the Implementation of Environmental Safeguards
Ministry of Environment, Forest & Climate Change
Regional Office, Gandhinagar
(for the period up to December, 2025)

DATA SHEET

1.	Project type: –River-valley/ Mining / Industry / Thermal / Nuclear / Other (specify)		:	Infra I
2.	Name of the project		:	Augmentation of Liquid Cargo Handling Capacity from 8 MMTPA to 23.8 MMTPA Through Modernisation of Existing Pipeline Network at Oil Jetty Area, Deendayal Port Trust, Kandla
3.	Clearance letter (s) / OM No. and Date		:	Environment and CRZ clearance by MoEF&CC vide file no. 10-26/2018-IA.III dated 01/01/2024
4.	Location		:	
	a.	District (s)	:	Kutch
	b.	State (s)	:	Gujarat
	c.	Latitude/ Longitude	:	Latitude: 23°01'31.8"N to 23°02'32.2"N Longitude: 70°13'02.7"E to 70°13'23.4"E
5.	Address for correspondence			
	a.	Address of Concerned Project Chief Engineer (with pin code & Telephone/telex/fax numbers	:	Chief Engineer, Deendayal Port Authority, P.O. Box no. 50. A.O. Building, Annex Bldg. Gandhidham- 370 201. Phone: 02836 233192 Fax.: 02836 220050
	b.	Address of Project: Engineer/Manager (with pin code/ Fax numbers)	:	Dy.Chief Engineer (PL) Deendayal Port Authority, P.O. Box no. 50. A.O. Building, Annex Bldg. Gandhidham- 370 201.
6.	Salient features			
	a.	of the project		(see below)

Current Proposal	Augmentation of Liquid Cargo Handling Capacity from 8 MMTPA to 23.8 MMTPA Through Modernisation of Existing Pipeline Network at Oil Jetty Area
Location of Project	Oil Jetty Area of Deendayal Port, Kandla located on the western bank of Kandla Creek in the northeastern part of Gulf of Kutch, under village Kandla in Gandhidham Taluk of Kachchh District of Gujarat
Latitude	Deendayal Port: 22o58'15.5"N to 23o12'30"N Proposed Project: 23°01'31.8"N to 23°02'32.2"N
Longitude	Deendayal Port: 70o13'02.7"E to 70o38'00"E.

				<table><tr><td></td><td>Proposed Project: 70°13'02.7"E to 70°13'23.4"E</td></tr><tr><td>Land Requirement</td><td>No Additional Land required.</td></tr><tr><td>Capacity</td><td>Existing Cargo throughput is 8 MMTPA after revamping it will be 23.8 MMTPA.</td></tr><tr><td>Dredging Requirement</td><td>None</td></tr><tr><td>Construction</td><td>Only replacement & revamping of existing Pipeline network at Oil jetty area out of total of 167 pipelines 125 will be scrapped and the remaining 42 will be retained after final revamping there will be total 126 pipelines</td></tr><tr><td>Proposed Investment</td><td>Rs.171.32 Crores</td></tr></table>
	b.	Of the environmental management plans	:	A copy of the Environment Management Plan of the project has already been submitted along with the compliance report dated 02/06/2025
7.	Production details during the compliance period and (or) during the previous financial year		:	It is under Infrastructure & miscellaneous projects so production is not involved
8.	The breakup of the project area		:	
	a.	submergence area forest &non-forest	:	NIL
	b.	Others	:	NIL
9.	The breakup of the project affected the Population with an enumeration of Those losing houses/dwelling units Only agricultural land only, both Dwelling units & agricultural Land &landless labours/artisan		:	The activities are well within designated port limits.
	a.	SC, ST/Adivasis	:	Nil
10.	Financial details		:	
	a.	Project cost as originally planned and subsequently revised estimates and the year of price reference:		
	1.	Estimated Cost of the Project	:	Estimated Cost : Rs.171.32 Crores, Revised Estimated Project Cost: Rs. 211.61 Crore
	b.	The allocation made for environmental management plans with item-wise and year-wise Break-up.	:	a) The allocation made by DPA under the scheme of "Environmental Services & Clearance thereof other related Expenditure" during R BE 2024-25 is Rs. 585 Lakhs.
	c.	Benefit-cost ratio / Internal rate of Return and the year of assessment	:	IRR – 18.15%
	d.	Whether (c) includes the Cost of environmental management as shown in above.	:	Yes
	e.	Actual expenditure incurred on the project so far	:	142.90 Cr (Including GST)

	f.	Actual expenditure incurred on the environmental management plans so far		a) The expenditure made by DPA under the scheme of "Environmental Services & Clearance thereof other related Expenditure" is Rs 136 Lakhs For the period April 2025 to September 2025
11.	Forest land requirement		:	
	a.	The status of approval for the diversion of forest land for non-forestry use	:	NIL
	b.	The status of clearing felling	:	NIL
	c.	The status of compensatory afforestation it any	:	NIL
	d.	Comments on the viability & sustainability of the compensatory afforestation program in light of actual field experience so far	:	NIL
12.	The status of clear felling in non-forest areas (such as the submergence area of the reservoir and approach roads) is any with quantitative information.		:	NIL
13.	Status of construction		:	Work in progress
	a.	Date of commencement (Actual and/or planned)	:	--
	b.	Date of completion (Actual and/or planned)	:	--
14.	Reasons for the delay if the Project is yet to start			--
15.	Date of the site visit			
	a)	The dates on which the regional office monitored the project on pervious occasion. if any		06/09/2022
	b)	The date site visit for this monitoring report.		