DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

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

www.deendayalport.gov.in

EG/WK/4751/part (Stage II)/64 Dated: 17/07/2025

To,
Shri T.C. Patel,
The Unit Head, Kachchh,
Gujarat Pollution Control Board,
Paryavaran Bhavan,
Sector 10A, Gandhinagar- 382 010.

Sub: "Development of Integrated facilities (Stage II) within the existing Deendayal Port Trust (Erstwhile Kandla Port Trust) at District Kutch, Gujarat (1. Setting up of Oil Jetty no. 7, 2. Setting up of Barge Jetty at Jafrabadi, 3. Setting up of Barge Port at Veera, 4. Administrative office building at Tuna Tekra, 5. Road connecting from Veera Barge Jetty to Tuna gate by Deendayal Port Authority (Erstwhile Deendayal Port Trust)" – **Pointwise Compliance of the conditions stipulated in NOC issued by GPCB reg.**

Ref.:
1) NOC no. 74134 received vide letter no. GPCB/CCA-Kutch-1319/GPCB ID 48573 dated 27/11/2015
2) MoEF&CC, GOI granted EC&CRZ vide letter no. F.No.11-13/2015-IA-III dated 19/02/2020
3) GPCB issued EC to CTE (PCB ID 48573) vide order dated 13/10/2020
4) DPT letter EG/WK/4751/Part(Stage II)/54 dated 29/07/2021.
5) DPT letter EG/WK/4751/Part(Stage II)/145 dated 08/02/2022.
6) DPT letter EG/WK/4751/Part(Stage II)/140 dated 11/07/2022.
7) DPT letter EG/WK/4751/Part(Stage II)/145 dated 03/05/2023.
8) DPT letter EG/WK/4751/Part(Stage II)/369 dated 03/10/2023.
9) DPA letter EG/WK/4751/Part(Stage II)/110 dated 09/08/2024.
10) DPA letter EG/WK/4751/Part(Stage II)/36 dated 24/02/2025.

Sir,

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

In this connection, it is to state that, GPCB vide above mentioned letter no. GPCB/CCA-Kutch-1319/GPCB ID 48573 dated 27/11/2015 had granted the NOC/CTE to the aforesaid project.

Subsequently after obtaining Environmental and CRZ Clearance from MoEF&CC,GOI vide F.No.11-13/2015-IA-III dated 19/02/2020, DPA obtained EC to CTE (PCB ID 48573) from Gujarat Pollution Control Board vide order dated 13/10/2020 with a validity period of seven years.

.....Cont.....

Now, please find enclosed herewith, compliance report of conditions stipulated in CTE Order (period up October 2024 to March 2025) along with necessary enclosures as **Annexure I,** for kind perusal & record please.

Further, as per the MoEF&CC, Notification S.O.5845 (E) dated 26.11.2018, stated that "**In the said notification, in paragraph 10, in sub-paragraph (ii), for the words "hard and soft copies" the words "soft copy" shall be substituted**". Accordingly, we are submitting herewith soft copy of the same via e-mail ID kut-uh-gpcb@gujarat.gov.in.

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

Thanking You.

Yours faithfully,

XEN (EMC)
Deendayal Port Authority

Encl.: As above

Copy to: Regional Officer,
Gujarat Pollution Control Board,
Regional office,
Kutch (East), Gandhidham-**370201.**
Email Id. ro-gpcb-kute@gujarat.gov.in

ANNEXURE I

Point wise compliance

Subject: **Development of Integrated facilities (Stage-II) within the existing Deendayal Port Trust (Erstwhile Kandla Port Trust) at District Kutch, Gujarat. (1. Setting up of Oil Jetty No.7. 2. Setting up of Barge jetty at Jafarwadi 3. Setting up of Barge port at Veera; 4. Administrative office building at Tuna Tekra; 5. Road connecting from Veera barge jetty to Tuna gate by M/s Deendayal Port Trust (Erstwhile Kandla Port Trust)**

CURRENT STATUS OF WORK – Upto March 2025

Sr.No.	Name of Project	Status
1.	**Setting up of Oil Jetty No.7**	Under operation w.e.f January 2023.
2.	**Setting up of Barge jetty at Jafarwadi**	No construction activity started yet.
3.	**Setting up of Barge port at Veera**	No construction activity started yet.
4.	**Administrative office building at Tuna Tekra;**	No construction activity started yet.
5.	**Road connecting from Veera barge jetty to Tuna gate**	No construction activity started yet.

Subject: Development of Integrated facilities (Stage-II) within the existing Deendayal Port Trust (Erstwhile Kandla Port Trust) at District Kutch, Gujarat. (1. Setting up of Oil Jetty No.7. 2. Setting up of Barge jetty at Jafarwadi 3. Setting up of Barge port at Veera; 4. Administrative office building at Tuna Tekra; 5. Road connecting from Veera barge jetty to Tuna gate by M/s Deendayal Port Trust (Erstwhile Kandla Port Trust) (For the period up to March 2025)

Reference: NOC No. 74134 received vide letter no. GPCB/CCA-Kutch-1319/GPCB ID 48573 Dated 27/11/2015

<table>
<tr><th>Sr. No</th><th>Conditions</th><th>Compliance Status</th></tr>
<tr><td>1</td><td colspan="2">Specific Conditions</td></tr>
<tr><td>1</td><td>Applicant shall not carry out any kind of activities till Environmental Clearances and CRZ clearances is obtained from the statutory authority.</td><td>The MoEF&CC, GoI accorded EC & CRZ Clearance for "Development of Integrated facilities (Stage II) within the existing Deendayal Port Trust (Erstwhile Kandla Port Trust) at District Kutch, Gujarat (1. Setting up of Oil Jetty No. 7 2. Setting up of Barge Jetty at Jafrabadi 3. Setting up of Barge port at Veera 4. Administrative office building at Tuna Tekra 5. Road connecting from Veera barge jetty to Tuna gate by M/s Deendayal Port Trust" vide letter dated 19/2/2020.</td></tr>
<tr><td>2.</td><td>You shall strictly adhere to all conditions of Terms of References (TOR) (vide letter no. F No. 11-13/2015-IA-III) by MoEF&CC, New Delhi.</td><td>Based on the TOR issued by the MoEF&CC,GoI dated 23/06/2015, the EIA Consultant had prepared EIA/EMP report as per TOR and accordingly, the MoEF&CC,GoI had accorded the EC & CRZ Clearance dated 19/2/2020.</td></tr>
<tr><td>3.</td><td>No ground water shall be used for the project coming under dark zone without permission of competent authority.</td><td>No ground water will be used for the project.</td></tr>
<tr><td>3.</td><td colspan="2">Conditions Under Water Act</td></tr>
<tr><td>3.1</td><td>There shall be no Industrial water consumption and hence there shall be no generation from Manufacturing process and other ancillary industrial operations.</td><td>N/a</td></tr>
<tr><td>3.2</td><td>The quantity of domestic waste water (sewage) shall not exceed 18 KL/day</td><td>Agreed with the condition</td></tr>
<tr><td>3.3</td><td>The quality of the sewage shall confirm to the following standards
<table>
<tr><td>Parameters</td><td>Permissible Limit</td></tr>
<tr><td>BOD (5 days at 20 ^{0} C)</td><td>20 mg/liter</td></tr>
<tr><td>Suspended Solid</td><td>30 mg/lit</td></tr>
<tr><td>Residual Chlorine</td><td>Minimum 0.5 mg/liter</td></tr>
</table></td><td>Point Noted.
DPA appointed NABL Accredited laboratory for regular Monitoring of environmental parameters since the year 2016 in continuation of this DPA appointed M/s Gujarat Environment Management Institute (GEMI), Gandhinagar (NABL Accredited laboratory) for regular Monitoring of environmental parameters vide work order dated 15/02/2023. The work is in progress & DPA is submitting the monitoring data regularly to all the concerned authorities along with compliance reports submitted.

The latest Environmental Monitoring Reports is enclosed herewith as Annexure A</td></tr>
<tr><td>3.4</td><td>The sewage shall be treated in sewage treatment plant and confirm above standards shall be utilized for plantation/gardening area of 2,03,775 m^2 within the premises</td><td>Agreed with the condition.</td></tr>
<tr><td>3.5</td><td>The unit shall install meters at utilities for measuring category wise (category as given in Schedule II of "Water (prevention & control of Pollution) Cess Act-1977 Consumption of Water</td><td>Point Noted</td></tr>
<tr><td>4.</td><td colspan="2">Conditions under Air Act 1981:</td></tr>
<tr><td>4.1</td><td>The following shall be used as fuel in the D.G</td><td>Point Noted</td></tr>
</table>

<table>
<tr><td></td><td>sets as following rates after proposed expansion
<table><tr><td>Sr. No.</td><td>Name of Fuel</td><td>Quantity</td></tr><tr><td>1.</td><td>Diesel</td><td>50 Lit/day</td></tr></table></td><td></td></tr>
<tr><td>4.2</td><td>The applicant shall install & Operate air pollution control system in order to achieve process gas emission norms as prescribed below after proposed expansion
<table><tr><td>Sr no</td><td>Stack Attached to</td><td>Stack Height in meters</td><td>Parameter</td><td>Permissible limit</td></tr><tr><td>1.</td><td>D.G set (50 KV)</td><td>11</td><td>PM
SO2
NOx</td><td>150 mg/NM3
100 ppm
50 ppm</td></tr></table></td><td>DPA appointed NABL Accredited laboratory for regular Monitoring of environmental parameters since the year 2016 in continuation of this DPA appointed M/s Gujarat Environment Management Institute (GEMI), Gandhinagar (NABL Accredited laboratory) for regular Monitoring of environmental parameters vide work order dated 15/02/2023. The work is in progress & DPA is submitting the monitoring data regularly to all the concerned authorities along with compliance reports submitted.

The latest Environmental Monitoring Reports is enclosed herewith as Annexure A</td></tr>
<tr><td>4.3</td><td>The concentration of the following parameters in the ambient air within the premises of the industry shall not exceed the limits specified hereunder as per National Ambient Air Quality Emission Standards issued by Ministry of Environment, Forest and Climate Change dated 16th November 2009.
<table><tr><td>Parameters</td><td>Time Weighted Average</td><td>Concentration in Ambient air in µg/m3</td></tr><tr><td>Sulphur Dioxide (SO_2)</td><td>Annual
24 Hours</td><td>50
80</td></tr><tr><td>Nitrogen Dioxide (NO_2)</td><td>Annual
24 Hours</td><td>40
80</td></tr><tr><td>Particulate Matter (Size less than 10µm)</td><td>Annual

24 Hours</td><td>60

100</td></tr><tr><td>Particulate Matter (Size less than 2.5µm) or $PM_{2.5}$</td><td>Annual

24 Hours</td><td>40

60</td></tr></table></td><td>DPA appointed NABL Accredited laboratory for regular Monitoring of environmental parameters since the year 2016 in continuation of this DPA appointed M/s Gujarat Environment Management Institute (GEMI), Gandhinagar (NABL Accredited laboratory) for regular Monitoring of environmental parameters vide work order dated 15/02/2023. The work is in progress & DPA is submitting the monitoring data regularly to all the concerned authorities along with compliance reports Submitted.

The latest Environmental Monitoring Reports is enclosed herewith as Annexure A</td></tr>
<tr><td>4.4</td><td>The applicant shall provide portholes, ladder, platform etc at chimney(s) for monitoring the air emission and the same shall be open for inspection. The chimney(s) vents attached to various sources of emission shall be designed by numbers such as S-1, S-2, etc and these shall be painted/displayed to facilitate identification.</td><td>N/A</td></tr>
<tr><td>4.5</td><td>The Concentration of Noise in ambient air within the premises of industrial unit shall not exceed following levels:;
Between 6 A.M and 10 P.M : 75 dB(A)
Between 10 A.M and 6 P.M : 70 dB(A)</td><td>DPA appointed NABL Accredited laboratory for regular Monitoring of environmental parameters since the year 2016 in continuation of this DPA appointed M/s Gujarat Environment Management Institute (GEMI), Gandhinagar (NABL Accredited laboratory) for regular Monitoring of environmental parameters vide work order dated 15/02/2023. The work is in progress & DPA is submitting the monitoring data regularly to all the concerned authorities along with compliance reports submitted.

The latest Environmental Monitoring Reports is enclosed herewith as Annexure A</td></tr>
<tr><td>5.</td><td colspan="2">Conditions under Hazardous waste:</td></tr>
</table>

5.1	The applicant shall provide temporary storage facilities for each type of Hazardous waste as per Hazardous waste (Management, Handling & Transboundary Movement) Rules, 2016 as amended from time to time.	DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars regarding the reception facilities at Swachch Sagar portal
5.2	The applicant shall be obtain membership of common TSDF site for disposal of Hazardous waste as Categorized in Hazardous waste (Management, Handling & Transboundary Movement) Rules, 2008 as amended thereof	Not applicable
6.	**General Conditions**	
6.1	Unit shall develop green belt within premises as per the CPCB guidelines. However, if the adequate land is not available within premises, the unit shall tie up with local agencies like gram panchayat, school, social forestry office etc, for the plantation at suitable open land in nearby locality and submit an action plan of plantation for next three years to GPCB.	Point noted. DPA had already taken up Green belt development activity through Forest Department GoG at the cost of 352.32 lakhs (Green belt development in DPA area in an area of 31.942 Ha.). Further, it is relevant to mention here that, 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 GUIDEJ, dated 31st May, 2022 . The said work is completed and final report was submitted along with compliance submitted on 03/10/2023. 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 24/02/2025. Further, for project at Sr. no. 2 to 5 (construction not yet started), green belt will be developed as per the specified condition.
6.2	Adequate plantation shall be carried out all along the periphery of the industrial premises in such a way that the density of plantation is at least 1000 trees per acre of land and a green belt of 10 meters width is developed.	
6.3	The applicant shall have to submit the returns in prescribed form regarding water consumption and shall have to make payment of water cess to the Board under the water (Prevention and Control of Pollution) Cess Act - 1977	Agreed with the condition. DPA regularly submitted the Environmental Statement in Form V for the whole port area. Copy of same is already submitted along with compliance report submitted on 09/08/2024.
6.4	In case of change of ownership/management the name and address of the new owners/partners/directors/proprietor should immediately be intimated to the Board.	Point Noted.
6.5	The applicant shall however, not without the prior consent of the Board bring into use any new or altered outlet for the discharge of effluent or gaseous emission or sewage waste from the proposed industrial plant. The applicant is required to make applications to this Board for this purpose in the prescribed forms under the provisions of the of the Water (Prevention and Control of Pollution) Act-1974, the air (Prevention & Control of Pollution) Act - 1981 and the Environment (Protection) Act-	Point Noted for the compliance.

	1986	
6.6	The applicant also comply with the General conditions as per Annexure-I attached herewith (No. 1 to 38) (which ever applicable)	Point Noted for the compliance.
6.7	The overall noise level in and around the plant area shall be kept well within the standards by providing noise control measures including engineering control like acoustic insulation hood, silencers, enclosures etc on all sources of noise generation. The ambient noise level confirm to the standards prescribed under the Environment (Protection) Act, 1989 & Rules.	DPA appointed NABL Accredited laboratory for regular Monitoring of environmental parameters since the year 2016 in continuation of this DPA appointed M/s Gujarat Environment Management Institute (GEMI), Gandhinagar (NABL Accredited laboratory) for regular Monitoring of environmental parameters vide work order dated 15/02/2023. The work is in progress & DPA is submitting the monitoring data regularly to all the concerned authorities along with compliance reports submitted. The latest Environmental Monitoring Reports is enclosed herewith as **Annexure A**
6.8	Applicant is required to comply with the manufacturing, storage and Import of Hazardous Chemicals Rules-1989 framed under Environment (Protection) Act -1986	Point Noted.
6.9	If it is established by any competent authority that the damage is caused due to their industrial activities to any person or his property, in that case they are obliged to pay the compensation as determined by the competent authority.	Point Noted.
6.10	Applicant shall have to comply with all the guidelines/directives issued/being issued by MoEF/CPCB/DoEF from time to time.	Point Noted.
6.11	Applicant shall not use/withdraw ground water either during construction and/or operation phase.	No ground water will be drawn.
6.12	Environmental cell shall be setup and shall be responsible for the Environmental management.	DPA is already having Environment Management cell. Further, DPA has also appointed expert agency for providing Environmental Experts from time to time. Recently, DPA appointed M/s Precitech Laboratories, Vapi for providing Environmental Experts vide work order dated 5/2/2021 Further DPA has appointed Manager Environment on contractual basis for the period of 3+2 years. Details of the same submitted along with the compliance report submitted on 03/05/20223.
6.13	Monitoring in respect to Air, Water, Noise level shall be carried out and results shall be submitted to GPCB on quarterly basis.	DPA appointed NABL Accredited laboratory for regular Monitoring of environmental parameters since the year 2016 in continuation of this DPA appointed M/s Gujarat Environment Management Institute (GEMI), Gandhinagar (NABL Accredited laboratory) for regular Monitoring of environmental parameters vide work order dated 15/02/2023. The work is in progress & DPA is submitting the monitoring data regularly to all the concerned authorities along with compliance reports submitted. The latest Environmental Monitoring Reports is enclosed herewith as **Annexure A**

ANNEXURE A
Monitoring Report

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

(Monitoring Period: December 2024 -January 2025)

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

Submitted to:

Deendayal Port Authority (DPA), Kandla

Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

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

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

Certificate

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

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

S. S. O. & Lab Head

Authorized Signatory

About this Document

Gujarat Environment Management Institute (GEMI) has been assigned with the work of "Preparing and monitoring of Environmental monitoring and Management plan for Deendayal Port Authority (DPA) at Kandla and Vadinar for a period of 3 years" by DPA, Kandla. Under the said project the report titled *"Environment Monitoring Report (Dec-2024-Jan-2025)"* is prepared.

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

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List of Abbreviations

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

CHAPTER 1: INTRODUCTION

1.1 Introduction

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

1.2 Green Ports Initiative

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

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

DPA had also appointed GEMI as an Advisor for "Making Deendayal Port a Green Port-Intended Sustainable Development under the Green Port Initiatives. DPA has also signed MoU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by DPA. The plantation is being carried out by the Social Forestry division of Kachchh.

1.3 Importance of EMP

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

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

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

It identifies the principles, approach, procedures and methods that will be used to control and minimize the environmental and social impacts of operational activities associated with the port. An EMP is a required part of environmental impact assessment of a new port project but could also be evolved for existing ports. It is useful not only during the construction and operational phases of the new port but also for operation of existing ports to ensure the effectiveness of the mitigation measures implemented and to further provide guidance as to the most appropriate way of dealing with any unforeseen impacts.

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

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

This document presents the Environmental Monitoring Report (EMR) for Kandla and Vadinar for the environmental monitoring done during the period from 17th December-16th January 2024-2025.

1.4 Objectives and scope of the Study

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

The scope of work includes not limited to following:

1. To review the locations/stations of Ambient Air, Ambient Noise, drinking water, and Marine Water, Soil and Sediments monitoring within the impacted region in-and-around DPA establishment, in view of the developmental projects.
2. To assess the Ambient Air quality, quality at 6 stations at Kandla and 2 at Vadinar in terms of gases and particulate matter.
3. To assess the DG stack emissions (gases and particulate matter).
4. To assess Drinking water quality at twenty locations (18 at Kandla and 2 at Vadinar) in terms of Physical, Chemical and Biological parameters viz., Color, Odor, turbidity, conductivity, pH, Total Dissolved Solids, chlorides, Hardness, total iron, sulfate, NH_4, PO_4, and bacterial count on a monthly basis.
5. To assess the Marine water quality in terms of aquatic Flora and Fauna and Sediment quality in terms of benthic flora and fauna.
6. To assess Marine Water Quality and sediment in term of physical and chemical parameter.
7. To assess the trends of water quality in terms of Marine ecology by comparing the data collected over a specified time period.
8. Weekly sample collection and analysis of inlet & Outlet points of the Sewage Treatment Plant (STP) to check the water quality being discharged by DPA as per the CC&A.
9. Carrying out monthly Noise monitoring; twice a day at the representative stations for a period of 24 hours.
10. Meteorological parameters are very important from air pollution point of view, hence precise and continuous data collection is of utmost importance. Meteorological data on wind speed, wind direction, temperature, relative humidity, solar radiation and

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

11. To suggest mitigation measures, based on the findings of this study and also check compliance with Environmental quality standards, Green Port Initiatives, MIV 2030, and any applicable Statutory Compliance.
12. To recommend Environment Management Plans based on Monitoring programme and findings of the study.

CHAPTER 2: METHODOLOGY

2.1 Study Area

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

a. Kandla

Deendayal Port (Erstwhile Kandla Port) is one of the twelve major ports in India and is located on the West Coast of India, in the Gulf of Kutch at 23001'N and 70013'E in Gujarat. The Major Port Authorities Act 2021 is the governing statute for Administration of Major Ports, under which, Deendayal Port Trust (DPT) has become Deendayal Port Authority (DPA). At Kandla, DPA has sixteen (16) cargo berths for handling various types of Dry Bulk Cargo viz, fertilizer, food grains, Coal, sulphur, etc.

- **Climatic conditions of Kandla**

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

b. Vadinar

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

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

- **Climatic conditions of Vadinar**

Vadinar has a hot semi-arid climate. The summer season lasts from March-to-May and is extremely hot, humid, but dry. The climatic conditions in Vadinar are quite similar to that recorded in its district head quarter i.e., Jamnagar. The annual mean temperature is 26.7 °C. Rainy season with extremely erratic monsoonal rainfall that averages around 630 millimetres. The winter season is from October-to-February remains hot during the day but has negligible rainfall, low humidity and cool nights.

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

Map 1: Locations of Kandla and Vadinar Port

Map 2: Locations of Kandla Port

Map 3: Locations of Vadinar Port

2.2 Environmental Monitoring at Kandla and Vadinar

Regular monitoring of environmental parameters is of immense importance to assess the status of environment during project operation. With the knowledge of baseline conditions, the monitoring programme will serve as an indicator for identifying any deterioration in environmental conditions, thereby assist in recommending suitable mitigatory steps in time to safeguard the environment. Monitoring is as important as that of control of pollution since the efficiency of control measures can only be determined by a well-defined monitoring program. Environmental Monitoring is vital for monitoring the environmental status of the port for sustainable development. The list of main elements for which Environmental monitoring is to be carried out have been mentioned below:

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

GEMI has been entrusted by DPA to carry out the monitoring of the various aforementioned environmental aspects at the port, so as to verify effectiveness of prevailing Environment Management plan, if it confirms to the statutory and/or legal compliance; and identify any unexpected changes. Standard methods and procedures have been strictly adhered to in the course of this study. QA/QC procedures were strictly followed which covers all aspects of the study, and includes sample collection, handling, laboratory analyses, data coding, statistical analyses, interpretation and communication of results. The analysis was carried out in GEMI's NABL/MoEF accredited/recognized laboratory.

Methodology adopted for the study

Methodology is a strictly defined combination of practices, methods and processes to plan, develop and control a project along the continuous process of its implementation and successful completion. The aim of the project management methodology is to allow the control of whole process of management through effective decision-making and problem solving. The methodology adopted for the present study is shown in **Figure 1** as given below:

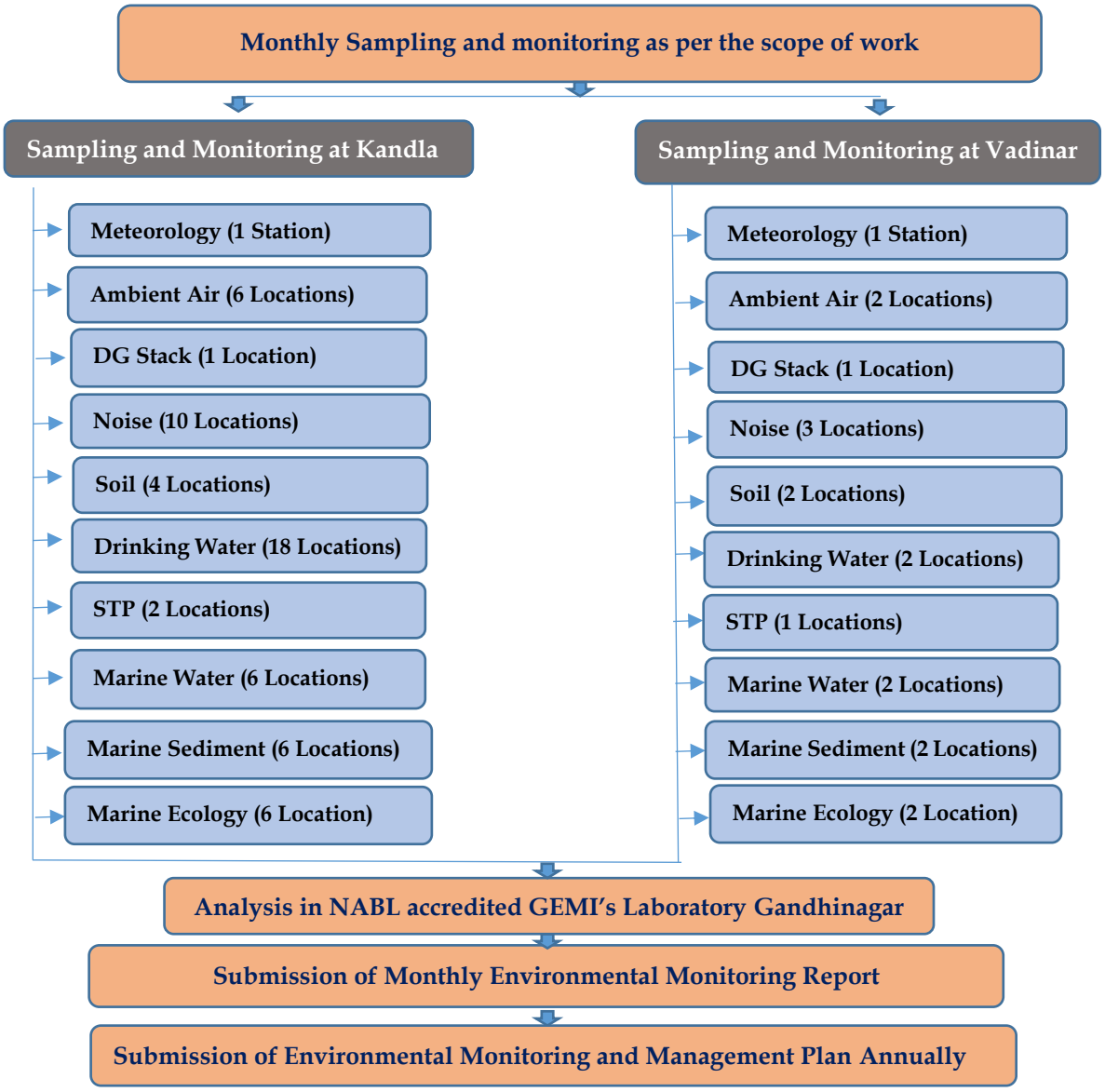


Figure 1: Methodology flow chart

The details of various sectors of Environment monitoring are described in subsequent chapters.

CHAPTER 3: METEOROLOGY MONITORING

3.1 Meteorology Monitoring

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

Table 1: Details of Automatic Weather Station

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

Methodology

During the study, a continuous automatic weather monitoring station was installed at both the sites to record climatological parameters such as Wind speed, Wind Direction, Relative Humidity, Solar Radiation, Rainfall and Temperature to establish general meteorological regime of the study area. The methodology adopted for monitoring meteorological data shall be as per the standard norms laid down by Bureau of Indian Standards (BIS) and the India Meteorological Department (IMD). The details of Automatic Weather Monitoring Station have been mentioned in **Table 2**.

Table 2: Automatic Weather Monitoring Station details

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

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

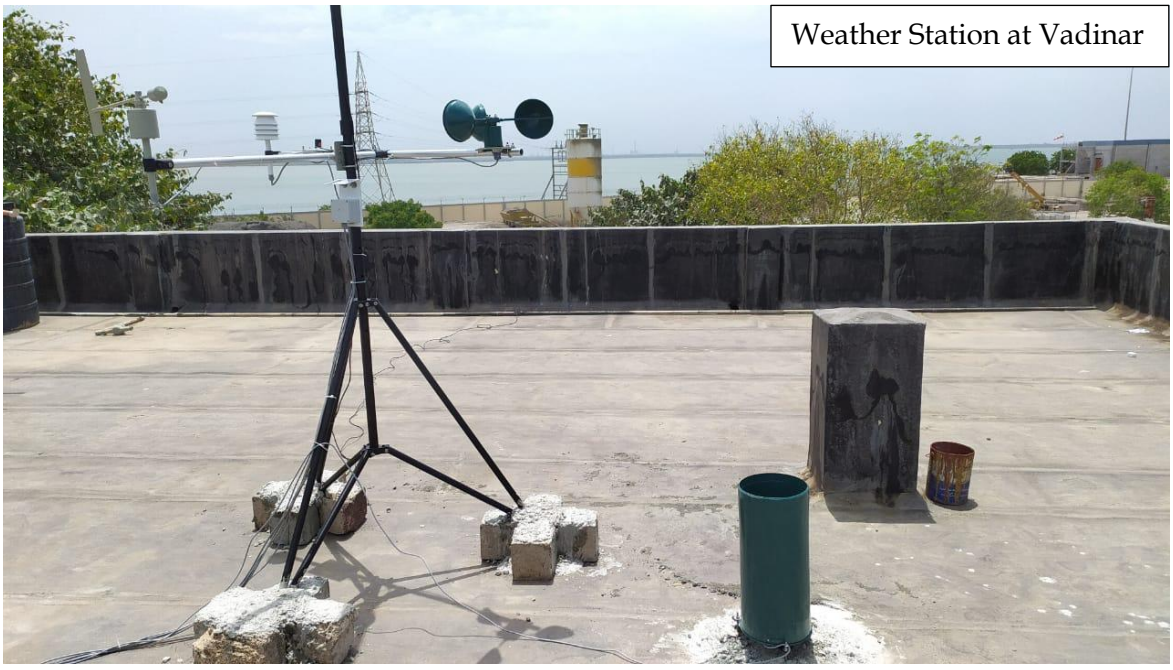


Figure 2: Photographs of Automatic Weather Monitoring Station at Kandla and Vadinar

3.2 Results and discussion

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

Table 3: Meteorological data for Kandla and Vadinar

Details of Micro-meteorological data at Kandla Observatory												
Monitoring Period	**Wind Speed (Km/h)**			**Temperature (°C)**			**Relative humidity (%)**			**Solar Radiation (W/m²)**	**Wind Direction (°)**	**Rainfall (mm)**
Stat.	**Mean**	**Max.**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**			
December-January, 2024-2025	7.25	48	3.12	20.27	34.1	13.5	52.38	78	27.8	57.19	South	0
Details of Micro-meteorological data at Vadinar Observatory												
Monitoring Period	**Wind Speed (Km/h)**			**Temperature (°C)**			**Relative humidity (%)**			**Solar Radiation (W/m²)**	**Wind Direction (°)**	**Rainfall (mm)**
Stat.	**Mean**	**Max.**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max.**	**Min**			
December-January, 2024-2025	7.91	74.7	2.96	20.90	27.3	14.1	60.62	104.1	29.4	69.28	South-West	0

3.3 Data Interpretation and Conclusion

- **Temperature**

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

- **Relative Humidity**

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

- **Rainfall**

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

- **Wind Speed**

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

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

- **Solar Radiation:**

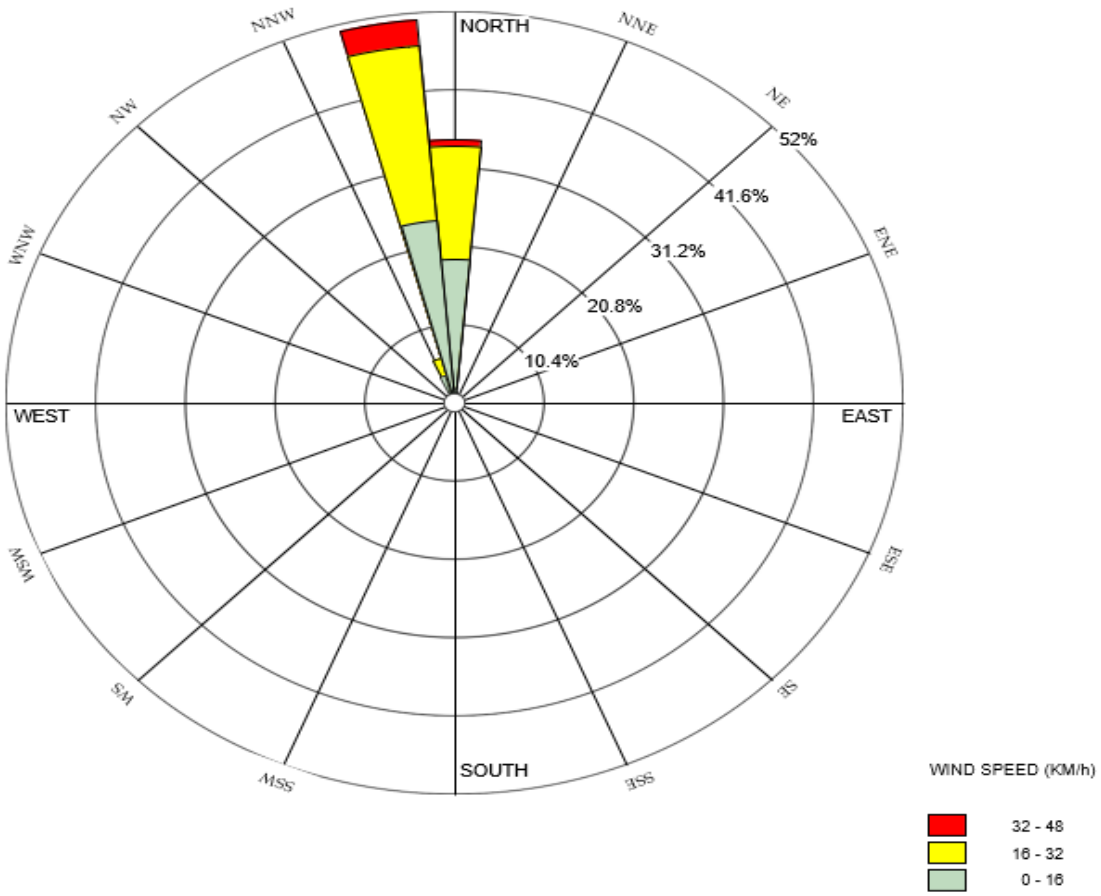
a. **Kandla:** The average Solar Radiation for the monitoring period was recorded as 57.19 W/m^2.
b. **Vadinar:** The average Solar Radiation was recorded as 69.28 W/m^2.

- **Wind rose diagram -**

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

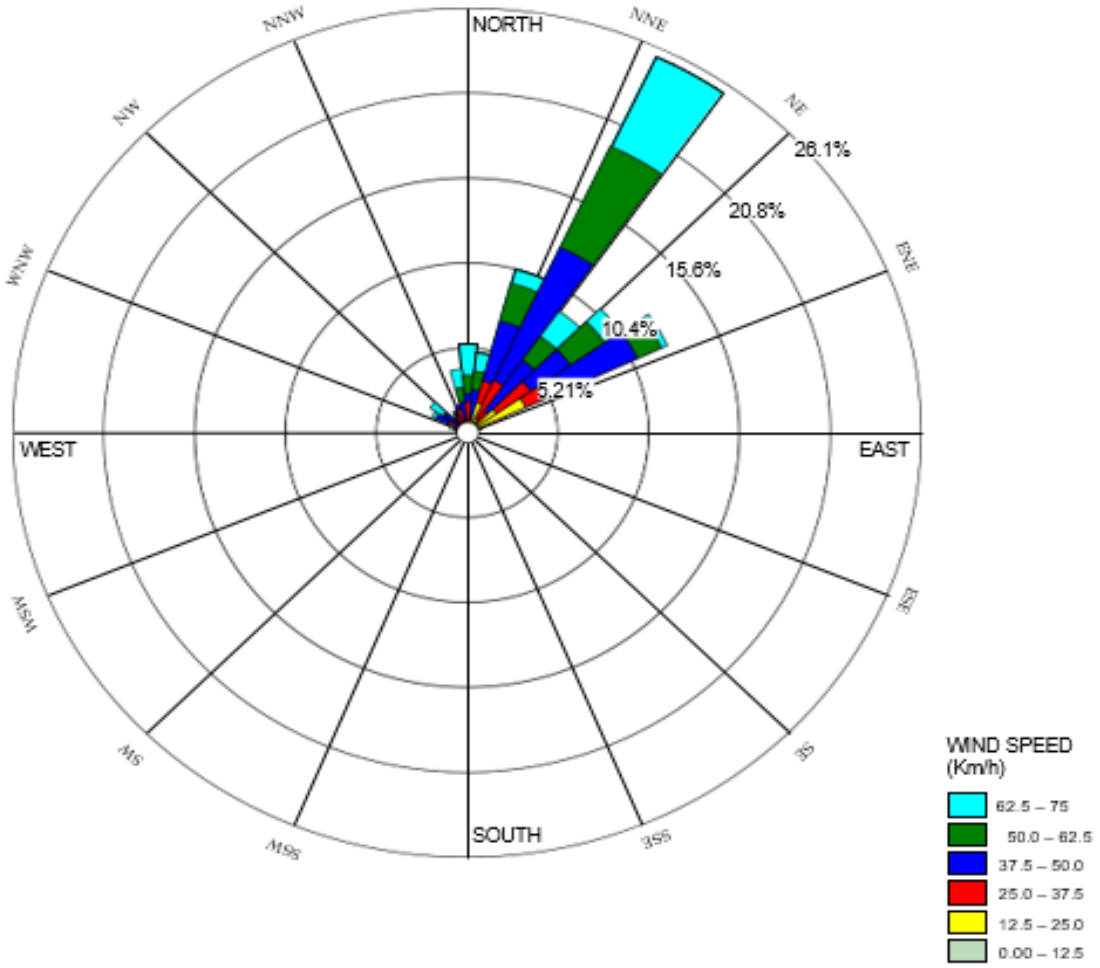
This Wind Rose Diagram reveals that at Kandla and Vadinar, during the monitoring period, the prevailing winds predominantly blow from the West South West direction at Kandla, whereas, high speed winds were also observed to blow from South direction. At Vadinar, the winds were observed to blow from South-West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

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



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

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



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

CHAPTER 4: AMBIENT AIR QUALITY MONITORING

4.1 Ambient Air Quality

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

Methodology

The study area represents the area occupied by DPA and its associated Port area. The sources of air pollution in the region are mainly vehicular traffic, fuel burning, loading & unloading of dry cargo, fugitive emissions from storage area and dust arising from unpaved village roads. Considering the below factors, under the study, as per the scope specified by DPA eight locations wherein, 6 stations at Kandla and 2 at Vadinar have been finalized within the study area

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

The description of various air quality stations monitored at Kandla and Vadinar have been specified in **Table 4**.

Table 4: Details of Ambient Air monitoring locations

Sr. No.	Location Code		Location Name	Latitude Longitude	Significance
1.	Kandla	A-1	Oil Jetty No. 1	23.029361N 70.22003E	Liquid containers and emission from ship
2.		A-2	Oil Jetty No. 7	23.043538N 70.218617E	
3.		A-3	Kandla Port Colony	23.019797N 70.213536E	Vehicular activity and dust emission
4.		A-4	Marine Bhavan	23.007653N 70.222197E	Construction and vehicular activity, road dust emission,
5.		A-5	Coal Storage Area	23.000190N 70.219757E	Coal Dust, Vehicular activity
6.		A-6	Gopalpuri Hospital	23.081506N 70.135258E	Residential area, dust emission, vehicular activity
7.	Vadinar	A-7	Admin Building	22.441806N 69.677056E	Vehicular activity
8.		A-8	Vadinar Colony	22.401939N 69.716306E	Residential Area, burning waste, vehicular activity

The monitoring locations at Kandla and Vadinar have been depicted in map in **Map 4 and 5** respectively.

Ambient Air monitoring photos

Kandla

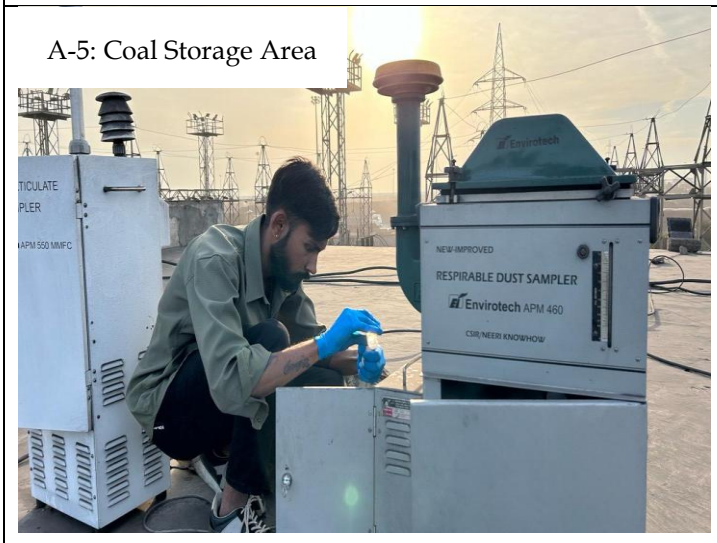
A-1: Oil Jetty No. 1

A-2: Oil Jetty No. 7

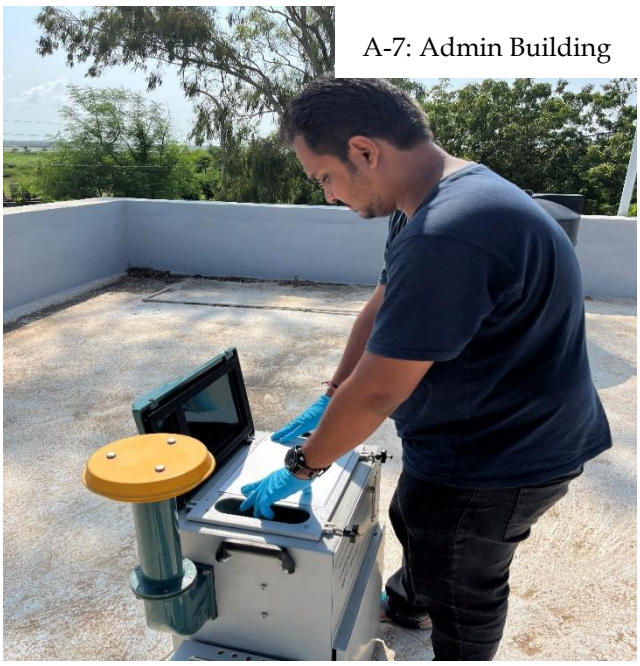
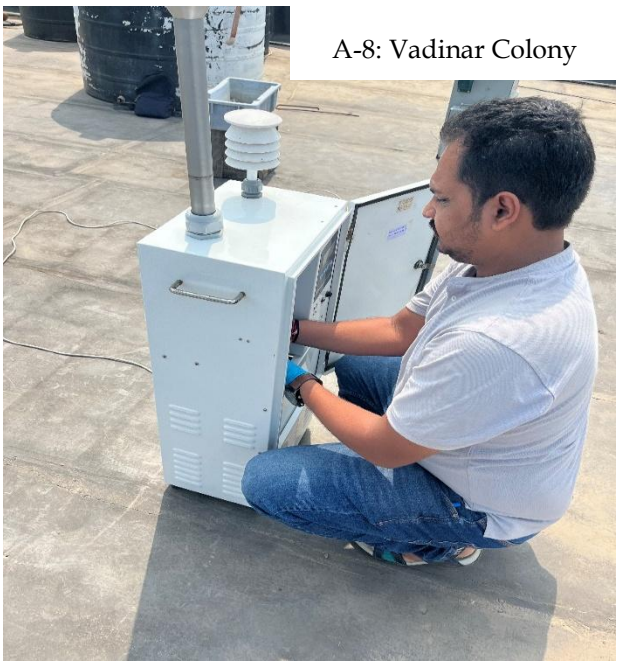
A-3: Kandla Port Colony

A-4: Marine Bhavan

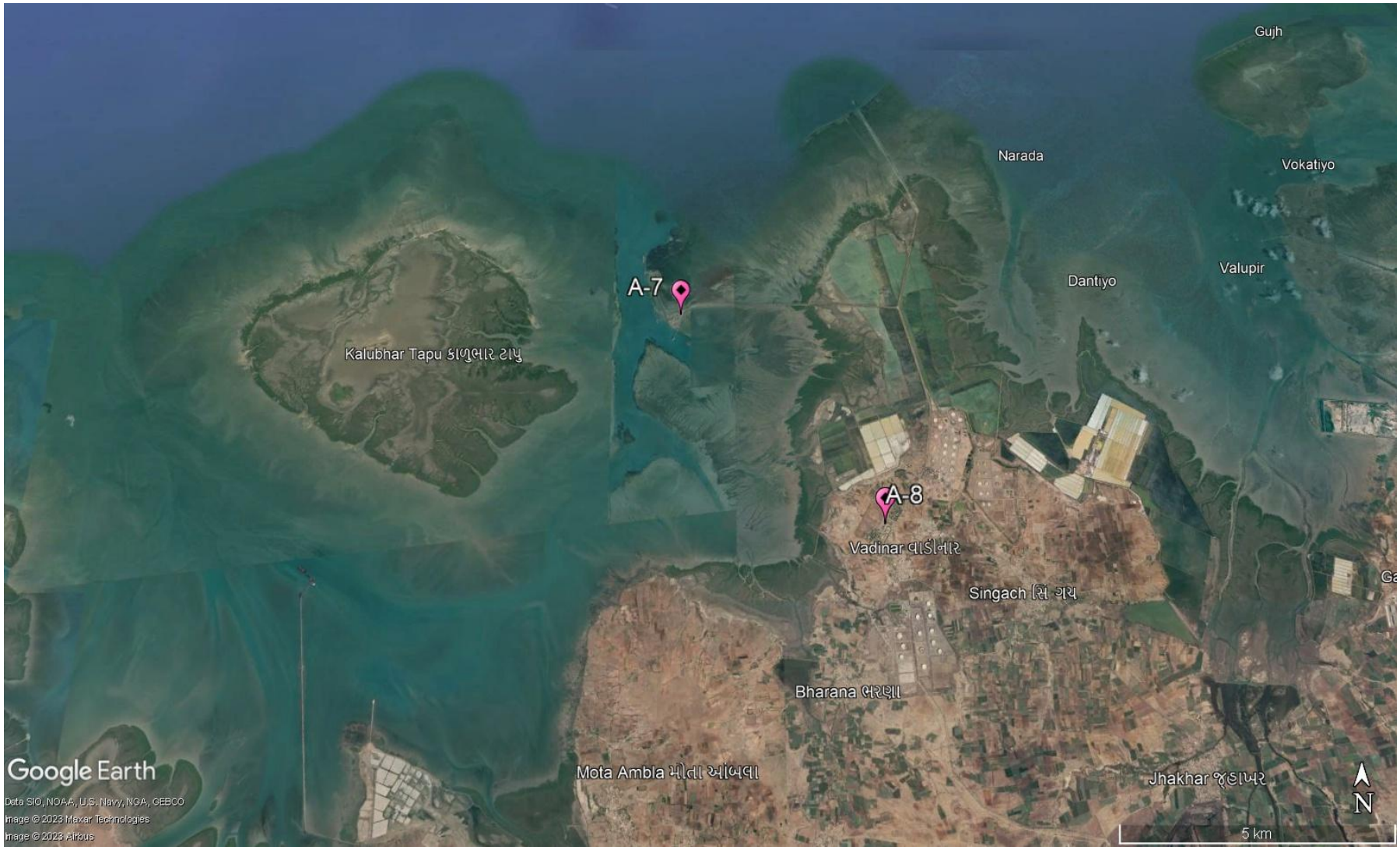
A-5: Coal Storage Area



A-6: Gopalpuri Hospital

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

Map 4: Locations for Ambient Air Monitoring at Kandla



Map 5: Locations for Ambient Air Monitoring at Vadinar

Frequency

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

Sampling and Analysis

The Sampling of the Ambient Air Quality parameters and analysis is conducted as per the CPCB guidelines of National Ambient Air Quality Monitoring. The sampling was performed at a height of 3.5 m (approximately) from the ground level. For the sampling of PM_{10}, calibrated 'Respirable Dust Samplers' were used, where Whatman GF/A microfiber filter paper of size 8"x 10" were utilized, where the Gaseous attachment of the make Envirotech instrument was attached with Respirable Dust Sampler for the measurement of SO_x and NO_x. The Fine Particulate Sampler for collection of $PM_{2.5}$ was utilized for the particulate matter of size <2.5 microns. A known volume of ambient air is passed through the cyclone to the initially pre-processed filter paper. The centrifugal force in cyclone acts on particulate matter to separate them into two parts and collected as following:

- Particles <10 µ size (Respirable): GF/A Filter Paper
- Particles <2.5 µ size (Respirable): Polytetrafluoroethylene (PTFE)

Sampling and analysis of ambient SO_2 was performed by adopting the 'Improved West and Gaeke Method'. The ambient air, drawn through the draft created by the RDS, is passed through an impinger, containing a known volume of absorbing solution of Sodium tetrachloromercurate, at a pre-determined measured flow rate of 1 liter/minute (L/min). Similarly, NO_x was performed by adopting the 'Jacob Hochheister Modified' (Na arsenite) method. The impinger contains known volume of absorbing solution of Sodium Arsenite and Sodium Hydroxide.

Data has been compiled for PM_{10}, $PM_{2.5}$, SO_x and NO_x samples of 24-hour carried out twice a week. In case of CO, one hourly sample were taken on selected monitoring days using the sensor-based CO Meter. For the parameters Benzene, Methane & Non-methane and Volatile Organic Carbons (VOCs), the Low Volume Sampler is used, where the charcoal tubes are used as sampling media. The sampling in the Low Volume Sampler (LVS) is carried out as per IS 5182 (Part 11): 2006 RA: 2017, where the ambient air flow rate is maintained at 200 cc/min, the volume of air that passes through the LVS during two hours monitoring is approx. 24 L.

The sampling of PAHs is carried out as per IS: 5182 (Part 12): 2004. Where, the EPM 2000 Filter papers are utilized in the Respirable Dust Sampler (RDS). For the parameters, Benzene, PAH & Non-methane VOC's, monthly monitoring is carried out. The details of the parameters with their frequency monitored are mentioned in **Table 5:**

Table 5: Parameters for Ambient Air Quality Monitoring

Sr. No.	Parameters	Units	Reference method	Instrument	Frequency
1.	PM_{10}	µg/m³	IS 5182 (Part 23): 2006	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-23): 2006	Twice in a week
2.	$PM_{2.5}$	µg/m³	IS:5182 (Part:24):2019	Fine Particulate Sampler (FPS) conforming to IS:5182 (Part-24): 2019	
3.	Sulphur Dioxide (SO_x)	µg/m³	IS 5182 (Part:2): 2001	Gaseous Attachment conforming to IS:5182 Part-2	
4.	Oxides of Nitrogen (NO_x)	µg/m³	IS:5182 (Part-6): 2006	Gaseous Attachment conforming to IS:5182 Part-6	
5.	Carbon Monoxide (CO)	mg/m³	GEMI/SOP/AAQM/11 ; Issue no 01, Date 17.01.2019: 2019	Sensor based Instrument	
6.	VOC	µg/m³	IS 5182 (Part 17): 2004	Low Flow Air Sampler	
8.	PAH	µg/m³	IS: 5182 (Part 12): 2004	Respirable Dust Sampler (RDS) conforming to IS:5182 (Part-12): 2004	Monthly
7.	Benzene	µg/m³	IS 5182 (Part 11): 2006 RA: 2017	Low Flow Air Sampler	
9.	Non-methane VOC	µg/m³	IS 5182 (Part 11): 2006	Low Volume Sampler	

4.2 Result and Discussion

The summarized results of ambient air quality monitoring for the study period are presented in **Table-6 to 9** along with the graphical representation from **Graph 1 to Graph 6.** Various parameters monitored during the study have been presented by their maximum, minimum, average and Standard deviation.

Table 6: Summarized results of PM_{10}, $PM_{2.5}$, SO_2, NO_x, VOC and CO for Ambient Air quality monitoring

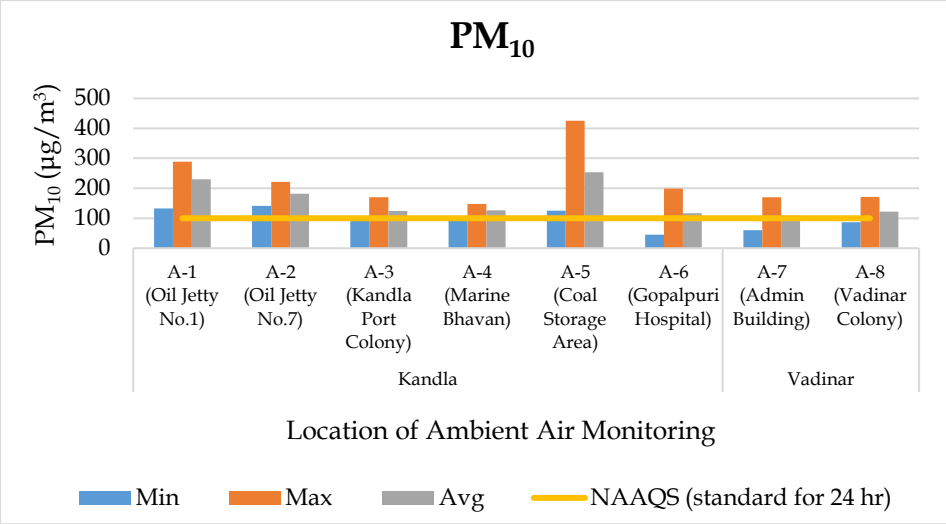
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	**PM_{10} (µg/m³)**	**$PM_{2.5}$ (µg/m³)**	**SO_2 (µg/m³)**	**NO_X (µg/m³)**	**VOC (µg/m³)**	**CO (mg/m³)**
	Duration	**(24 hr)**				**(2 hr)**	**(1 hr)**
	NAAQS by CPCB / **Monitoring days**	**100**	**60**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

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

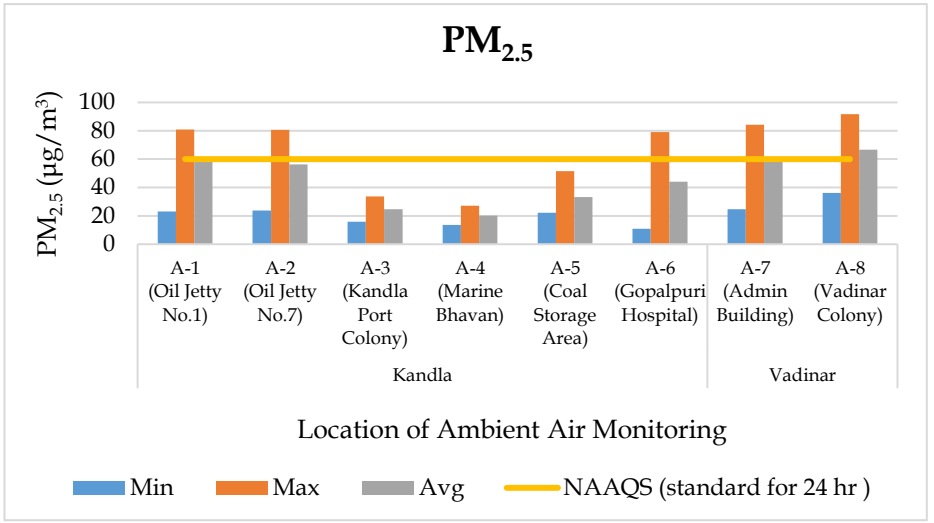
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
A-5: Coal Storage Area, Kandla	16-12-2024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

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

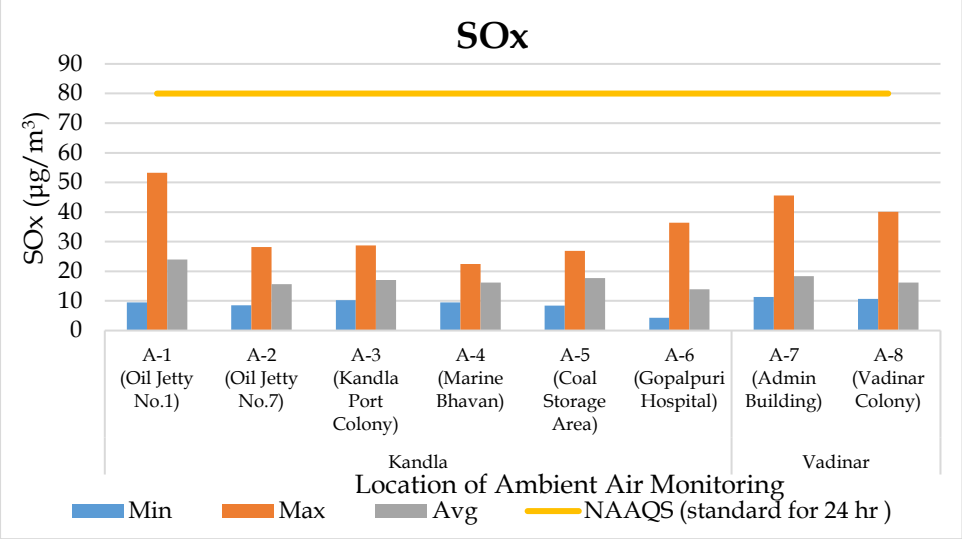
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar



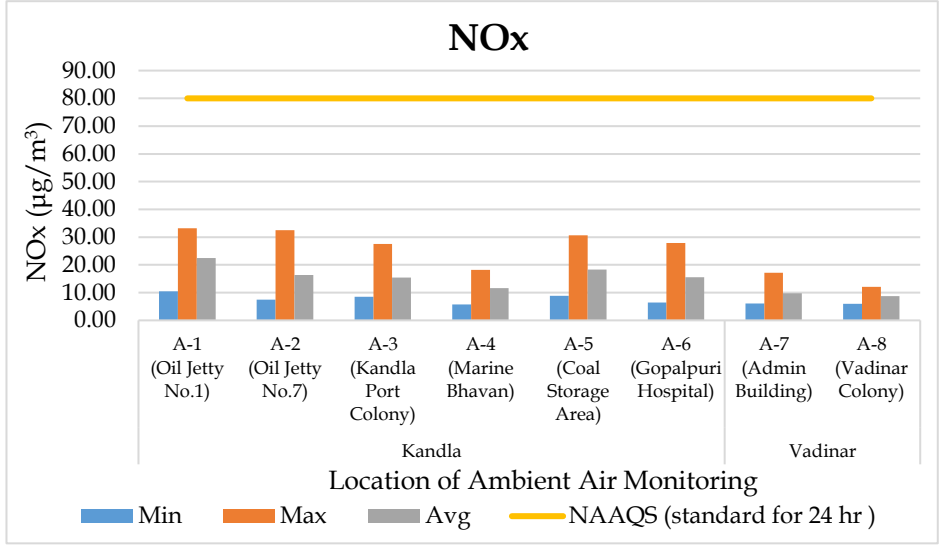
Graph 1: Spatial trend in Ambient PM_{10} Concentration



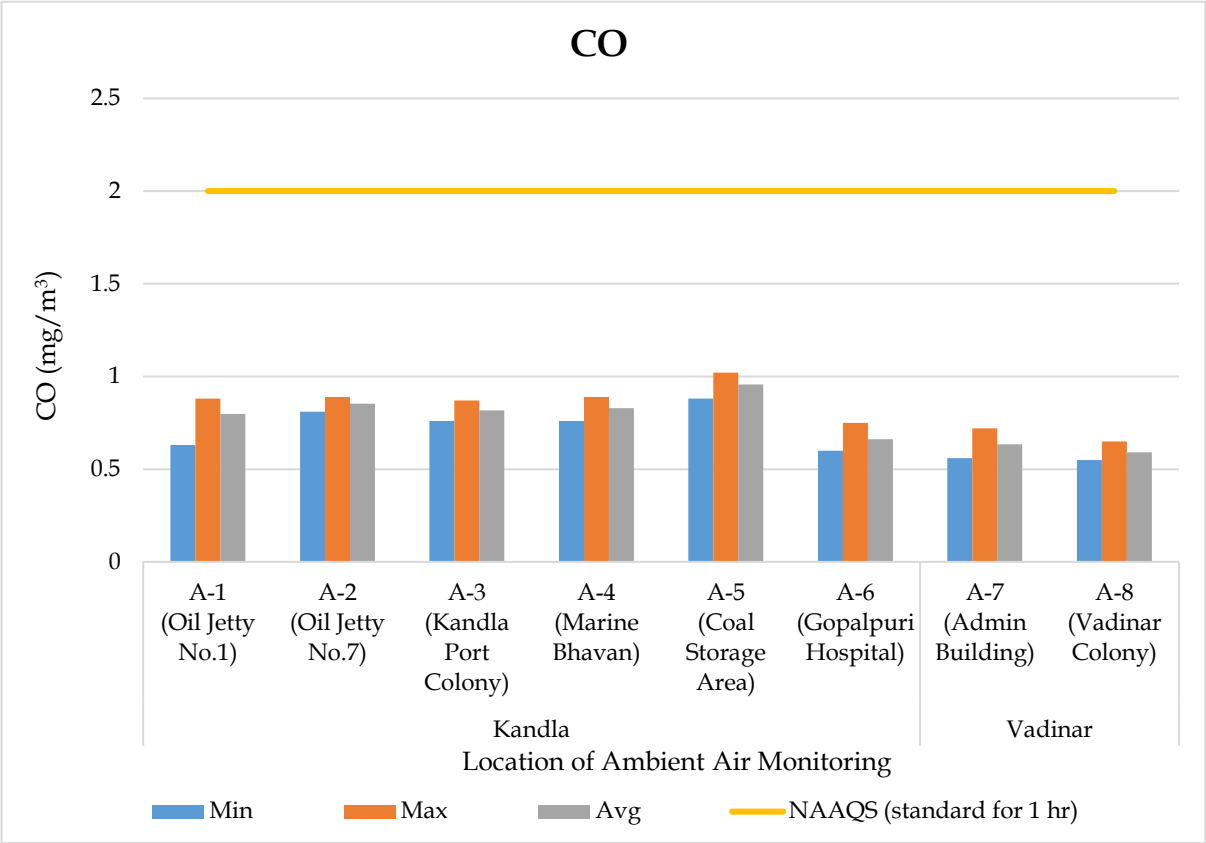
Graph 2: Spatial trend in Ambient $PM_{2.5}$ Concentration



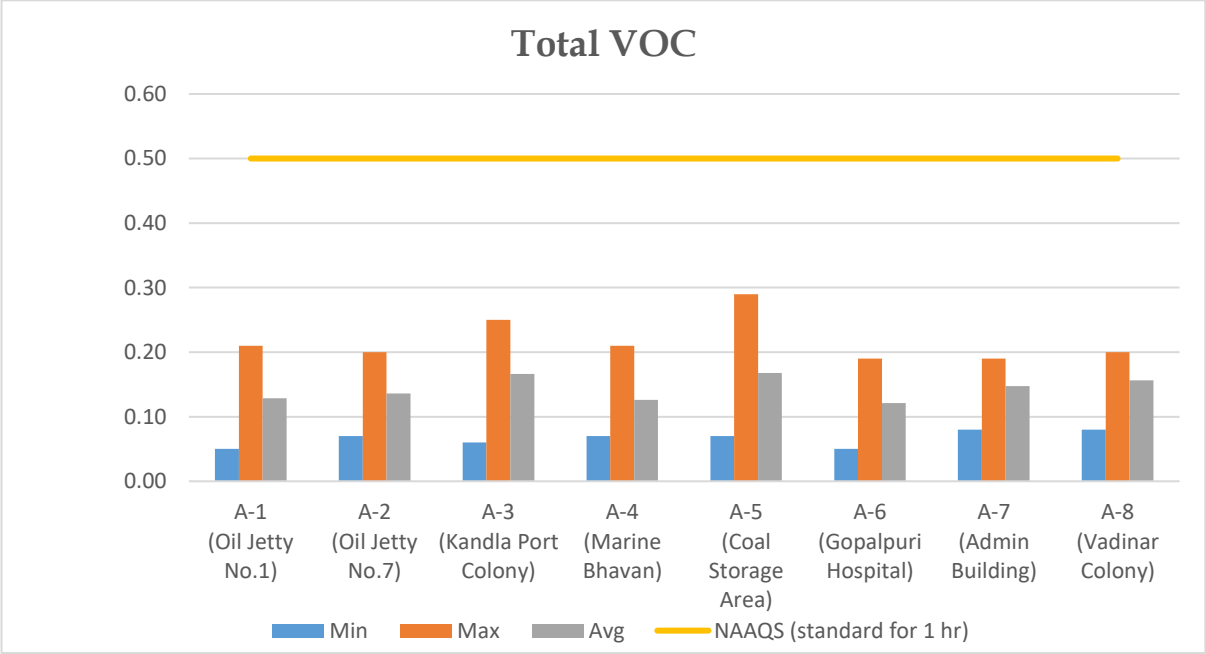
Graph 3: Spatial Trend in Ambient SOx Concentration



Graph 4: Spatial trend in Ambient Nox Concentration



Graph 5: Spatial trend in Ambient CO Concentration



Graph 6: Spatial trend in Ambient Total VOCs

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

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

Table 8: Summarized results of Polycyclic Aromatic Hydrocarbons

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

Table 9: Summarized results of Non-methane VOC

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

4.3 Data Interpretation and Conclusion

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

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

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

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

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

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

1. **Port Machinery:** Port activities involve the use of various machinery and equipment, including cranes, for lifts, tugboats, and cargo handling equipment. These machines often rely on diesel engines, which can emit pollutants such as NO_x, Particulate matter, and CO. Older or poorly maintained equipment tends to generate higher emissions.
2. **Port Vehicles:** Trucks and other vehicles operating within port and port area contributes to air pollution. Similar to port machinery, diesel-powered vehicles can emit NO_x, PM, CO, and other pollutants such as PAH, VOCs etc. Vehicle traffic and congestion in and around port areas can exacerbate the air quality issues.
3. Apart from that, construction and demolition activities majorly contribute to particulate matter pollution.

4.4 Remedial Measures:

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

- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle-Mask advised in sensitive areas. Covering vehicles with tarpaulin during transportation will help to reduce the suspension of pollutants in air.
- Frequent water sprinkling on roads to reduce dust suspension due to vehicular movement, this can be use during transporting coal to avoid suspension of coal dust.
- Use of proper transport methods, such as a conveyor belt, for excavated material and screens around the construction site.
- Temporary pavement of roads in construction site could considerably reduce dust emission. Prohibition of use of heavy diesel oil as fuel could be possibly reduce

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

- Investing in infrastructure for cold ironing allows ships to connect to the electrical grid while docked, reducing the need for auxiliary engines and associated emissions.
- Implementing efficient cargo-handling processes, optimizing logistics to reduce congestion and idling times, and encouraging use of cleaner port machinery and vehicles can all contribute to reducing air pollution in port areas.

CHAPTER 5: DG STACK MONITORING

5.1 DG Stack Monitoring

A diesel generator is a mechanical-electrical machine that produces electrical energy (electricity) from diesel fuel. They are used by the residential, commercial, charitable and governmental sectors to provide power in the event of interruption to the main power, or as the main power source. Diesel generating (DG) sets are generally used in places without connection to a power grid, or as an emergency power supply if the grid fails. These DG sets utilize diesel as fuel and generate and emit the air pollutants such as Suspended Particulate Matter, SO_2, NO_x, CO, etc. from the stack during its functioning. The purpose of stack sampling is to determine emission levels from plant processes to ensure they are in compliance with any emission limits set by regulatory authorities to prevent macro environmental pollution. The stack is nothing but chimney which is used to disperse the hot air at a great height, emissions & particulate matters that are emitted. Hence, monitoring of these stacks attached to DG Sets is necessary in order to quantify the emissions generated from it.

As defined in scope by DPA, the monitoring of DG Stack shall be carried out at two locations, one at Kandla and one at Vadinar. The details of the DG Sets at Kandla and Vadinar have been mentioned in **Table 10** as follows:

Table 10: Details of DG Stack monitoring locations

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

The map depicting the locations of DG Stack Monitoring to be monitored in Kandla and Vadinar have been mentioned in **Map 6 and 7** as follows:

Map 6: Locations for DG Stack monitoring at Kandla

Map 7: Locations for DG Stack monitoring at Vadinar

Methodology:

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

Table 11: DG stack parameters

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

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

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

Frequency

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

5.2 Result and Discussion

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

Table 12: DG monitoring data

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

5.3 Data Interpretation and Conclusion

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

CHAPTER 6: NOISE MONITORING

6.1 Noise Monitoring

Noise can be defined as an unwanted sound, and it is therefore, necessary to measure both the quality as well as the quantity of environmental noise in and around the study area. Noise produced during operation stage and the subsequent activities may affect surrounding environment impacting the fauna and as well as the human population. Under the scope, the noise monitoring is required to be carried out at 10 locations in Kandla and 3 locations in Vadinar. The sampling locations for noise are not only confined to commercial areas of DPA but also the residential areas of DPA.

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

Table 13: Details of noise monitoring locations

Sr. No.	Location Code		Location Name	Latitude/ Longitude
1.	Kandla	N-1	Oil Jetty 7	23.043527N 70.218456E
2.		N-2	West Gate No.1	23.006771N 70.217340E
3.		N-3	Canteen Area	23.003707N 70.221331E
4.		N-4	Main Gate	23.007980N 70.222525E
5.		N-5	Main Road	23.005194N 70.219944E
6.		N-6	Marin Bhavan	23.007618N 70.222087E
7.		N-7	Port & Custom Building	23.009033N 70.222047E
8.		N-8	Nirman Building	23.009642N 70.220623E
9.		N-9	ATM Building	23.009985N 70.221715E
10.		N-10	Wharf Area/ Jetty	22.997833N 70.223042E
11.	Vadinar	N-11	Near Main Gate	22.441544N 69.674495E
12.		N-12	Near Vadinar Jetty	22.441002N 69.673147E
13.		N-13	Port Colony Vadinar	22.399948N 69.716608E

Map 8: Locations for Noise Monitoring at Kandla

Map 9: Locations for Noise Monitoring at Vadinar

Methodology:

The intensity of sound energy in the environment is measured in a logarithmic scale and is expressed in a decibel (dB(A)) scale. The ordinary sound level meter measures the sound energy that reaches the microphone by converting it into electrical energy and then measures the magnitude in dB(A). Whereas, in a sophisticated type of sound level meter, an additional circuit (filters) is provided, which modifies the received signal in such a way that it replicates the sound signal as received by the human ear and the magnitude of sound level in this scale is denoted as dB(A). The sound levels are expressed in dB(A) scale for the purpose of comparison of noise levels, which is universally accepted. Noise levels were measured using an integrated sound level meter of the make Envirotech Sound Level Meter (Class-I) (model No. SLM-109). It has an indicating mode of Lp and Leq. Keeping the mode in Lp for few minutes and setting the corresponding range and the weighting network in "A" weighting set the sound level meter was run for one-hour time and Leq was measured at all locations.

Frequency

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

Table 14: Details of the Noise Monitoring

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

Standard for Noise

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

Table 15: Ambient Air Quality norms in respect of Noise

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

6.2 Result and Discussion

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

Table 16: The Results of Ambient Noise Quality

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

6.3 Data Interpretation and Conclusion

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

6.4 Remedial Measures

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

CHAPTER 7: SOIL MONITORING

7.1 Soil Quality Monitoring:

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

As defined in scope by Deendayal Port Authority (DPA), Soil Quality Monitoring shall be carried out at Six locations, four at Kandla and two at Vadinar. The details of the soil monitoring locations within the Port area of DPA are mentioned in **Table 17:**

Table 17: Details of the Soil quality monitoring

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

Methodology

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

The samples of soil collected from the locations of Kandla and Vadinar and analyzed for the various physico-chemical parameter. Collection and analysis of these samples was carried out as per established standard methods and procedures. The samples were analyzed for selected parameters to get the present soil quality status and environmental risks associated with various practices prevalent at the location. GEMI has framed its own guidelines for collection of soil samples titled as ***'Soil Sampling Manual'***. Soil samples were collected from 30 cm depth below the surface using scrapper, filled in polythene bags, labelled on-site with specific location code and name and sent to GEMI's laboratory, Gandhinagar for further detailed analysis. The samples collected from all locations are homogeneous representative of each location. The list of parameters to be monitored under the projects for the Soil Quality Monitoring been mentioned in **Table 18** as follows:

Frequency

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

Table 18: Soil parameters

Sr. No.	Parameters	Units	Reference method	Instruments
1.	TOC	%	Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934)	Titration Apparatus
2.	Organic Carbon	%		
3.	Inorganic Phosphate	Kg/Hectare	Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017 Determination of Available Phosphorus in Soil	UV-Visible Spectrophotometer
4.	Texture	-	Methods Manual Soil Testing in India January 2011,01	Hydrometer
5.	pH	-	IS 2720 (Part 26): 1987	pH Meter
6.	Conductivity	µS/cm	IS 14767: 2000	Conductivity Meter
7.	Particle size distribution & Silt content	-	Methods Manual Soil Testing in India January 2011	Sieves Apparatus
8.	SAR	meq/L	Procedures for Soil Analysis, International Soil Reference and Information Centre, 6th Edition 2002 13-5.5.3 Sodium Absorption Ratio (SAR), Soluble cations	Flame Photometer
9.	Water Holding Capacity	%	NCERT, Chapter 9, 2022-23 and Water Resources Department Laboratory Testing Procedure for Soil & Water Sample Analysis	Muffle Furnace
10.	Aluminium	mg/Kg	EPA Method 3051A	ICP-OES
11.	Chromium	mg/Kg		
12.	Nickel	mg/Kg		
13.	Copper	mg/Kg	Methods Manual Soil Testing in India January, 2011, 17a	
14.	Zinc	mg/Kg	Methods Manual Soil Testing in India January, 2011, 17a	
15.	Cadmium	mg/Kg	EPA Method 3051A	
16.	Lead	mg/Kg		
17.	Arsenic	mg/Kg		
18.	Mercury	mg/Kg		

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

Map 10: Locations for Soil Quality Monitoring at Kandla

Map 11: Locations for Soil Quality Monitoring at Vadinar

7.2 Result and Discussion

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

Table 19: Soil Quality for the sampling period

Sr. No	Location / Parameters	Unit	Kandla				Vadinar	
			S-1 (Oil Jetty 7)	S-2 IFFCO Plant)	S-3 (Khori Creek)	S-4 (Nakti Creek)	S-5 (Near SPM)	S-6 (Near Vadinar Jetty)
1	pH	-	8.73	8.25	8.51	8.44	7.85	8.38
2	Conductivity	µS/cm	12210	13780	2630	15690	271	231
3	Inorganic Phosphate	Kg/ha	0.68	1.62	1.94	1.28	0.87	0.86
4	Organic Carbon	%	0.41	0.39	0.3	0.78	0.35	0.82
5	Organic Matter	%	0.71	0.67	0.52	1.35	0.6	1.42
6	SAR	meq/L	18.31	12.29	1.31	13.21	0.10	0.13
7	Aluminium	mg/Kg	12387	11554	8105	11739	34107	31358.80
8	Chromium	mg/Kg	52.24	52.52	49.18	58.81	69.59	71.12
9	Nickel	mg/Kg	22.89	15.87	21.32	28.84	28.84	32.53
10	Copper	mg/Kg	77.03	85.80	70.86	24.96	89.51	76.23
11	Zinc	mg/Kg	73.96	95.08	61.84	63.50	62.67	63.70
12	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
14	Arsenic	mg/Kg	0.95	0.93	2.31	3.86	0.35	0.72
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	52	47.2	48.8	60	47.2	65.59
17	Sand	%	61.69	67.68	70.4	57.69	78.24	78.96
18	Silt	%	26	32	21.28	39.99	20	14
19	Clay	%	12.32	0.32	8.32	2.32	1.76	7.04
20	Texture	-	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	Loamy sand

7.3 Data Interpretation and Conclusion

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

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

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

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

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

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

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

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

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

Heavy Metals

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

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

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

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

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

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

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

CHAPTER 8: DRINKING WATER MONITORING

8.1 Drinking Water Monitoring

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

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

Table 20: Details of Drinking Water Sampling Locations

Sr. No.	Location Code		Location Name	Latitude/ Longitude
1.	Kandla	DW-1	Oil Jetty 7	23.043527N 70.218456E
2.		DW-2	Shramdeep	23.009631N, 70.220877E
3.		DW-3	North Gate	23.007938N 70.222411E
4.		DW-4	Workshop	23.009372N 70.222236E
5.		DW-5	Canteen Area	23.003707N 70.221331E
6.		DW-6	West Gate 1	23.006771N 70.217340E
7.		DW-7	Sewa Sadan -3	23.009779N 70.221838E
8.		DW-8	Nirman Building	23.009642N 70.220623E
9.		DW-9	Custom Building	23.018930N 70.214478E
10.		DW-10	Port Colony Kandla	23.019392N 70.212619E
11.		DW-11	Wharf Area/ Jetty	22.997833N 70.223042E
12.		DW-12	Hospital Kandla	23.018061N 70.212328E
13.		DW-13	A.O. Building	23.061914N 70.144861E
14.		DW-14	School Gopalpuri	23.083619N 70.132061E
15.		DW-15	Guest House	23.078830N 70.131008E
16.		DW-16	E- Type Quarter	23.083306N 70.132422E
17.		DW-17	F- Type Quarter	23.077347N 70.135731E
18.		DW-18	Hospital Gopalpuri	23.081850N 70.135347E
19.	Vadinar	DW-19	Near Vadinar Jetty	22.440759N 69.675210E
20.		DW-20	Near Port Colony	22.401619N 69.716822E

Map 12: Locations for Drinking Water Monitoring at Kandla

Map 13: Locations for Drinking Water Monitoring at Vadinar

Methodology

The water samples were collected from the finalized sampling locations and analyzed for physico-chemical and microbiological parameter, for which the analysis was carried out as per APHA, 23rd Edition and Indian Standard method in GEMI's NABL Accredited Laboratory, Gandhinagar. GEMI has followed the CPCB guideline as well as framed its own guidelines for the collection of water/wastewater samples, under the provision of Water (Preservation and Control of Pollution) Act 1974, titled as '**Sampling Protocol for Water & Wastewater**'; approved by the Government of Gujarat vide letter no. ENV-102013-299-E dated 24-04-2014. The samples under the study were collected and preserved as per the said Protocol. The parameters finalized to assess the drinking water quality have been mentioned in **Table 21** as follows:

Table 21: List of parameters for Drinking Water Quality monitoring

Sr. No.	Parameters	Units	Reference method	Instrument
1.	pH	-	APHA, 23rd Edition (Section-4500-H^+B):2017	pH Meter
2.	Colour	Hazen	APHA, 23rd Edition, 2120 B:2017	Color Comparator
3.	EC	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
4.	Turbidity	NTU	APHA, 23rd Edition (Section -2130 B):2017	Nephlo Turbidity Meter
5.	TDS	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with filtration assembly and Oven
6.	TSS	mg/L	APHA, 23rd Edition, 2540 D: 2017	
7.	Chloride	mg/L	APHA, 23rd Edition (Section-4500-Cl-B):2017	Titration Apparatus
8.	Total Hardness	mg/L	APHA, 23rd Edition (Section-2340 C):2017	
9.	Ca Hardness	mg/L	APHA, 23rd Edition (Section-3500-Ca B):2017	
10.	Mg Hardness	mg/L	APHA, 23rd Edition (Section-3500-Mg B):2017	
11.	Free Residual Chlorine	mg/L	APHA 23rd Edition, 4500	
12.	Fluoride	mg/L	APHA, 23rd Edition (Section-4500-F-D):2017	UV- Visible Spectrophotometer
13.	Sulphate	mg/L	APHA, 23rd Edition (Section 4500-SO4-2-E):2017	
14.	Sodium	mg/L	APHA, 23rd Edition (Section-3500-Na-B):2017	Flame Photometer
15.	Potassium	mg/L	APHA,23rd Edition, 3500 K-B: 2017	
16.	Salinity	mg/L	APHA, 23rd Edition (section 2520 B, E.C. Method)	Salinity /TDS Meter
17.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3- B: 2017	UV- Visible Spectrophotometer

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

8.2 Result and Discussion

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

Table 22: Summarized results of Drinking Water quality

Sr. No.	Parameters	Units	Standard values as per IS		Kandla																	Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
1.	pH	-	6.5-8.5	-	8.40	7.20	7.54	7.41	7.02	7.99	7.36	7.16	6.91	6.93	7.99	7.15	7.50	6.96	6.99	7.10	7.08	6.76	6.90	6.79
2.	Colour	Hazen	5	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.	EC	µS/ cm	-	-	125.5	279	23.1	43.9	50	149	23	25.4	61.4	217	138	212	65.4	203	174.4	49.2	29.7	126.8	165.3	105.6
4.	Salinity	PSU	-	-	0.06	0.13	0.02	0.03	0.03	0.06	0.02	0.02	0.03	0.11	0.09	0.10	0.04	0.10	0.09	0.03	0.02	0.06	0.08	0.05
5.	Turbidity	NTU	1	5	0.59	0.64	0.56	0.71	0.64	0.65	0.65	0.69	0.73	BQL	0.98	BQL	0.52	0.71	BQL	BQL	0.63	0.83	BQL	BQL
6.	Chloride	mg/L	250	1000	28.58	60.12	7.88	13.80	11.50	111.97	7.88	7.88	16.75	45.33	109.97	45.33	17.74	48.29	43.36	15.77	9.86	35.48	20.70	13.80
7.	Total Hardness	mg/L	200	600	16	40	2	2	5	180	2	2.5	7	42	160	34	8	26	10	4	2	6	54	22
8.	Ca Hardness	mg/L	-	-	8	18	1.5	1.5	3	100	1.5	2	4	24	90	18	2	12	8	2.5	1.5	4	26	12
9.	Mg Hardness	mg/L	-	-	8	22	BQL	BQL	2	80	BQL	BQL	3	18	70	16	6	14	2	1.5	BQL	2	28	10
10.	Free Residual Chlorine	mg/L	0.2	1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
11.	TDS	mg/L	500	2000	66	92	12	22	26	342	12	14	32	112	346	108	34	106	90	26	16	66	84	54
12.	TSS	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
13.	Fluoride	mg/L	1.0	1.5	BQL	BQL	BQL	0.62	BQL	0.435	BQL	BQL	BQL	BQL	0.349	BQL	BQL	BQL	0.35	BQL	BQL	BQL	BQL	BQL
14.	Sulphate	mg/L	200	400	BQL	15.25	BQL	BQL	BQL	36.66	BQL	BQL	BQL	11.59	35.50	10.59	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
15.	Nitrate	mg/L	45	-	BQL	1.635	BQL	BQL	1.040	5.851	BQL	BQL	BQL	1.236	5.470	1.246	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
16.	Nitrite	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	0.033	BQL	BQL	BQL	BQL	0.263	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17.	Sodium	mg/L	-	-	19.91	30.35	BQL	BQL	7.26	76.79	BQL	BQL	BQL	17.55	71.89	16.59	5.08	19.27	16.79	BQL	BQL	5.25	8.67	5.06
18.	Potassium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

Sr. No.	Parameters	Units	Standard values as per IS		Kandla																	Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
19.	Hexavalent Chromium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	TON	Agreeable		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	0.01	0.05	BQL	BQL	BQL	BQL	BQL	9.792	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	0.003	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	0.05	1.5	BQL	BQL	BQL	BQL	0.0072	BQL	BQL	BQL	0.0080	0.0062	BQL	0.0058	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.0086
24.	Iron	mg/L	0.3	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.139	BQL	BQL
25.	Lead	mg/L	0.01	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.00335	BQL
26.	Manganese	mg/L	0.1	0.3	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
27.	Mercury	mg/L	0.001	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
28.	Total Chromium	mg/L	0.05	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Zinc	mg/L	5	15	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Total Coliform*	MPN/ 100ml	Shall not be detected		150	BQL	BQL	BQL	BQL	BQL	BQL	10	BQL	BQL	85	BQL	65	40	110	20	BQL	170	235	BQL

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

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

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

8.3 Data Interpretation and Conclusion

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

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

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

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

8.4 Remedial Measures

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

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

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

CHAPTER 9: SEWAGE TREATMENT PLANT MONITORING

9.1 Sewage Treatment Plant (STP) Monitoring:

The principal objective of STP is to remove contaminants from sewage to produce an effluent that is suitable to discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. As defined in the scope by Deendayal Port Authority (DPA), Kandla, the STP Monitoring is to be carried out weekly at three locations, one at Kandla, one at Gopalpuri and one STP at Vadinar. The samples from the inlet and outlet of the STP have been collected weekly. The details of the locations of STP to be monitored for Kandla and Vadinar have been mentioned in **Table 23** as follows:

Table 23: Details of the monitoring locations of STP

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

The Consolidated Consent and Authorization (CC&A) issued by the GPCB were referred for the details of the STP for Kandla and Gopalpuri. The CC&A of Kandla and Gopalpuri entails that the treated domestic sewage should conform to the norms specified in **Table 24**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

Table 24: Treated effluent Standards (as per CC&A of Kandla STP)

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

The detailed process flow diagram of the Kandla and Gopalpuri STP have been mentioned in **Figure 3 and 4** as follows:

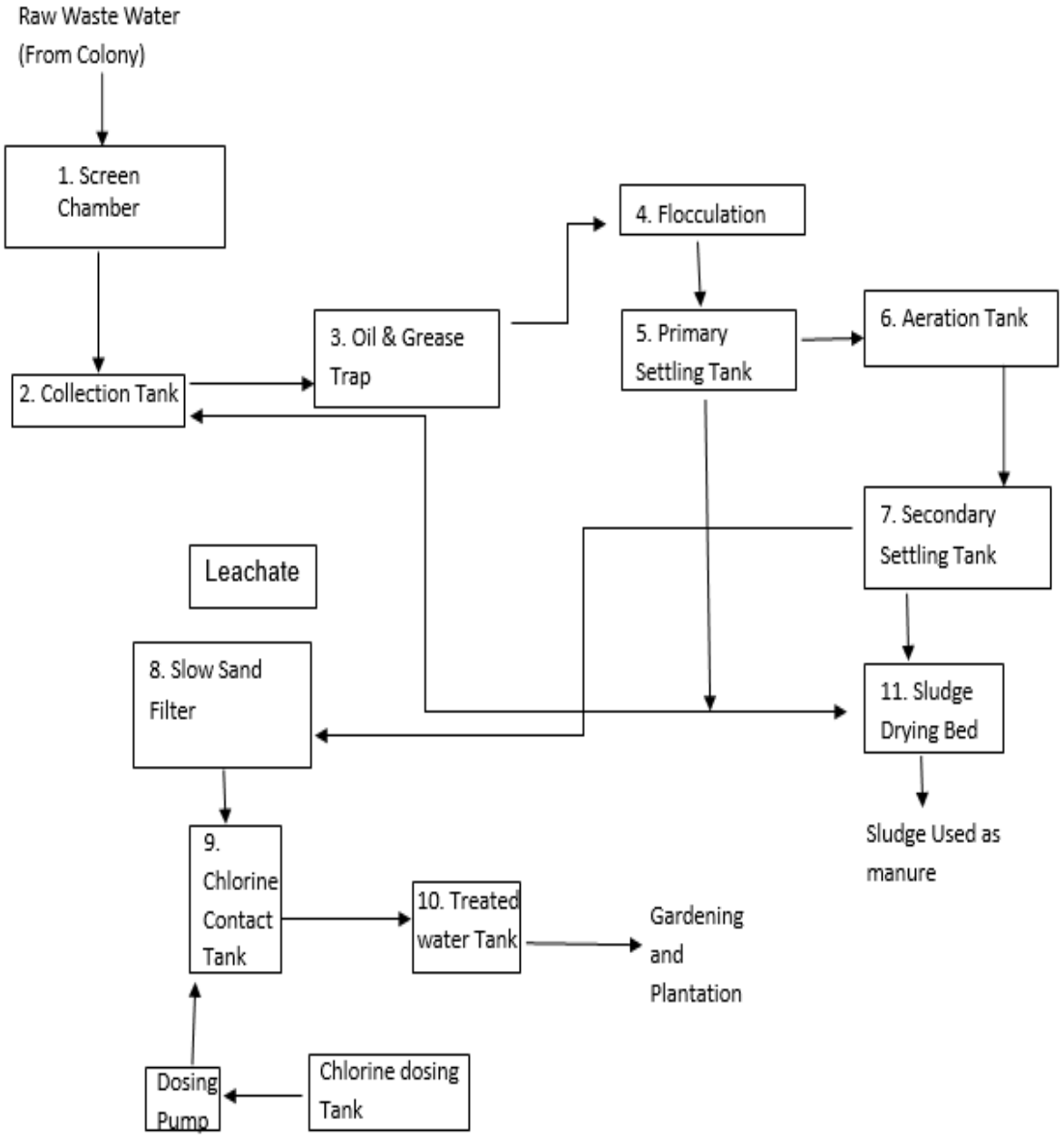


Figure 3: Process flow diagram of STP at Kandla

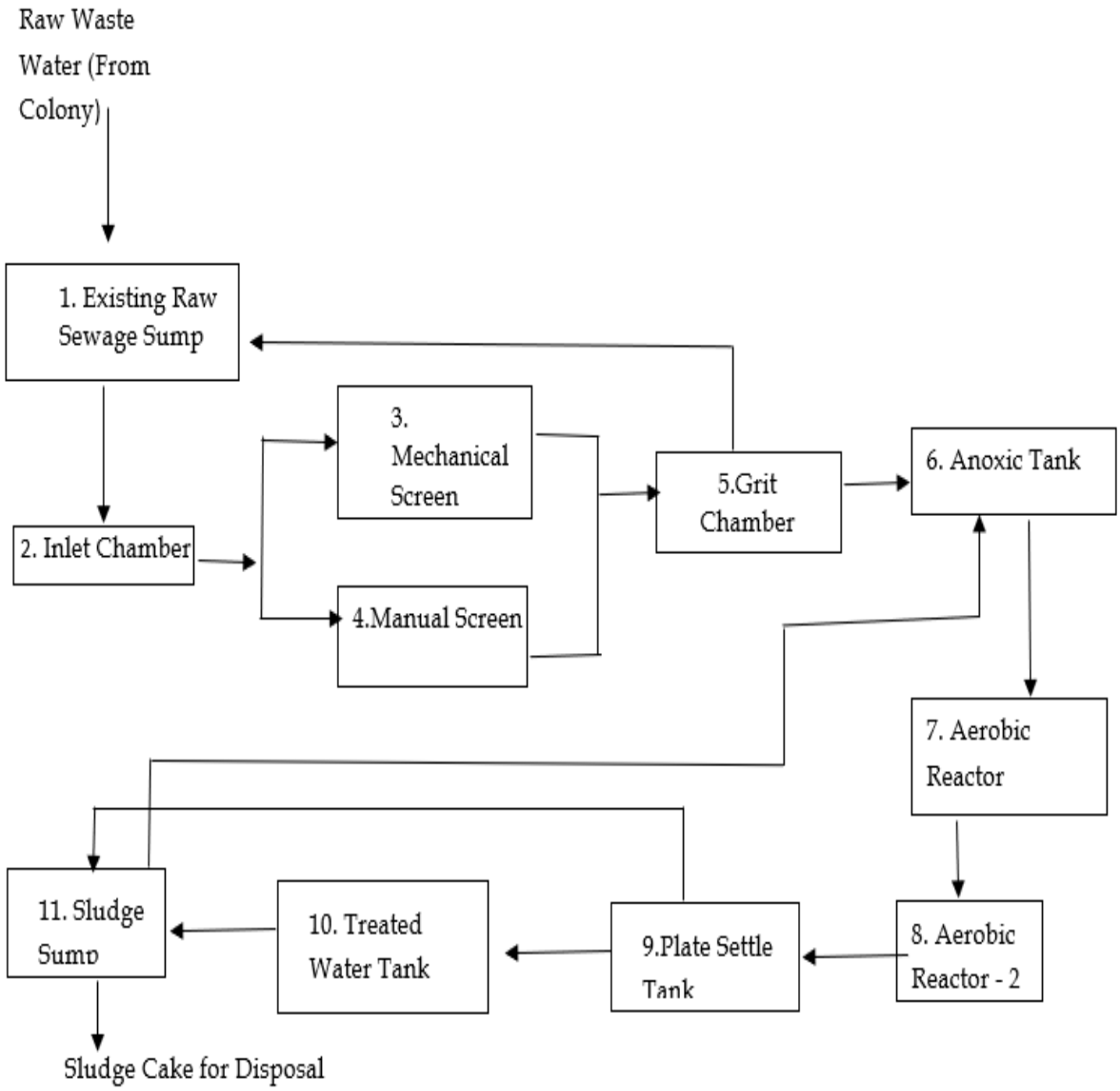


Figure 4: Process flow diagram of STP at Gopalpuri

STP at Vadinar

The STP at Vadinar has been built with a treatment capacity of 450 KLD/day. The Consolidated Consent and Authorization (CC&A) issued by the GPCB has been referred for the details of the said STP. The CC&A of the Vadinar STP suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 25**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

Table 25: Norms of treated effluent as per CC&A of Vadinar STP

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

The detailed process flow diagram of the Vadinar STP have been mentioned in **Figure 5** as follows:

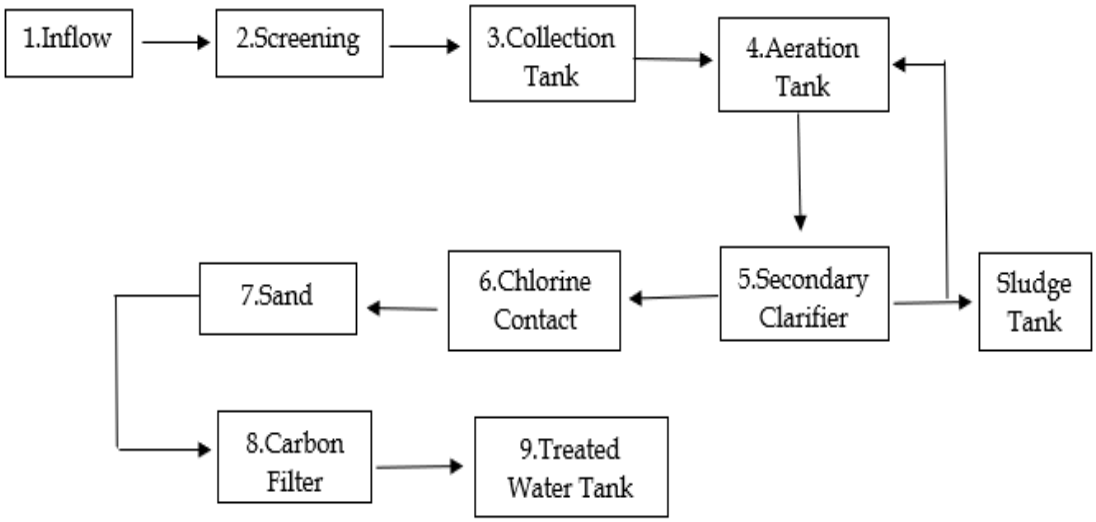
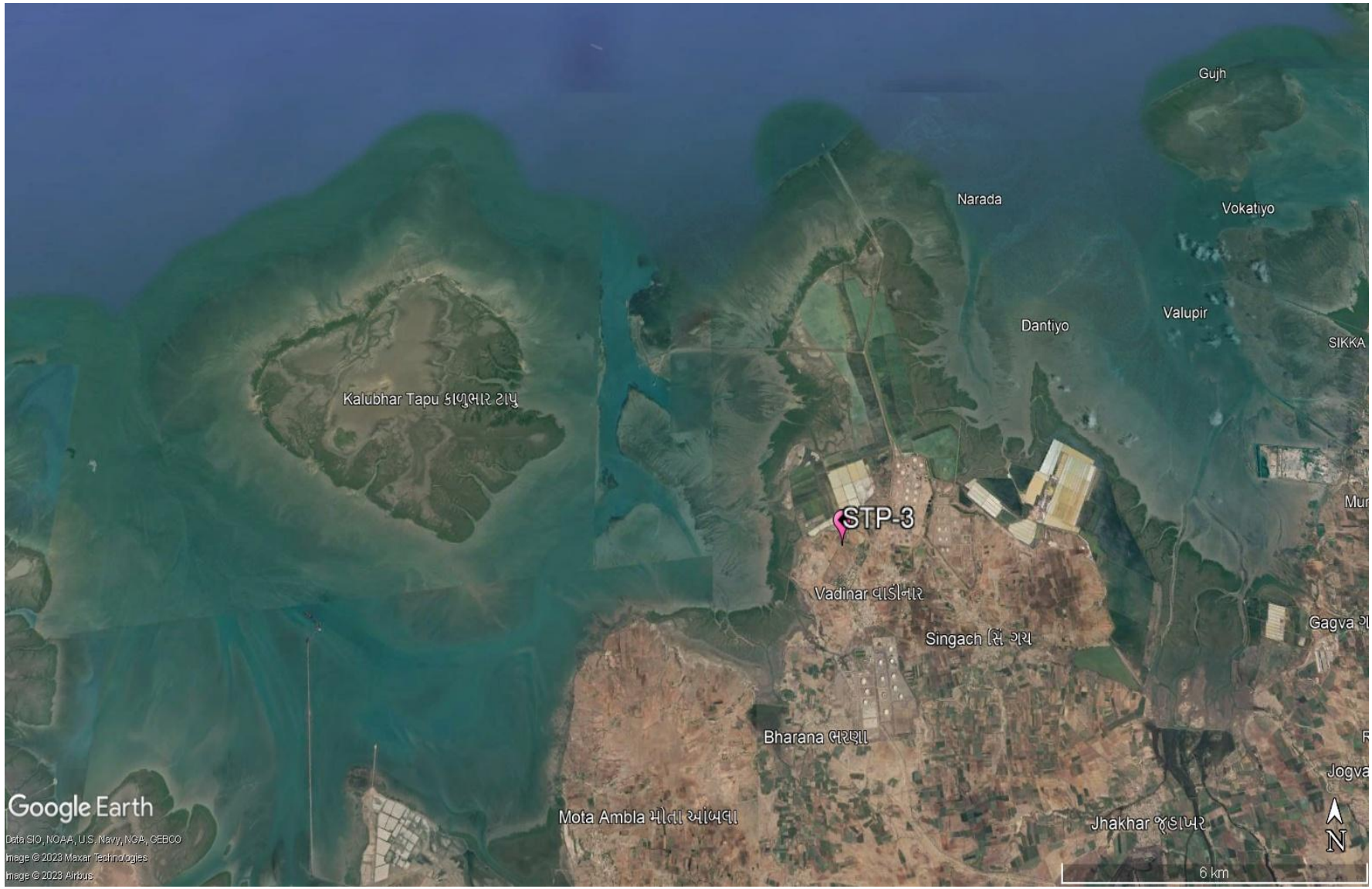


Figure 5: Process flowchart for the STP at Vadinar

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

Map 14: Locations for STP Monitoring at Kandla



Map 15: Locations for STP Monitoring at Vadinar

Methodology

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

The water samples were collected from inlet and the outlet of the STP's and analyzed for physico-chemical and microbiological parameter. Collection and analysis of these samples was carried out as per established standard methods and procedures for the examination of water. The samples were analyzed for selected parameters to establish the existing water quality of the inlet and outlet points of the STP. GEMI has framed its own guidelines for collection of water/wastewater samples titled as 'Sampling Protocol for Water & Wastewater'; which has been approved by the Government of Gujarat vide letter no. ENV-102013-299-E dated 24-04-2014 under the provision of Water (Preservation and Control of Pollution) Act 1974. The sample collection and preservation are done as per the said Protocol. Under the project, the list of parameters to be monitored for the STP have been mentioned in **Table 26** as follows:

Frequency

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

Table 26: List of parameters monitored for STP's at Kandla and Vadinar

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

9.2 Result and Discussion

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

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

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

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

Sr No.	Parameter	Units	GPCB Norms (Vadinar)	Week 3 of December		Week 4 of December		Week 1 of January		Week 2 of January	
				STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)
1.	pH	-	**6.5-8.5**	7.28	7.44	7.15	7.20	6.52	7.12	7.03	7.16
2.	TDS	mg/L	-	408	382	488	374	418	362	424	358
3.	TSS	mg/L	**20**	8	4	72	10	90	6	38	4
4.	COD	mg/L	**50**	168.0	56.0	293.2	52.2	498.0	32.4	196.8	36.1
5.	DO	mg/L	-	1.2	8.4	0.7	7.0	BQL	6.0	1.5	6.9
6.	BOD	mg/L	**10**	50.40	5.60	91.63	6.53	149.40	3.24	59.04	3.61
7.	SAR	meq/L	-	2.21	2.60	1.37	2.31	2.13	2.21	2.45	1.96
8.	Total Coliforms	MPN/100ml	**100-230**	1600	1600	1600	1600	1600	1600	1600	1600

BQL: Below Quantification limit; Total Suspended Solids (QL=2), Dissolved Oxygen (QL=0.5), Biochemical Oxygen Demand (QL=3 mg/L)

9.3 Data Interpretation and Conclusion

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

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

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

9.4 Remedial Measures:

- The quantum of raw sewage (influent) entering the STP should be monitored by installation of the flow meter. If the quantity of the sewage exceeds the treatment capacity of the treatment plant, then provision of additional capacity of collection sump should be provided.
- The adequacy and efficacy of the stages of Sewage treatment units shall be conducted.
- The results show the presence of total coliforms; hence the method of disinfection (Chlorination) sodium or calcium Hypochlorite can be used.
- Effectiveness of any technology depends on factors such as the specific pollutants in the wastewater, plant size, local regulations, and available resources. There are several processes that may be implemented such as - Advanced oxidation process involve using strong oxidants to break down complex organic compounds. Methods like Fenton's reagent (hydrogen peroxide and iron catalyst) and UV/H_2O_2 treatment can help in reducing COD through oxidation.

- Electrochemical processes like Electrocoagulation (EC) and Electrooxidation (EO) that involve the application of an electric current to facilitate the removal of pollutants through coagulation, flocculation, and oxidation. These methods can be useful for treating sewage containing various pollutants.

CHAPTER 10: MARINE WATER QUALITY MONITORING

10.1 Marine Water

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

Major water quality concerns at ports include wastewater and leakage of toxic substances from ships, stormwater runoff, etc. This discharge of wastewater, combined with other ship wastes which includes sewage and wastewater from other on-board uses, is a serious threat to the water quality as well as to the marine life. As defined in the scope by DPA, the Marine Water sampling and analysis has to be carried out at a total of eight locations, six at Kandla and two at Vadinar. The marine water sampling has been carried out with the help of Niskin Sampler with a capacity of 5L. The Niskin Sampler is a device used to take water samples at a desired depth without the danger of mixing with water from other depths. Details of the locations to be monitored have been mentioned in **Table 29:**

Table 29: Details of the sampling locations for Marine water

Sr. No.	Location Code		Location Name	Latitude Longitude
1.	Kandla	MW-1	Near Passenger Jetty One	23.017729N 70.224306E
2.		MW-2	Kandla Creek (nr KPT Colony)	23.001313N 70.226263E
3.		MW-3	Near Coal Berth	22.987752N70.227923E
4.		MW-4	Khori Creek	22.977544N 70.207831E
5.		MW-5	Nakti Creek (nr Tuna Port)	22.962588N 70.116863E
6.		MW-6	Nakti Creek (nr NH-8A)	23.033113N 70.158528E
7.	Vadinar	MW-7	Near SPM	22.500391N 69.688089E
8.		MW-8	Near Vadinar Jetty	22.440538N 69.667941E

The map depicting the locations of Marine Water to be sampled and analysed for Kandla and Vadinar have been mentioned in **Map 16 and 17** as follows:

Map 16: Locations for Marine Water Monitoring at Kandla

Map 17: Locations for Marine Water Monitoring at Vadinar

Methodology

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

Frequency:

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

Table 30: List of parameters monitored for Marine Water

Sr. No	Parameters	Units	Reference method	Instrument
1.	Electrical Conductivity	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
2.	Dissolved Oxygen (DO)	mg/L	APHA, 23rd Edition, 4500 O C, 2017	Titration Apparatus
3.	pH	-	APHA, 23rd Edition (Section-4500-H+B):2017	pH meter
4.	Color	Hazen	APHA, 23rd Edition, 2120 B: 2017	Color comparator
5.	Odour	-	IS 3025 Part 5: 2018	Heating mantle & odour bottle
6.	Turbidity	NTU	IS 3025 Part 10: 1984	Nephlo Turbidity Meter
7.	Total Dissolved Solids (TDS)	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with Filtration Assembly and Oven
8.	Total Suspended Solids (TSS)	mg/L	APHA, 23rd Edition, 2540 D: 2017	
9.	Particulate Organic Carbon	mg/L	APHA, 23rd Edition, 2540 D and E	TOC analyser
10.	Chemical Oxygen Demand (COD)	mg/L	IS-3025, Part- 58: 2006	Titration Apparatus plus Digester
11.	Biochemical Oxygen Demand (BOD)	mg/L	IS-3025, Part 44,1993,	BOD Incubator plus Titration apparatus
12.	Silica	mg/L	APHA, 23rd Edition, 4500 C, 2017	UV- Visible Spectrophotometer
13.	Phosphate	mg/L	APHA, 23rd Edition, 4500 P-D: 2017	
14.	Sulphate	mg/L	APHA, 23rd Edition, 4500 SO4-2 E: 2017	
15.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3-B: 2017	

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

10.2 Result and Discussion

The quality of the Marine water samples collected from the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 31**. The said water quality has been represented in comparison with the standard values as stipulated by CPCB for Class SW-IV Waters.

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

Sr. No.	Parameters	Unit	Primary Water Quality Criteria for Class SW-IV Waters	Kandla						Vadinar	
				MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8
1.	Density	kg/m³	-	1.021	1.02	1.02	1.021	1.022	1.021	1.02	1.021
2.	pH	-	6.5-9.0	8.13	8.11	8.19	8.24	8.12	8.2	8.19	8.24
3.	Color	Hazen	No Noticeable	5	5	5	5	5	5	5	5
4.	EC	µS/cm	-	51,500	52,300	54,100	54,300	52,400	51,800	54,100	54,300
5.	Turbidity	NTU	-	97	125	4.12	3.42	131	112	4.12	3.42
6.	TDS	mg/L	-	33,326	37,182	32,478	33,142	34,109	33,806	32,478	33,142
7.	TSS	mg/L	-	347	421	115	195	332	411	115	195
8.	COD	mg/L	-	32.7	30.9	47.89	51.26	31.56	33.11	47.89	51.26
9.	DO	mg/L	3.0 mg/L	5.9	6.3	6.1	5.7	6.1	5.8	6.1	5.7
10.	BOD	mg/L	5.0 mg/L	8.15	8.3	7.42	7.13	10.2	9.92	7.42	7.13
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	2364.6	2684.7	2897.4	3157.3	2739.8	2457.3	2897.4	3157.3
13.	Nitrate	mg/L	-	4.63	3.48	3.41	2.980	3.86	4.12	3.41	2.980
14.	Nitrite	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
15.	Phosphate	mg/L		BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
16.	Silica	mg/L	-	3.01	2.71	0.93	0.79	3.83	2.76	0.93	0.79
17.	Sodium	mg/L	-	9485	9206	9,827	9,541	9642	9468	9,827	9,541
18.	Potassium	mg/L	-	360.21	320	421.7	391.40	347.60	247.67	421.7	391.40
19.	Hexavalent Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	-	-	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	-	BQL	6.22	BQL	BQL	6.68	BQL	BQL	BQL
24.	Iron	mg/L	-	1.831	2.281	0.586	0.378	1.819	2.192	0.586	0.378
25.	Lead	mg/L	-	3.16	3.22	2.412	2.984	2.41	3.36	2.412	2.984
26.	Manganese	mg/L	-	92.18	134.29	42.57	BQL	92.74	116.68	42.57	BQL
27.	Total Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
28.	Zinc	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Mercury	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Particulate Organic Carbon	mg/L	-	1.08	0.68	0.55	0.72	0.98	1.18	0.65	0.72
31.	Total Coliforms	MPN/ 100ml	500/100 ml	16	15	10	24	10	15	10	24

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

10.3 Data Interpretation and Conclusion

The Marine water quality of Deendayal Port Harbor waters at Kandla and Vadinar has been monitored for various physico-chemical and biological parameters during the monitoring period. The detailed interpretation of the parameters in comparison to the Class SW-IV for Harbour Waters is as follows:

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

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

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

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

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

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

CHAPTER 11: MARINE SEDIMENT QUALITY MONITORING

11.1 Marine Sediment Monitoring

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

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

Methodology

As defined in the scope by DPA, the Marine Sediment sampling is required to be carried out once in a month at total eight locations, i.e., six at Kandla and two at Vadinar. The sampling of the Marine Sediment is carried out using the Van Veen Grab Sampler (make Holy Scientific Instruments Pvt. Ltd). The Van Veen Grab sampler is an instrument to sample (disturbed) sediment up to a depth of 20-30 cm into the sea bed. While letting the instrument down on the seafloor, sediment can be extracted. The details of locations of Marine Sediment to be monitored under the study are mentioned in **Table 32** as follows:

Table 32: Details of the sampling locations for Marine Sediment

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

The map depicting the locations of Marine Sediment sampling at Kandla and Vadinar have been mentioned in **Map 18 and 19** as follows:

Map 18: Location of Marine Sediment Monitoring at Kandla

Map 19: Locations of Marine Sediment Monitoring at Vadinar

The list of parameters to be monitored under the projects for the Marine Sediment sampling been mentioned in **Table 33** as follows:

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

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

11.2 Result and Discussion

The quality of Marine Sediment samples collected from the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 34.**

Table 34: Summarized result of Marine Sediment Quality

Sr No.	Parameters	Unit	Kandla						Vadinar	
			MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Inorganic Phosphate	kg/ ha	4.41	10.27	22.43	8.63	15.6	14.5	3.16	2.17
2.	Phosphate	mg/Kg	1055.2	1862.2	1586.7	653.7	816.3	667.1	203.5	247.4
3.	Organic Matter	%	0.81	0.31	0.27	0.51	0.73	0.33	0.65	0.87
4.	Sulphate as SO^{4-}	mg/Kg	190.09	170.70	210.19	155.27	92.28	101.26	84.17	115.9
5.	Calcium as Ca	mg/Kg	2165.50	2439.90	1890.90	2947.40	1693.10	2368.70	2427.7	2389.6
6.	Magnesium as Mg	mg/Kg	1584.50	1725.00	1826.00	1623.00	1421.10	1089.30	1198.2	1478
7.	Silica	g/Kg	582.9	476.3	421.3	291.71	236.4	325.63	290.1	408.3
8.	Nitrite	mg/Kg	0.32	0.64	0.39	0.41	0.49	0.59	0.16	0.3
9.	Nitrate	mg/Kg	21.48	18.36	29.31	23.63	14.51	16.13	13.2	7.96
10	Sodium	mg/Kg	3514	2453	2619	3219	3442	2916	6136	8643
11	Potassium	mg/Kg	2084	1967.9	2819	3071.2	2741	2613.7	2938	2481
12	Copper	mg/Kg	2283.3	1826.7	1278.5	2379.5	1628.3	1347.8	1493.78	1681.39
13	Aluminium	mg/Kg	49.51	38.7	36.83	49.1	47.2	51.3	53.6	29.7
14	Chromium	mg/Kg	3.11	3.57	4.07	3.91	4.97	5.27	4.58	3.78
15	Nickel	mg/Kg	43.35	38.9	21.47	28.11	22.64	24.39	14.79	26.87
16	Zinc	mg/Kg	61.16	54.6	49.3	47.7	51.26	40.65	23.68	42.96
17	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
18	Lead	mg/Kg	4.97	5.02	3.84	5.11	4.76	4.26	4.76	5.22
19	Arsenic	mg/Kg	4.47	2.55	5.2	3.63	2.98	3.21	2.83	3.42
20	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Texture	-	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loam

11.3 Data Interpretation and Conclusion

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

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

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

Heavy Metals

The sediment quality of Kandla and Vadinar has been compared with respect to the Average Standard guideline applicable for heavy metals in marine sediment specified by EPA have been mentioned in **Table 35.**

Table 35: Standard Guidelines applicable for heavy metals in sediments

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

(Source: G Perin et al. 1997)

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

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

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

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

Analysis of the sediments indicates moderate pollution. However, it may be noted that, the sediments are highly dynamic being constantly deposited and carried away by water currents. Hence maintaining the quality of sediments is necessary as it plays a significant role in regulating the quality of the marine water and the marine ecology.

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

CHAPTER 12: MARINE ECOLOGY MONITORING

12.1 Marine Ecological Monitoring

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

As defined in the scope by DPA, the Marine Ecological Monitoring is required to be carried out once a month specifically at eight locations, six at Kandla and two at Vadinar. The sampling of the Benthic Invertebrates has been carried out with the help of D-frame nets, whereas the sampling of zooplankton and phytoplankton has been carried out with the help of Plankton Nets (60 micron and 20 micron). The details of the locations of Marine Ecological Monitoring have been mentioned in **Table 37** as follows:

Table 37: Details of the sampling locations for Marine Ecological

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

The map depicting the locations of Marine Ecological monitoring in Kandla and Vadinar have been mentioned in **Map 20 and 21** as follows:

Map 20: Locations of Marine Ecological Monitoring at Kandla

Map 21: Locations of Marine Ecological Monitoring at Vadinar

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

Table 38: List of parameters to be monitored for Marine Ecological Monitoring

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

Methodology

- **Processing for chlorophyll estimation:**

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

- **Phytoplankton Estimation**

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

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

- **Zooplankton Estimation**

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

- **Benthic Organisms Estimation**

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

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

- **Diversity Index**

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

1. **Shannon-Wiener's index:**

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

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

Where, ∑ = Summation symbol,

pi = Relative abundance of the species,

ln = Natural logarithm

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

2. **Simpson's index:**

A reasonably high level of dominance by one or a small number of species is indicated by the range of **0.89 to 0.91**. The general health and stability of the ecosystem may be

impacted by this dominance. Community disturbances or modifications that affect the dominant species may be more likely to have an impact. The dominating species determined by the Simpson's index can have big consequences on how the community is organised and how ecological interactions take place.

The formula for calculating D is presented as:

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

Where, ∑ = Summation symbol, pi = Relative abundance of the species

3. Margalef's diversity index:

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

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

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

Where, N = total number of individuals collected

S = No. of taxa or species or genera

4. Berger-Parker index:

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

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

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

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

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

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

5. **Evenness index–**

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

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

Where, H= Shannon value

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

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

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

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

12.2 Result and Discussion

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

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

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

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

- **Productivity (Net and Gross)**
  Gross primary productivity (GPP) is the rate at which organic matter is synthesised by producers per unit area and time (GPP). The amount of carbon fixed during photosynthesis by all producers in an ecosystem is referred to as gross primary productivity. The monitoring location of Kandla reported GPP value in range between **0.69 to 1.63 mg/L/48 Hr** where the highest value recorded for ME-4 (Khori Creek) and lowest recorded at ME-6(Nakti creek (near NH-8A)). In Vadinar, the value of **GPP** was observed **0.88** at ME-7 (Near SPM) and **1.23** at ME-8 (Near Vadinar Jetty) monitoring station.

  Net primary productivity, is the amount of fixed carbon that is not consumed by plants, and it is this remaining fixed carbon that is made available to various consumers in the ecosystem. The Net primary productivity of the monitoring location at Kandla from (ME-1 to ME-6) has been recorded in as **BQL (Below Quantification Limit).** While in Vadinar, the value of **NPP** was observed **BQL (Below Quantification Limit).** at ME-7 (Near SPM) and ME-8 (Near Vadinar Jetty) monitoring station.

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

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

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

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

Ecological Diversity

Phytoplankton: For the evaluation of the Phytoplankton population in DPA Kandla and Vadinar within the immediate surroundings of the port, sampling was conducted during the study period. Total 8 sampling locations were studied i.es. sampling locations (6 from Kandla and two from Vadinar).

The details of variation in abundance and diversity in phytoplankton communities is mentioned in **Table 40**.

Table 40: Phytoplankton variations in abundance and diversity in sub surface sampling stations

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Bacillaria sp.	212	-	-	202	-	436	-	187
Biddulphia sp.	-	315	235	137	118	-	268	159
Chaetoceros sp.	317	166	-	-	-	561	186	-
Chlamydomonas sp.	185	-	188	-	298	-	-	319
Cyclotella sp.	126	468	-	266	125	-	408	107
Coscinodiscus sp.	-	-	426	-	-	286	-	160
Ditylum sp	-	225	-	271	-	-	270	-
Fragilaria sp.	486	174	142	158	210	153	-	181
Bacteriastrum sp.	252	-	-	-	119	146	161	-
Pleurosigma sp.	-	-	308	-	-	-	125	212
Navicula sp.	147	-	-	147	374	252	-	183
Merismopedia sp.	-	156	177	-	-	-	-	-
Synedra sp.	-	-	-	-	-	-	232	-
Skeletonema sp.	239	-	-	256	415	118	-	329
Oscillatoria sp.	-	201	355	-	-	-	178	-
Thallassiosira	187	-	158	-	175	123	163	280
Gomphonema sp.	-	345	-	178	-	-	135	-
Density-Units/L	**2151**	**2050**	**1989**	**1615**	**1834**	**2075**	**2126**	**2117**
No. of genera	**9**	**8**	**8**	**8**	**8**	**8**	**10**	**10**

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

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

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

Table 41: Species richness Index and Diversity Index in Phytoplankton

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	9	8	8	8	8	8	10	10
Individuals	2151	2050	1989	1615	1834	2075	2126	2117
Shannon diversity	2.11	1.96	1.93	1.75	1.81	1.89	2.22	2.23
Simpson 1-D	0.87	0.86	0.86	0.87	0.85	0.83	0.89	0.89
Species Evenness	0.96	0.94	0.93	0.84	0.87	0.91	0.96	0.97
Margalef richness	1.04	0.92	0.92	0.95	0.93	0.92	1.17	1.18
Berger-Parker	0.23	0.23	0.21	0.17	0.23	0.27	0.19	0.16
Relative abundance	0.42	0.39	0.40	0.50	0.44	0.39	0.47	0.47

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

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

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

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

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

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

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

Table 42: Zooplankton variations in abundance and diversity in sub surface sampling stations

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Acartia sp.	-	1	1	1	-	2	2	-
Acrocalanus	1	-	1	-	1	-	2	-
Amoeba	-	1	1	2	-	1	1	2
Brachionus sp.	2	1	-	-	1	2	-	1
Calanus sp.	2	1	1	2	2	-	-	-
Cladocera sp.	1	-	-	-	-	-	1	-
Cyclopoid sp.	-	1	3	2	1	1	1	3
Copepod larvae	1	2	-	1	-	1	1	1
Diaptomus sp.	-	-	1	-	2	-	1	-
Eucalanus sp.	2	1	-	1	-	1	-	2
Mysis sp.	-	-	2	-	1	-	-	1
Paracalanus sp.	1	1	-	-	-	1	1	1
Density Unit/L	**10**	**9**	**10**	**9**	**8**	**9**	**10**	**11**
No. of genera	**7**	**8**	**7**	**6**	**6**	**7**	**8**	**7**

A total of 12 groups/taxa of zooplankton were recorded in Kandla and Vadinar during the study period which mainly constituted by *Mysis*, *brachionus*, *Calanus*, fish and shrimp larval forms. *Cladocera, Mysis* and *Paracalanus* had the largest representation at all stations from (ME-1 to ME-8). The density of Zooplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from **8 to 10 units/L**, while for Vadinar its density of zooplankton observed **10 units/L at ME-7** and **11 units/L at ME-8**. During the sampling, zooplankton communities were dominated by *Cyclopoid sp, Calanus sp, Amoeba* in Kandla, while *Cyclopoid sp* and *Calanus sp* had the largest representation at monitoring location of Vadinar.

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

Table 43: Species richness Index and Diversity Index in Zooplankton

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	7	8	7	6	6	7	8	7
Individuals	10	9	10	9	8	9	10	11
Shannon diversity	1.89	1.93	1.83	1.66	1.56	1.8	2.03	1.93
Simpson (1-D)	0.93	0.97	0.91	0.92	0.93	0.94	0.96	0.91
Species Evenness	0.97	0.93	0.94	0.93	0.87	0.93	0.98	0.99
Margalef	2.61	3.19	2.61	2.28	2.4	2.73	3.04	2.5
Berger-Parker	0.2	0.22	0.3	0.22	0.25	0.22	0.2	0.27
Relative abundance	70	88.89	70	66.67	75	77.78	80	63.64

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

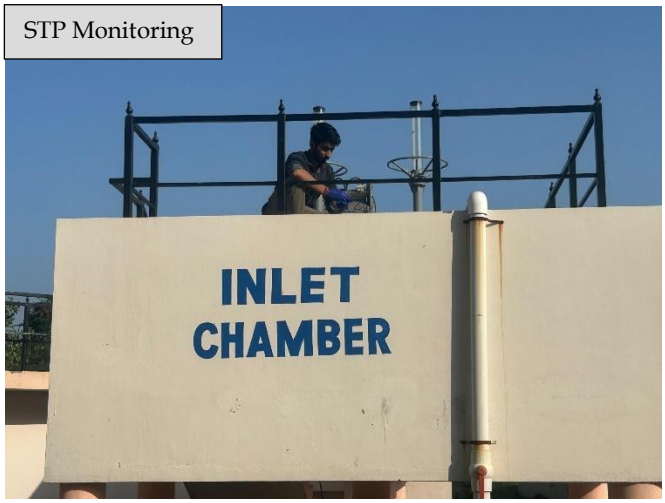
- **Berger-Parker Index (d)** of benthic organism was in the range of 0.25 **to 0.33** between selected sampling stations from ME-1 to ME-6 with an average value of **0.29** at Kandla creek and nearby creeks. Berger-Parker Index (d) of benthic organism in the sampling stations of Vadinar, was observed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

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

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

Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla

STP Monitoring



Noise Monitoring

Soil Monitoring

Marine Monitoring

Air Monitoring

Drinking Water Monitoring

Annexure 2: Photographs of the Environmental Monitoring conducted at Vadinar

Air Monitoring

Noise Monitoring

STP Monitoring

Drinking water Monitoring

Marine Monitoring

Soil Monitoring

Source: GEMI

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