DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

Tel(O) : (02836) 220038,
Fax : (02836) 220050
E Mail : kptdesignsection@gmail.com
Website: www.deendayalport.gov.in

www.deendayalport.gov.in

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

Ref: - EG/WK/4684(EC)/Part VII/ 45 Date: 27/03/2024

To,
Shri T. C. Patel,
Kutch Unit Head,
Gujarat Pollution Control Board,
Paryavaran Bhavan, Sector 10A,
Gandhinagar- 382 010 Email-kut-uh-gpcb@gujarat.gov.in

Sub: "Creation of water front facilities (Oil Jetties 8, 9, 10 & 11) and development of land of area 554 acres for associated facilities for storage at Old Kandla, Gandhidham, Kutch, Gujarat by M/s Deendayal Port Authority (Erstwhile: Deendayal Port Trust)- **Submission of Point-wise Compliance of Conditions stipulated in the NOC/CTE reg.**

Ref.:
1) NOC No. 94118 received vide letter no. PC/CCA-Kutch-1524/GPCB ID 56985 Dated 23/07/2018.
2) Extension and Correction to CTE issued by GPCB vide PC/CCA-Kutch-1524/GPCB ID 56985 Dated 30/09/2023 valid upto 19/11/2030
3) DPT Letter No. EG/WK/4684(EC)/PartVII/29 dated 29/06/2021
4) DPT Letter No. EG/WK/4684(EC)/PartVII/141 dated 08/02/2022
5) DPA letter No. EG/WK/4684(EC)/PartVII/129 dated 30/06/2022
6) DPA letter No. EG/WK/4684(EC)/PartVII/297 dated 05/05/2023
7) DPA letter No. EG/WK/4684(EC)/PartVII/362 dated 18/09/2023

Sir,

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

In this connection, it is to state that, vide above referred Letter No- PC/CCA-Kutch-1524/GPCB ID 56985 Dated 23/07/2018 had granted NOC/CTE with validity up to 03/04/2023. And further issued extension to the CTE vide PC/CCA-Kutch-1524/GPCB 56985 dated 30/09/2023 valid upto 19/11/2030.

DPA vide above mentioned letters had submitted the compliance report of condition stipulated in CTE/NOC to the GPCB.

Now, please find enclosed herewith, compliance report of conditions stipulated in CTE order (period **upto November, 2023**) along with necessary enclosures as **Annexure I,** for your 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 approval of the Chief Engineer, Deendayal Port Authority.

Yours faithfully,

27/3/24

Dy. Chief Engineer & EMC (I/C)

Deendayal Port Authority

Copy to : Regional Officer, (Kutch East)
Gujarat Pollution Control Board,
Room No. 215 – 217, Regional Office,
2nd Floor, A.O Building,
Deendayal Port Trust,
Gandhidham (Kutch)– 370 201
Email Id. ro-gpcb-kute@gujarat.gov.in

/

ANNEXURE – 1

CTE Compliance

Annexure 1

Compliance Report (for the period upto November, 2023)

Subject: Point wise compliance report of conditions stipulated in the NOC/CTE issued by GPCB for the project "Creation of water front facilities (Oil Jetties 8, 9, 10 & 11) and development of land of area 554 acres for associated facilities for storage at Old Kandla, Gandhidham, Kutch, Gujarat by M/s Deendayal Port Authority."

Reference: NOC No. 94118 received vide letter no. PC/CCA-Kutch-1524/GPCB ID 56985 dated 23/07/2018 and its extension and correction issued by GPCB vide PC/CCA-Kutch-1524/GPCB ID 56985 dated 30/09/2023 valid upto 19/11/2030.

<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>Proposed jetties shall be handled of 3.5 MMTPA of liquid Cargo of edible oil, Fertilizers & food grains etc.</td><td>As per Environmental Clearance granted by MoEF&CC dated 20.11.2020, "the capacity of each jetty is 3.5 MMTPA for handling all types of Liquid Cargo".
(Correction in CTE order issued by GPCB vide PC/CCA-Kutch-1524/GPCB ID 56985 dated 30/09/2023) attached herewith as Annexure A</td></tr>
<tr><td>2.</td><td>Unit shall strictly adhere to all conditions of TOR issued by MoEF&CC. Delhi dated 04/07/2017 & shall not carry out any construction activities till obtaining EC and CRZ from competent authority.</td><td>DPA has already received the EC and CRZ clearance from MoEF&CC vide file no. 10-1/2017-1A-111 dated 20/11/2020 and CRZ recommendation from GCZMA vide letter no. ENV-10-2018-24-T cell dated 30/07/2020. Copy also submitted in the compliance report submitted on 05/05/2023.</td></tr>
<tr><td>3.</td><td>No ground water shall be withdrawn without prior approval from competent authority.</td><td>DPA is not using ground water for any of the purpose.</td></tr>
<tr><td>2</td><td colspan="2">Conditions Under Water Act</td></tr>
<tr><td>2.1</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>It is here by assured that Water is used only for the domestic purpose and there is no Industrial water consumption and no waste water generation from the Industrial purpose.</td></tr>
<tr><td>2.2</td><td>Domestic water Consumption shall not exceed 20 KL/day</td><td>Point noted for the compliance.</td></tr>
<tr><td>2.3</td><td>The quantity of domestic waste water (sewage) shall not exceed 16 KL/day</td><td>Point noted for the compliance.</td></tr>
<tr><td>2.4</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>pH</td><td>6.5-9.0</td></tr>
<tr><td>BOD (5 days at 20 ^{0} C)</td><td>30 mg/lit</td></tr>
<tr><td>Suspended Solid</td><td>20 mg/lit</td></tr>
<tr><td>Fecal Coliform</td><td>1000 MPN/100 ml</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.

Copy of latest monitoring report is attached herewith as Annexure B</td></tr>
</table>

<table>
<tr><td>2.5</td><td>The domestic sewage shall be treated in sewage treatment plant and treated sewage confirming to standard mentioned in 2.4 shall be reused in various activities shall not be used for gardening and plantation purpose in premises.</td><td>The domestic sewage will be treated in sewage treatment plant of the DPA.</td></tr>
<tr><td>3</td><td colspan="2">Conditions under air act 1981:</td></tr>
<tr><td>3.1</td><td>There shall be no use of fuel; hence there is no flue gas emission from manufacturing activities and other ancillary operations.</td><td>No fuel is being used; hence there is no flue gas emission from manufacturing activities and other ancillary operations.</td></tr>
<tr><td>3.2</td><td>There shall be no process gas emission from manufacturing and other ancillary activities.</td><td>No manufacturing process is involved and hence there is no process gas emission from manufacturing and other ancillary activities.</td></tr>
<tr><td>3.3</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/m^3</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.

Copy of latest monitoring report is attached herewith as Annexure B</td></tr>
<tr><td>3.4</td><td>The level 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.

Copy of latest monitoring report is attached herewith as Annexure B</td></tr>
<tr><td>4</td><td colspan="2">Conditions under Hazardous waste:</td></tr>
<tr><td>4.1</td><td>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.</td><td>Point Noted for the Compliance.

DPA has a contract with the GPCB/CPCB authorized Recycler for disposal of Haz. Waste.</td></tr>
<tr><td>4.2</td><td>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, 2016 as amended from time to time</td><td>Not applicable</td></tr>
<tr><td>5</td><td colspan="2">General Conditions</td></tr>
<tr><td>5.1</td><td>Any change in the personnel, equipment or working conditions as mentioned in the consents form/order should immediately be intimated to this Board.</td><td>Point noted for the compliance.</td></tr>
</table>

5.2	The waste generator shall be totally responsible for (i.e Collection, Storage, transportation and ultimate disposal) of the wastes generated.	Point noted for the compliance.
5.3	Record of Waste generation, its management and annual return shall be submitted to Gujrat pollution Control Board in Form-4 by 31st January of every year.	Point noted for the compliance.
5.4	In case of any accident, details of the same shall be submitted in Form-5 to Gujrat pollution Control Board	Point noted for the compliance.
5.5	Applicant shall comply relevant provision of "Public Liability Insurance Act-91"	Point noted for the compliance.
5.6	Unit shall take all concrete measures to show tangible results in waste generation, reduction, avoidance, reuse and recycle. Action taken in this regard shall be submitted within three months and also along with Form-4.	Point noted for the compliance.
5.7	Industry shall have to display on-line data outside the main factory gate with regard to quantity and nature of hazardous chemicals being handled in the plant, including waste water and air emissions and solid hazardous waste generated within the factory premises.	Point noted for the compliance.
5.8	Adequate plantation shall be carried out all 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 shall be developed	Point noted for the compliance.
5.9	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	Only construction work of Oil Jetty No.8 - Jetty and allied facilities is in progress. In the operation phase, DPA shall regularly submit the returns in prescribed form regarding water consumption.

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ANNEXURE – A

CTE Extension dated 30/09/2023

GUJARAT POLLUTION CONTROL BOARD

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

GPCB

By R.P.A.D

AMENDMENT TO CONSENT TO ESTABLISH (CTE)
CTE-129018

NO: PC/ CCA- KUTCH-1524/ GPCB ID: 56985/ **Date: - /09/2023**

To,
M/s. Deendayal Port Trust,
Kandla Port Trust Land,
A.O. Building, P.O. Box no.50,
Tal : Gandhidham, Dist : Kutch – 370 201.

Subject : Consent to Establish (CTE) issued vides CTE – **94118** vide letter no. **PC/ CCA- KUTCH-1524/ GPCB ID: 56985 / 462839 dated 23/07/2018.**

Reference :
1. Board has issued CTE vide letter no. **PC/ CCA- KUTCH-1524/ GPCB ID: 56985 / 462839** dated 23/07/2018.
2. Environmental Clearance issued by MoEF & CC dated 20/11/2020.
3. This office circular dated 06/02/2016 & 08/03/2022.
4. Your application for CTE validity extension Inward no. 277183 dated – 22/04/2023.
5. CTN correction application inward no. 700536 dated 09/11/2021.

Sir,

Without prejudice to the powers of this Board under the Water (Prevention and Control of Pollution) Act-1974, the Air (Prevention and Control of Pollution) Act-1981 and the Environment (Protection) Act-1986 and without reducing your responsibilities under the said Acts in any way. The Board had granted **Consent to Establish (NOC)** vide order no. **PC/ CCA-KUTCH-1524/ GPCB ID: 56985 / 462839 dated 23/07/2018** for the plant at **Kandla Port Trust Land, A.O. Building, P.O. Box no.50, Tal: Gandhidham, Dist. Kutch.**

Accordingly Board has referred your letter dated 22/04/23 requesting for extending the validity of CTE upto EC validity.

The Board has right to review & amend the conditions of the said CTE order wrt to Board circular dated 08/03/2022. Now considering your application for CTE-Amendment inward no. 277183 dated 22/04/2023 for validity extension of the CTE order dated 23/07/2018, the said order is amended as below:

1. The validity mentioned in the CTE order no- **94118** issued vide letter no. **PC/ CCA- KUTCH-1524/ GPCB ID: 56985 / 462839 dated 23/07/2018 shall be extended up to 19/11/2030.**

2. Proposed jetties 8,9,10 & 11 shall be handled of 3.5 MMTP/Annum each of liquid cargo of edible oil, fertilizer & food grains etc.
3. Industry shall comply with all conditions of Environment Clearance and CRZ Clearance granted from MoEF & CC vide order no. 10-1/2017-IA-III dated 20/11/2020.

4. The rest of the conditions of Consent to Establish (CTE) order No: **CTE – 94118** vide letter no. **PC/ CCA- KUTCH-1524/ GPCB ID: 56985 / 462839 dated 23/07/2018** shall remain unchanged and industry shall comply with the same judicially.

For and on behalf of
Gujarat Pollution Control Board

(T.C. Patel)
Unit Head

/

ANNEXURE – B

Latest Environmental 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: October-November, 2023)

Document Ref No.: GEMI/DPA/782(2)(2)/2023-24/54

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"

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 (October-November, 2023)"* is prepared.

- **Name of the Report:** *Environment Monitoring Report (October-November, 2023)*
- **Date of Issue:** 19/12/2023
- **Version:** 1.0
- **Report Ref.:** GEMI/DPA/782(2)(2)/2023-24/54

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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.

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 monitoring period of 17th October-16th November, 2023.

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.

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CHAPTER 2: METHODOLOGY

2.1 Study Area

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

a. Kandla

Deendayal Port (Erstwhile Kandla Port) is one of the twelve major ports in India and is located on the West Coast of India, in the Gulf of Kutch at 23001'N and 70013'E in 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 **Figure 1** as follows:

Figure 1: Locations Map of Kandla and Vadinar

Figure 2: Map of Kandla Port

Figure 3: Map of Vadinar Port

2.2 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 4** as given below:

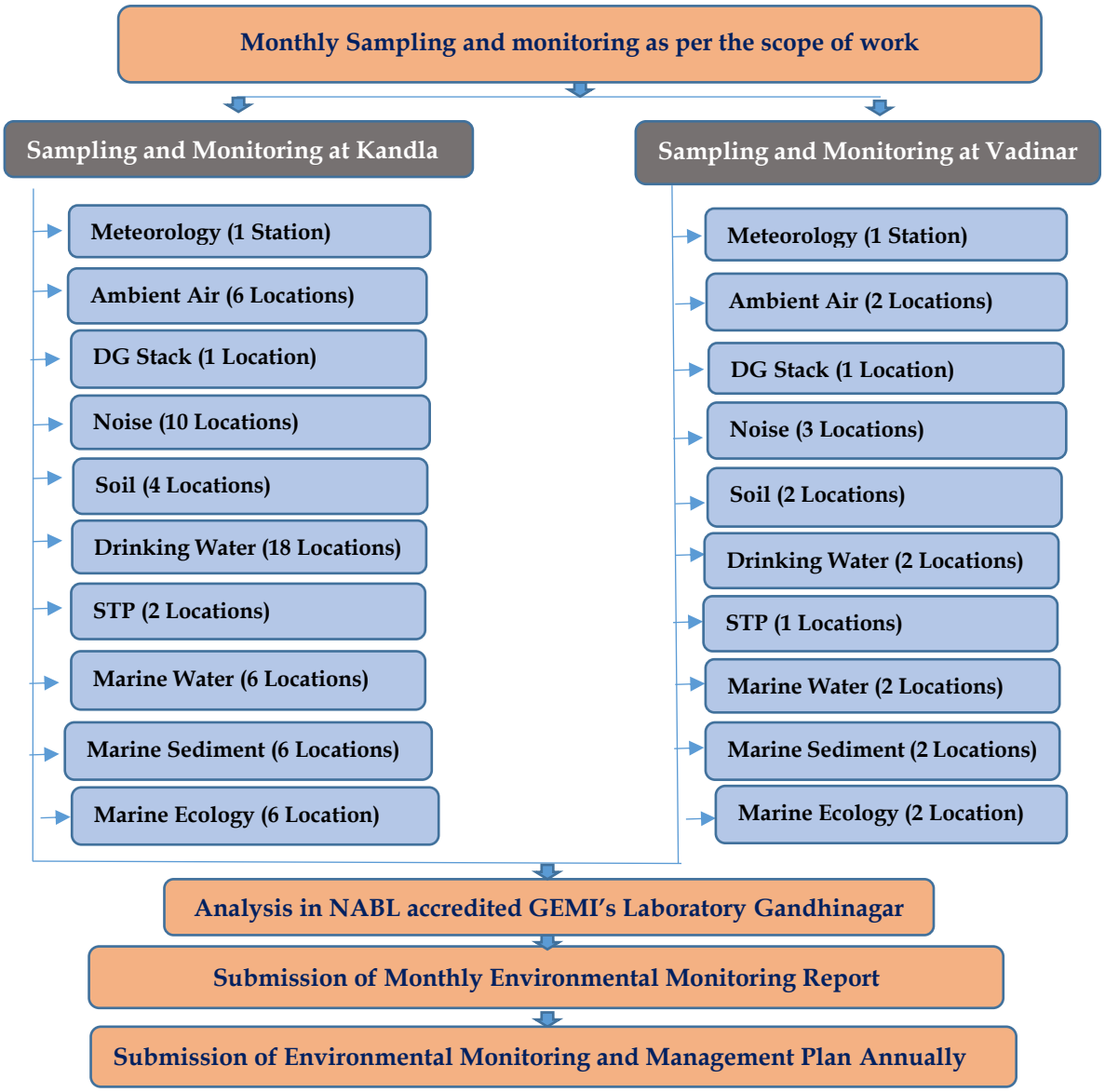

Figure 4: Methodology flow chart

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

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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.

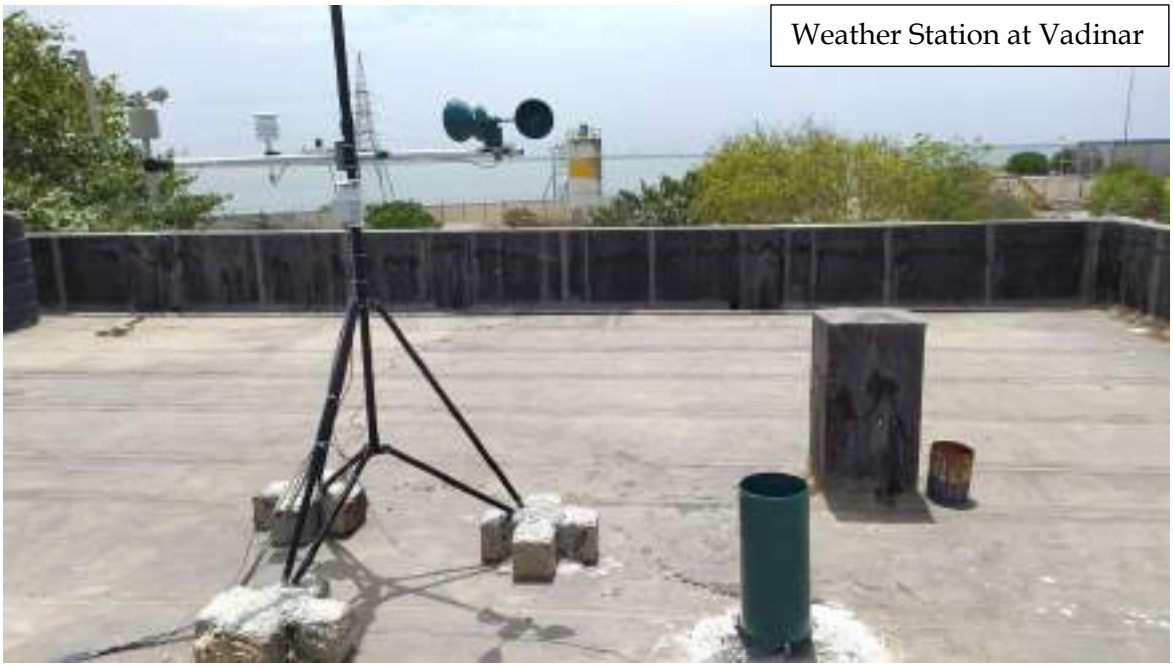


Figure 5: Photographs of Automatic Weather Monitoring Station at Kandla and Vadinar

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**			
September-October 2023	1.15	9.85	0.025	30.41	31.24	29.63	52.18	55.40	49.02	65.11	North	0.012
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**			
September-October 2023	4.17	13.80	1.77	27.28	27.89	27.10	61.15	63.61	59.58	81.61	North-east	0.18

3.3 Data Interpretation and Conclusion

- **Temperature**

a. **Kandla:** The ambient temperature for the monitoring period varies between the range of 29.63-31.24°C for Kandla, with average temperature of 30.41°C.
b. **Vadinar:** The ambient temperature for the monitoring period varies between the range of 27.1-27.89°C for Vadinar, with average temperature of 27.28°C.

- **Relative Humidity**

a. **Kandla**: The Relative Humidity recorded between the range of 49.02-55.40%, with average Humidity of 52.18%.
b. **Vadinar:** During the study period, the Relative Humidity varies between 59.58-63.61%, with average Humidity of 61.15%.

- **Rainfall**

a. **Kandla:** The average rainfall during the monitoring period was found to be 0.012 mm.
b. **Vadinar:** The average rainfall was found to be 0.18 mm.

- **Wind Speed**

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

a. **Kandla:** Wind speed recorded ranges between 0.025-9.85 Km/hr.
b. **Vadinar:** During the monitoring period, the Wind speed recorded ranges between 1.77-13.80 Km/hr.

- **Solar Radiation:**

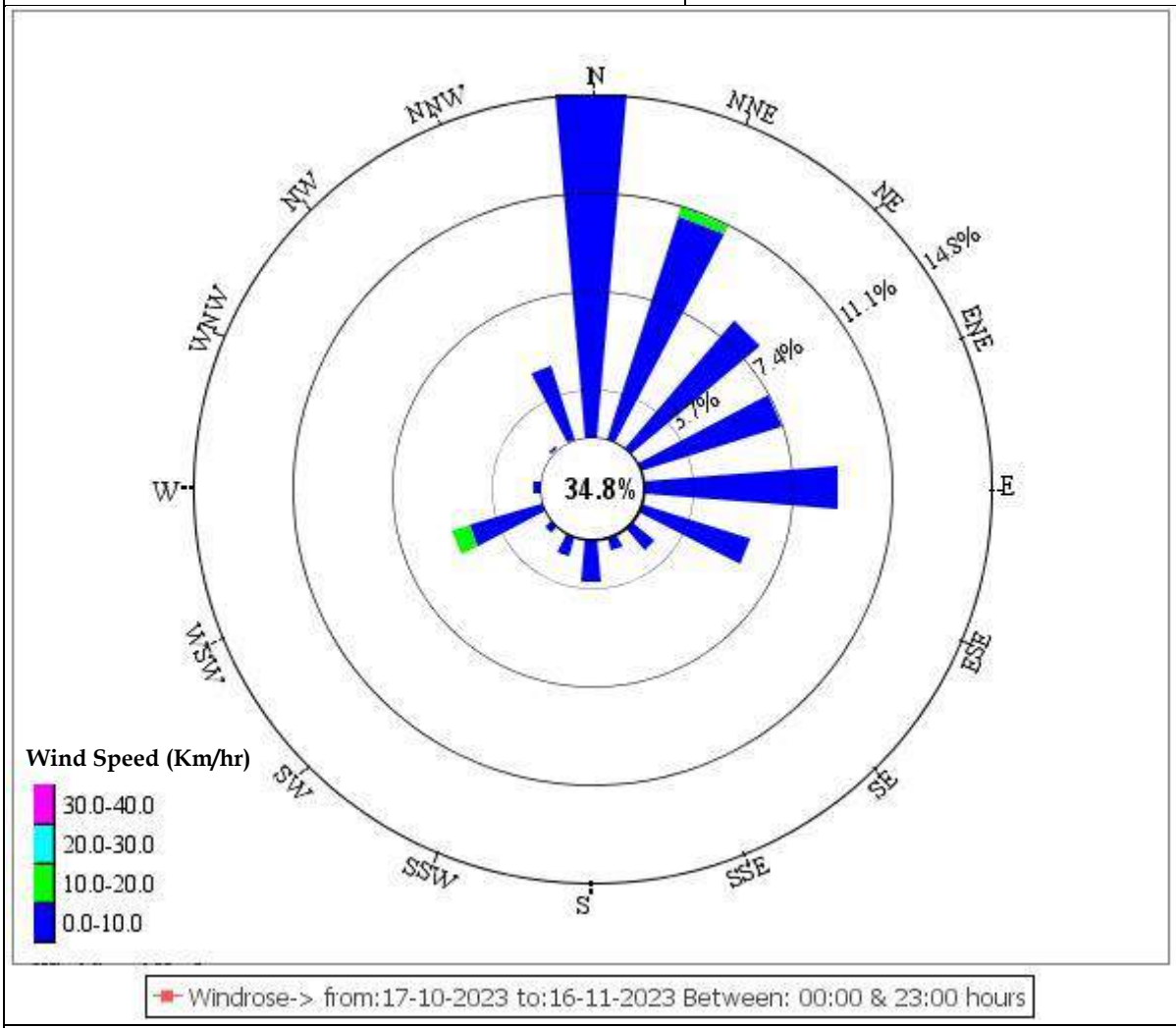
a. **Kandla:** The average Solar Radiation for the monitoring period was recorded as 65.11 W/m^2.
b. **Vadinar:** The average Solar Radiation was recorded as 81.61 W/m^2.

- **Wind rose diagram -**

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

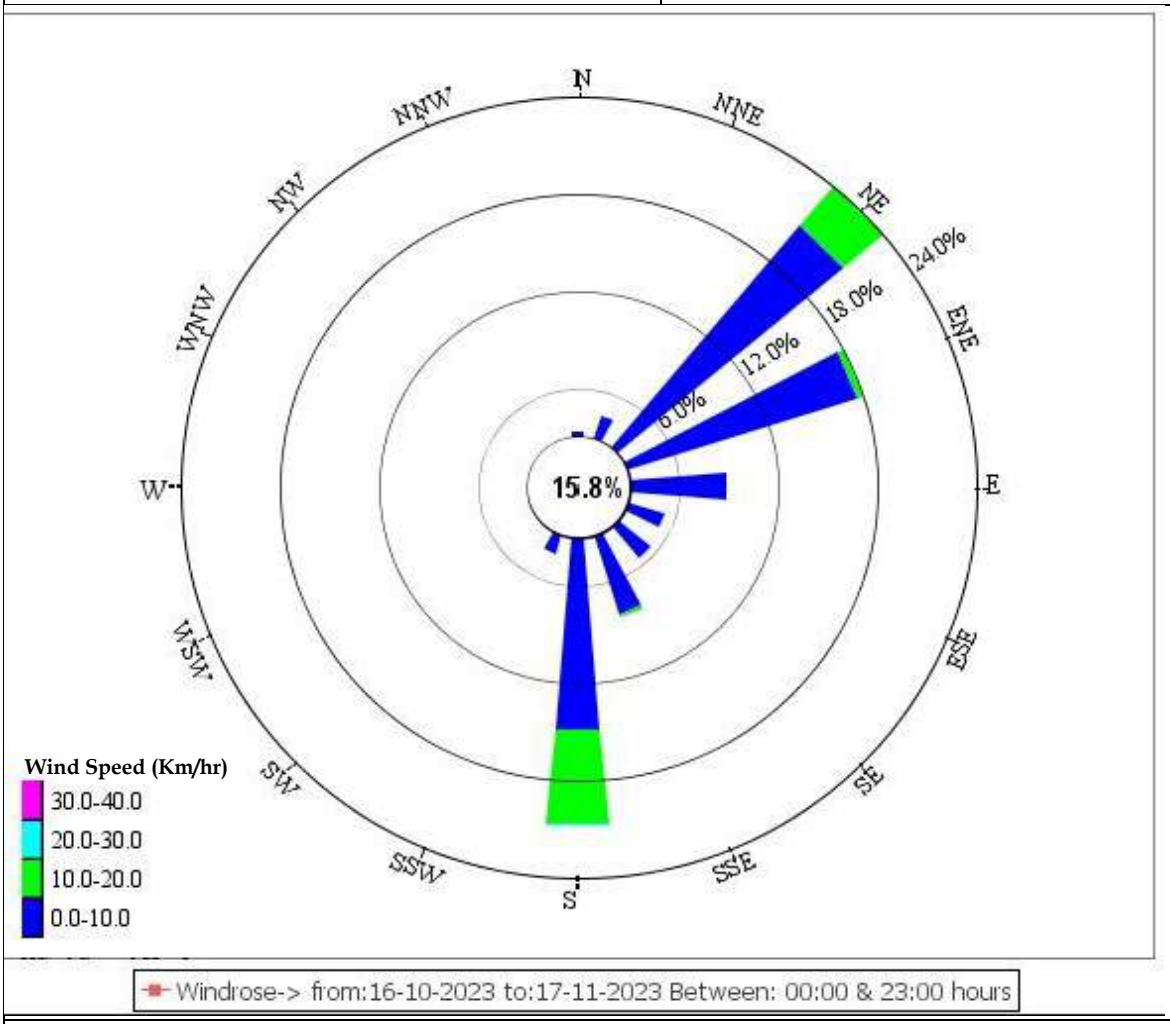
This Wind Rose Diagram reveals that at Kandla, during the period the prevailing winds predominantly blow from the North direction. Whereas the winds at Vadinar were observed to blow mainly from North-east and South directions.

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 October to 16th November, 2023.

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 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 **Figure 6 and 7** respectively.

Ambient Air monitoring and sampling photographs

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	

Figure 6: Location Map for Ambient Air Monitoring at Kandla

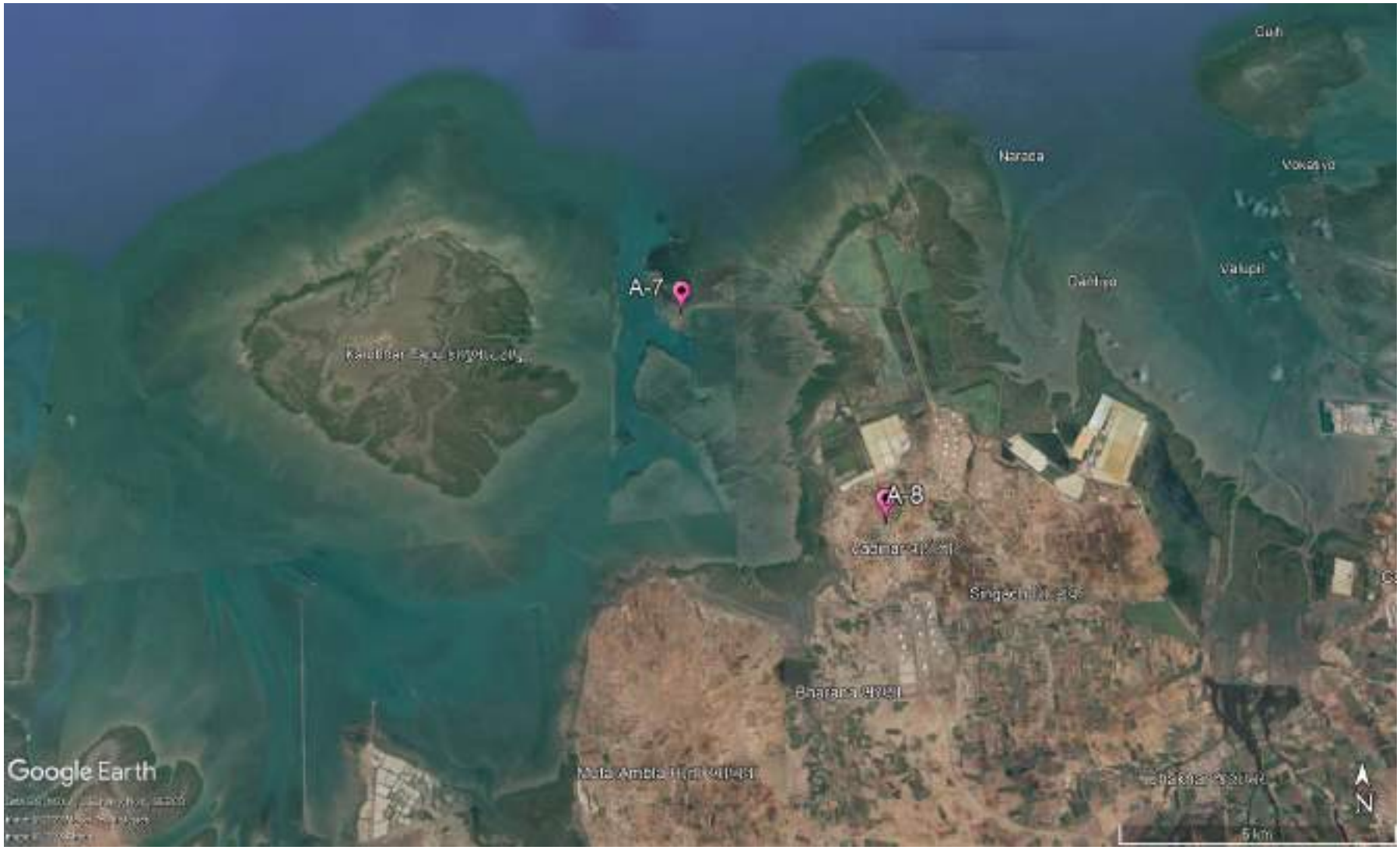


Figure 7: Location Map for Ambient Air Monitoring at Vadinar

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"x10" 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	mg/m³	GEMI/SOP/AAQM/11; Issue no 01, Issue date 17.01.2019: 2019	Sensor based Instrument (Make: Vaibhav Instruments)	
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**.**

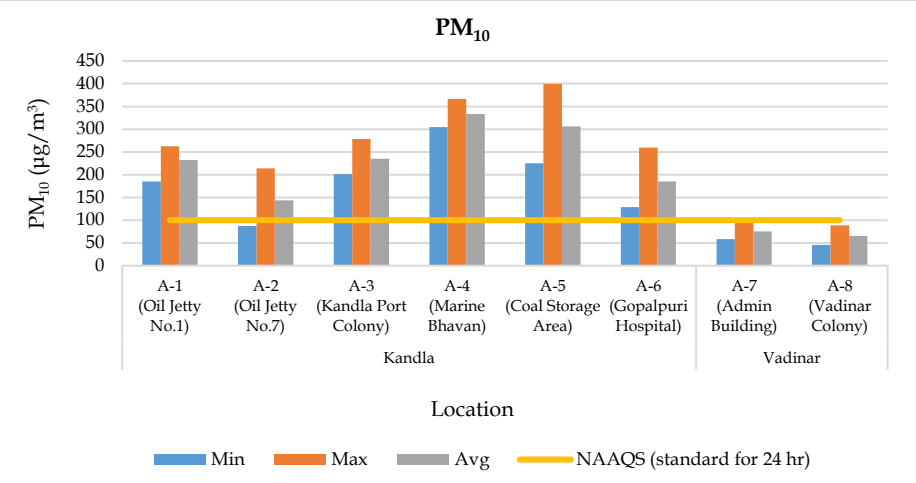
Table 6: Summarized results of PM_{10}, $PM_{2.5}$, SO_2, NO_x, VOC and CO for Ambient Air quality monitoring at Kandla and Vadinar

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration µg/m³ except for CO in mg/m³					
	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		**100**	**60**	**80**	**80**	**-**	**2**
A-1: Oil Jetty No.1, Kandla	20-Oct-23	232.58	40.91	4.7	7.76	2.14	0.88
	21-Oct-23	213.22	35.08	3.25	13.53	2.69	0.81
	25-Oct-23	185.15	36.29	2.23	4.72	3.14	0.89
	27-Oct-23	227.56	37.27	3.78	3.22	2.58	0.87
	30-Oct-23	245.15	53.43	1.26	4.12	1.67	0.86
	06-Nov-23	262.34	89.64	2.29	3.25	2.69	0.77
	07-Nov-23	231.86	77.44	3.47	5.71	2.47	0.80
	13-Nov-23	261.03	42.61	4.12	4.12	1.54	0.78
	Minimum	**185.15**	**35.08**	**1.26**	**3.22**	**1.54**	**0.77**
	Maximum	**262.34**	**89.64**	**4.70**	**13.53**	**3.14**	**0.89**
	Average	**232.36**	**51.58**	**3.14**	**5.80**	**2.37**	**0.83**
	Std. Deviation	**25.36**	**20.79**	**1.13**	**3.46**	**0.55**	**0.05**
A-2: Oil Jetty No.7, Kandla	20-Oct-23	127.03	36.73	3.32	4.21	3.17	0.76
	21-Oct-23	87.15	32.02	3.68	14.2	2.17	0.75
	25-Oct-23	104.01	38.91	2.65	4.35	1.07	0.79
	27-Oct-23	141.01	32.25	4.12	2.14	1.06	0.77
	30-Oct-23	180.20	61.97	2.88	3.46	2.17	0.80
	06-Nov-23	213.56	91.63	2.32	3.41	4.21	0.80
	07-Nov-23	150.32	61.32	1.79	5.34	2.59	0.69
	13-Nov-23	143.77	33.12	2.49	5.21	1.94	0.74
	Minimum	**87.15**	**32.02**	**1.79**	**2.14**	**1.06**	**0.69**
	Maximum	**213.56**	**91.63**	**4.12**	**14.20**	**4.21**	**0.80**
	Average	**143.38**	**48.49**	**2.91**	**5.29**	**2.30**	**0.76**
	Std. Deviation	**40.20**	**21.41**	**0.76**	**3.75**	**1.05**	**0.04**
A-3: Kandla Port Colony, Kandla	20-Oct-23	238.95	39.23	2.43	19.46	2.14	0.89
	21-Oct-23	265.34	53.14	2.92	26.17	1.16	0.71
	25-Oct-23	210.38	39.27	3.37	33.6	1.52	0.72
	27-Oct-23	228.56	52.00	4.12	30.06	1.90	0.85
	30-Oct-23	278.39	68.57	3.82	<6	2.67	0.82
	06-Nov-23	242.11	41.16	16.50	80.67	2.17	0.94
	07-Nov-23	214.63	77.18	51.15	63.63	2.91	0.82
	13-Nov-23	201.36	54.11	4.19	2.36	2.31	0.85
	Minimum	**201.36**	**39.23**	**2.43**	**2.36**	**1.16**	**0.71**
	Maximum	**278.39**	**77.18**	**51.15**	**80.67**	**2.91**	**0.94**
	Average	**234.97**	**53.08**	**11.06**	**36.56**	**2.10**	**0.83**
	Std. Deviation	**26.90**	**13.87**	**16.84**	**26.77**	**0.57**	**0.08**
A-4: Marine Bhavan, Kandla	20-Oct-23	366.89	38.55	2.86	10.37	1.69	0.85
	21-Oct-23	353.17	37.76	1.53	12.77	1.75	0.85
	25-Oct-23	304.36	43.36	3.09	5.12	3.16	0.73
	27-Oct-23	312.04	36.10	3.94	10.14	2.71	0.87
	30-Oct-23	342.55	62.65	4.15	13.57	1.84	0.88
	06-Nov-23	349.61	62.15	7.93	41.39	1.69	1.04

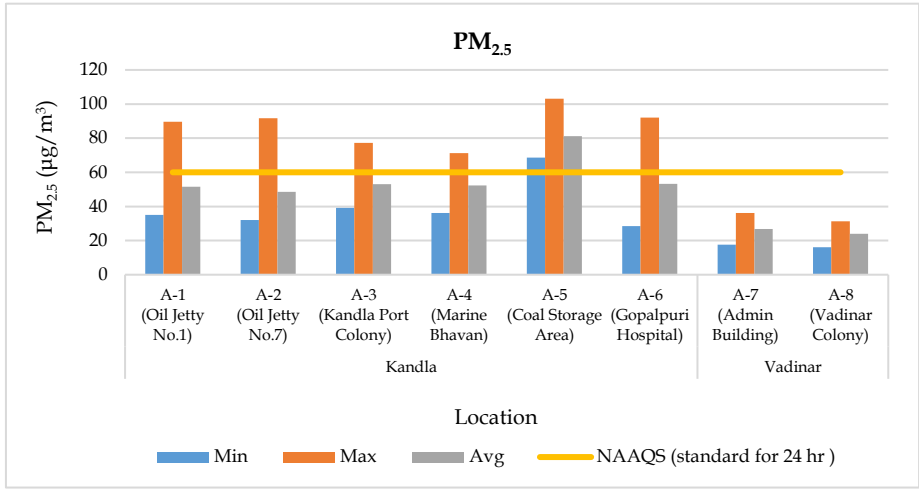
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration µg/m³ except for CO in mg/m³					
	Pollutants	PM_{10} µg/m³	$PM_{2.5}$ µg/m³	SO_2 µg/m³	NO_X µg/m³	VOC µg/m³	CO mg/m³
	Duration	(24 hr)				(2 hr)	(1 hr)
NAAQS by CPCB		100	60	80	80	-	2
	07-Nov-23	320.23	71.27	5.30	45.28	2.17	0.96
	13-Nov-23	321.20	66.74	4.89	23.54	1.74	0.86
	Minimum	**304.36**	**36.10**	**1.53**	**5.12**	**1.69**	**0.73**
	Maximum	**366.89**	**71.27**	**7.93**	**45.28**	**3.16**	**1.04**
	Average	**333.76**	**52.32**	**4.21**	**20.27**	**2.09**	**0.88**
	Std. Deviation	**22.30**	**14.71**	**1.92**	**15.18**	**0.56**	**0.09**
A-5: Coal Storage Area, Kandla	20-Oct-23	302.65	88.49	3.34	13.78	1.47	0.96
	21-Oct-23	225.34	70.72	2.86	4.98	1.52	0.94
	25-Oct-23	229.36	103.06	2.19	14.22	2.90	0.89
	27-Oct-23	399.32	76.10	1.91	25.48	2.14	0.98
	30-Oct-23	383.09	86.11	2.58	18.12	3.21	1.03
	06-Nov-23	265.80	73.95	3.31	6.06	2.67	1.17
	07-Nov-23	303.82	68.67	4.02	8.49	2.84	1.13
	13-Nov-23	341.86	82.13	4.48	15.88	1.76	0.96
	Minimum	**225.34**	**68.67**	**1.91**	**4.98**	**1.47**	**0.89**
	Maximum	**399.32**	**103.06**	**4.48**	**25.48**	**3.21**	**1.17**
	Average	**306.41**	**81.15**	**3.09**	**13.38**	**2.31**	**1.01**
	Std. Deviation	**65.41**	**11.35**	**0.88**	**6.80**	**0.68**	**0.10**
A-6: Gopalpuri Hospital, Kandla	20-Oct-23	165.34	35.6	5.05	3.54	1.26	0.68
	21-Oct-23	161.65	32.84	4.62	5.13	1.47	0.86
	25-Oct-23	128.59	28.57	4.01	4.25	2.10	0.59
	27-Oct-23	157.05	36.63	3.81	4.33	1.69	0.68
	30-Oct-23	209.53	75.71	2.84	5.78	2.18	0.66
	06-Nov-23	259.88	88.11	2.38	6.24	1.11	0.71
	07-Nov-23	250.67	91.97	3.58	4.87	1.69	0.78
	13-Nov-23	146.34	36.14	4.19	12.91	2.07	0.74
	Minimum	**128.59**	**28.57**	**2.38**	**3.54**	**1.11**	**0.59**
	Maximum	**259.88**	**91.97**	**5.05**	**12.91**	**2.18**	**0.86**
	Average	**184.88**	**53.20**	**3.81**	**5.88**	**1.70**	**0.71**
	Std. Deviation	**49.15**	**27.06**	**0.88**	**2.97**	**0.40**	**0.08**
A-7: Admin Building, Vadinar	20-Oct-23	67.21	30.27	16.32	12.03	2.14	0.21
	21-Oct-23	79.45	27.45	18.53	8.12	3.14	0.67
	25-Oct-23	72.18	24.12	12.11	16.28	2.74	0.44
	27-Oct-23	58.39	25.69	9.18	32.17	2.01	0.54
	30-Oct-23	95.17	21.85	10.78	14.82	1.47	0.43
	06-Nov-23	88.21	36.15	15.14	12.67	2.03	0.74
	07-Nov-23	71.64	31.52	19.42	13.74	1.49	0.65
	13-Nov-23	69.17	17.55	14.72	13.11	1.71	0.62
	Minimum	**58.39**	**17.55**	**9.18**	**8.12**	**1.47**	**0.21**
	Maximum	**95.17**	**36.15**	**19.42**	**32.17**	**3.14**	**0.74**
	Average	**75.18**	**26.83**	**14.53**	**15.37**	**2.09**	**0.54**
	Std. Deviation	**11.90**	**5.86**	**3.63**	**7.19**	**0.59**	**0.17**
	20-Oct-23	53.17	24.52	22.47	9.34	2.74	0.25

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration µg/m³ except for CO in mg/m³					
	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		**100**	**60**	**80**	**80**	**-**	**2**
A-8: Vadinar Colony, Vadinar	21-Oct-23	78.29	19.67	18.6	14.28	2.16	0.74
	25-Oct-23	88.34	26.34	12.70	6.45	2.30	0.69
	27-Oct-23	64.21	28.41	15.90	15.14	2.10	0.54
	30-Oct-23	47.13	31.25	11.36	12.07	1.47	0.64
	06-Nov-23	86.42	16.12	16.12	11.94	1.08	0.52
	07-Nov-23	57.95	21.66	17.82	14.75	1.75	0.42
	13-Nov-23	45.87	23.71	21.13	13.95	2.10	0.47
	Minimum	**45.87**	**16.12**	**11.36**	**6.45**	**1.08**	**0.25**
	Maximum	**88.34**	**31.25**	**22.47**	**15.14**	**2.74**	**0.74**
	Average	**65.17**	**23.96**	**17.01**	**12.24**	**1.96**	**0.53**
	Std. Deviation	**17.14**	**4.84**	**3.83**	**3.02**	**0.52**	**0.16**

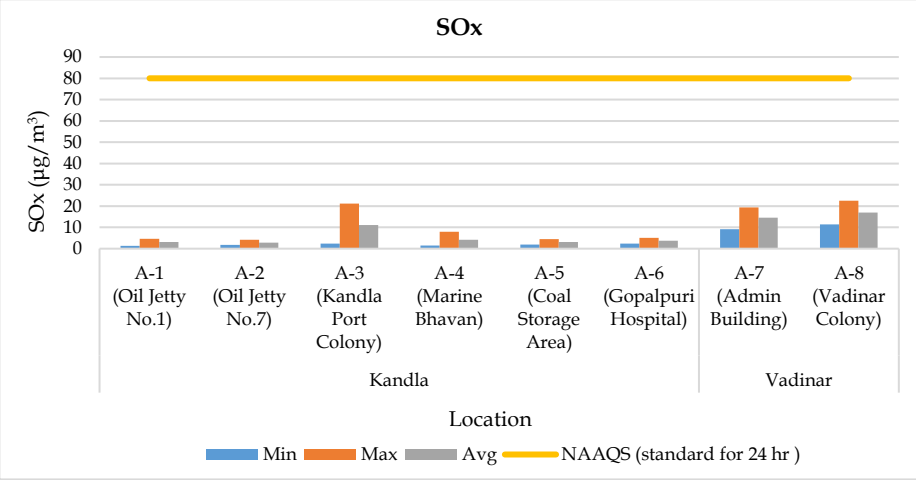
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar)



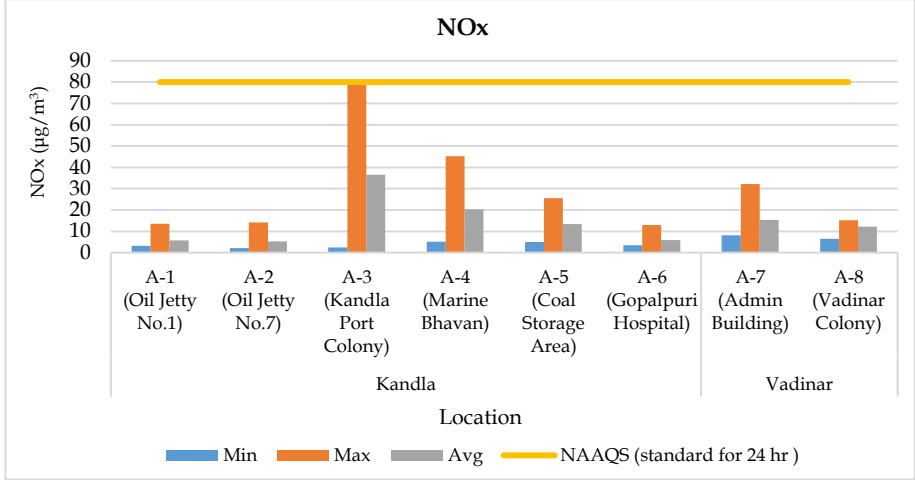
Graph 1: Spatial trend in Ambient PM_{10} Concentration



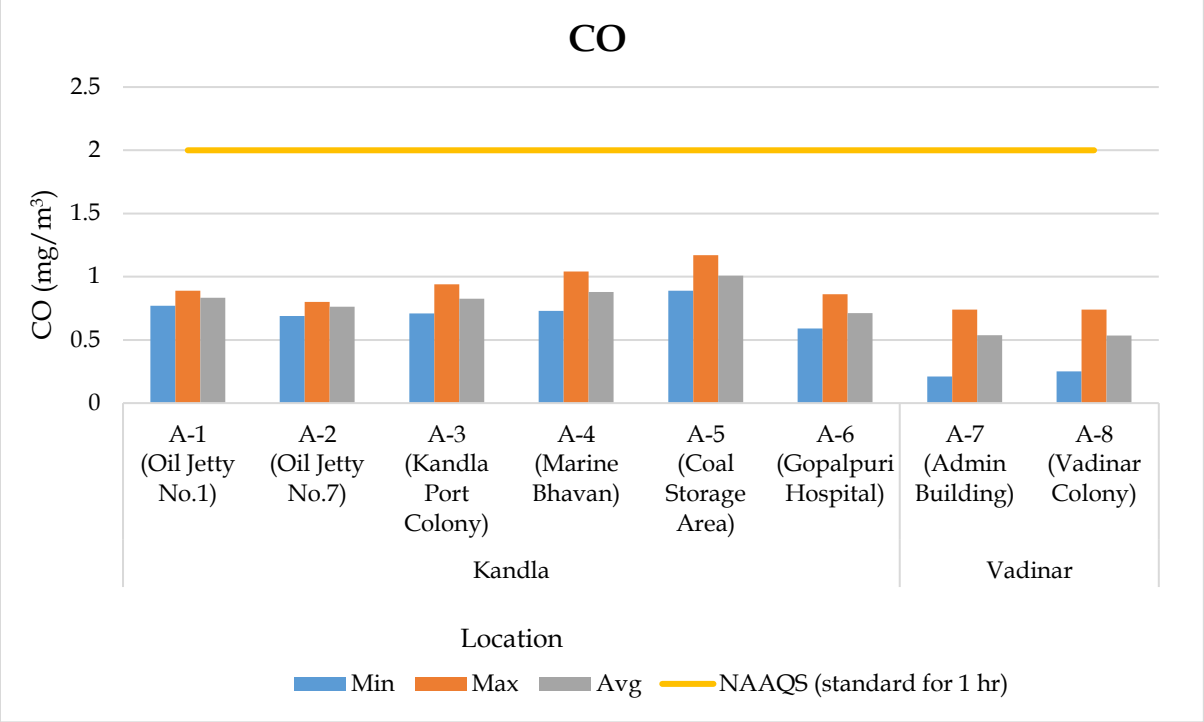
Graph 2: Spatial trend in Ambient $PM_{2.5}$ Concentration



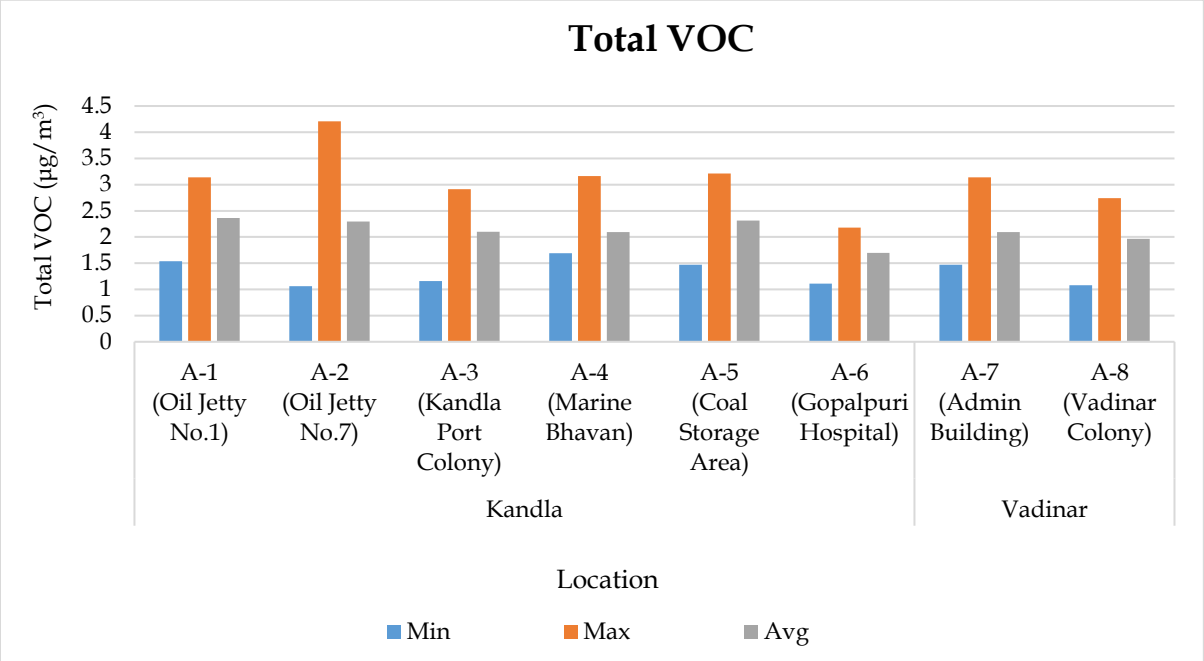
Graph 3: Spatial trend in Ambient SO_x Concentration



Graph 4: Spatial trend in Ambient NO_x Concentration



Graph 5: Spatial trend in Ambient CO Concentration



Graph 6: Spatial trend in Ambient Total VOCs

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

Benzene (µg/m³)									
Sr. No	Kandla						Vadinar		NAAQS standards (24 hr)
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	
1	0	0	0	0	0	0	0.12	0.14	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	1.02	0.9	0.12	0.14	0.37	0.77	0.65	0.28
2	Acenaphthylene	0.49	0.37	0.54	0.95	0.14	0.46	0.28	0.44
3	Acenaphthene	0.12	0.09	0.13	0.66	0.41	0.12	0.41	0.61
4	Fluorene	0.39	0.34	0.46	0.37	0.57	0.45	0.39	0.14
5	Anthracene	0.13	0.42	0.97	0.28	0.62	0.91	0.41	0.43
6	Phenanthrene	0.00	0.00	0.00	0.03	0.17	0.00	0.82	0.28
7	Fluoranthene	0.24	0.19	0.97	0.63	0.14	0.28	0.03	0.64
8	Pyrene	0.36	0.14	0.67	0.55	0.28	0.34	0.07	0.11
9	Chrycene	0.16	0.22	0.96	0.42	0.19	0.54	0.14	0.06
10	Banz(a)anthracene	0.47	0.94	0.45	0.14	0.52	0.63	1.01	0.74
11	Benzo[k]fluoranthene	0.54	0.61	0.74	0.93	0.56	0.41	0.7	0.39
12	Benzo[b]fluoranthene	0.12	0.46	0.62	1.08	0.41	0.67	0.25	0.45
13	Benzopyrene	0.9	0.33	0.49	0.75	0.27	0.41	0.96	0.63
14	Indeno [1,2,3-cd] fluoranthene	0.13	0.77	0.42	0.48	0.73	0.67	0.52	0.46
15	Dibenz(ah)anthracene	0.11	0.14	0.69	0.13	0.51	0.28	0.17	0.71
16	Benzo[ghi]perylene	0.31	0.24	0.21	0.46	0.61	0.76	0.22	0.63

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	2.11	2.67	3.54	1.07	1.19	2.01	2.15	1.67

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 87.15 to 399.89 µg/m³**.** PM_{10} exceeded NAAQS at all the monitoring locations of Kandla. Whereas, at Vadinar, the concentration varies 45.87 to 95.17 µg/m³ where majority of the monitoring days complies with the stipulated norm (100 µg/m³) for both monitoring locations.

- The highest concentration of PM_{10} at locations A-3 i.es Kandla Port Colony could be attributed to the presence of heavy vehicular traffic in upwind areas which bring higher impact causing the dispersion of emitted particulate matter in the ambient air. The unloading of coal directly in the truck, using grabs causes the coal to disperse in the air as well as coal dust to fall and settle on the ground. This settled coal dust again mixes with the air while trucks travel through it. Also, the coal-loaded trucks are generally not always covered with tarpaulin sheets and this might result in increased suspension of coal from trucks/dumpers during its transit from vessel to yard or storage site. This might increase the PM_{10} in and around the Coal storage area and Marine bhavan.
- The **$PM_{2.5}$** concentrations at Kandla monitoring location varies from 28.57 to 103.06 µg/m³. $PM_{2.5}$ exceeded NAAQS limit at location A-1 (Oil Jetty No.1), A-5 (Coal Storage Area) and A-6 (Gopalpuri Hospital). Whereas, at Vadinar its concentration varies at Vadinar from 16.12 to 36.15 µg/m³ which falls within the limit of NAAQS i.e. 60 µg/m³.
- The concentration of **SO_x** varies from 1.26 to 21.15 µg/m³ at Kandla and 9.18 to 22.47 µg/m³ at Vadinar. The range falls within the prescribed limit of NAAQS of 80 µg/m³ for both the monitoring site.
- The concentration of **NO_x** varies from 2.14 to 80.67 µg/m³ at Kandla and 6.45 to 32.17 µg/m³ at Vadinar. The range 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 0.59 to 1.17 mg/m³ at Kandla and 0.21 to 0.74 mg/m³ at Vadinar. The range falls within the norm of 2 mg/m³ specified by NAAQS.
- The concentration of **Total VOCs** levels was recorded in range of 1.06 to 4.21 µg/m³ at Kandla and 1.08 to 3.14 µg/m³ at Vadinar. The main source of VOCs in the ambient air may be attribute to the burning of Gasoline and Natural gas in Vehicle exhaust and burning fossil fuels, wood, and garbage all release VOCs into the atmosphere. During the monitoring period, the wind flows towards West-south-west 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.
- The concentration of **Benzene** was not detected for the Ambient Air Monitoring locations of Kandla, whereas at Vadinar the Benzene concentration falls within the range of 0.12-1.04 µg/m³. The said concentration complies with the specified limit of 5 µg/m³ for both the study areas.
- **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. Comparative higher concentration of PAH was detected at location A-4 i.e Marine Bhavan and A-5 i.e. Coal Storage area, which is a commercial area. PAHs are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They the higher concentration which result from burning coal, oil, gas, road dust, etc might be attributed to higher traffic density in the area. 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 1.07 to 3.54 µg/m^3. While at Vadinar, the NM VOC concentration falls in the range of 1.67 to 2.15 µg/m^3.

With reference to the Ambient Air Quality monitoring conducted under the study, it may be concluded that the particulate matter PM_{10} and $PM_{2.5}$, were reported in higher concentration and apparently exceeds the NAAQS particularly at locations of Kandla. The gaseous pollutants (NO_x, SO_x, CO, VOCs etc.) falls within the permissible limit. The probable reason contributing to these emissions of pollutants into the atmosphere in-and-around the port area are summarized as follows-

1. **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.

4.4 Remedial Measures:

Efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits. 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.
- Ensuring maintenance of engines and machinery to comply with emission standards.
- 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.

- Retrofitting ships with exhaust gas cleaning systems can help reduce sulfur emissions. Engine upgrades, such as optimizing fuel combustion and improving engine efficiency, can reduce overall emissions.
- 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.

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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 8 and 9** as follows:

Figure 8: Location Map for DG Stack monitoring at Kandla

Figure 9: Location Map 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: Parameters to be monitored under the study

Sr. No.	Parameter	Unit	Instrument
1.	Suspended Particulate Matter	mg/Nm^3	Stack Monitoring Kit
2.	Sulphur Dioxide (SO_2)	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: The results of DG Sets for Kandla and Vadinar

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	98.47	41.96
2.	Sulphur Dioxide (SO_2) (PPM)	100	6.45	N.D.
3.	Oxides of Nitrogen (NO_x) (PPM)	50	52.19	22.75
4.	Carbon Monoxide (CO) (%)	1	0.18	0.016
5.	Carbon Dioxide (CO_2) (%)	-	2.57	1.24

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 SPM, SO_2, NOx and CO.

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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 **Figure 10 and 11** 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

Figure 10: Location Map for Noise Monitoring at Kandla

Figure 11: Location Map 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 that carried out at Kandla and Vadinar

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

Standard for Noise

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

Table 15: Ambient Air Quality norms in respect of Noise

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

6.2 Result and Discussion

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

Table 16: The Results of Ambient Noise Quality

Sr. No.	Station Code	Station Name	Category of Area	Standard	Day Time			Standard	Night Time		
					Max.	Min.	Leq dB(A) Total		Max.	Min.	Leq dB(A) Total
1	N-1	Oil Jetty 7	A	75	55.2	38.9	49.6	70	42.6	33.0	40.0
2	N-2	West Gate No.1	A	75	66.1	48.0	60.5	70	50.1	41.1	46.3
3	N-3	Canteen Area	B	65	60.2	44.2	55.5	55	49.2	37.2	43.2
4	N-4	Main Gate	A	75	58.4	46.9	54.9	70	45.4	37.9	42.1
5	N-5	Main Road	A	75	61.5	39.4	55.7	70	47.6	35.6	43.2
6	N-6	Marin Bhavan	B	65	62.3	39.5	56.9	55	42.0	34.6	38.9
7	N-7	Port & Custom Building	B	65	54.6	39.4	49.5	55	46.6	36.4	42.4
8	N-8	Nirman Building	B	65	54.5	42.6	50.7	55	44.3	38.6	41.4
9	N-9	ATM Building	B	65	58.1	41.6	53.9	55	45.9	37.2	41.9
10	N-10	Wharf Area/ Jetty	A	75	61.5	42.6	56.3	70	47.2	40.6	44.6
11	N-11	Near Main Gate	A	75	71.1	57.5	59.0	70	68.9	57.0	57.8
12	N-12	Near Vadinar Jetty	A	75	72.8	59.0	62.1	70	62.1	53.0	55.4
13	N-13	Port Colony Vadinar	C	55	60.1	49.0	50.1	45	62.8	48.0	49.4

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. The Day Time the average noise level at all 10 locations at Kandla ranged from 49.5 dB(A) to 60.5 dB(A), while at Vadinar, the noise levels for the three-location ranged from 50.1 dB(A) to 62.1 dB(A). Whereas, during Night Time the average Noise Level ranged from 38.9 dB(A) to 46.3 dB(A) at Kandla and 49.4 dB(A) to 57.8 dB(A) at Vadinar which was within the permissible limits for the industrial, residential and commercial area except for location N-13 which exceeds the stipulated norms for night time.

6.4 Remedial Measures

As per the noise level found within the norms thus no need to bring it down from the existing level however, the noise could be considerably reduced by adoption of low noise equipment or installation of sound insulation fences. Green belt of plants can be a good barrier. 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 locations

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: List of parameters to be monitored for Soil Quality

Sr. No.	Parameters	Units	Reference method	Instruments
1.	TOC	%	Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934)	Titration Apparatus
2.	Organic Carbon	%		
3.	Inorganic Phosphate	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 12 and 13** as follows:

Figure 12: Location Map for Soil Quality Monitoring at Kandla

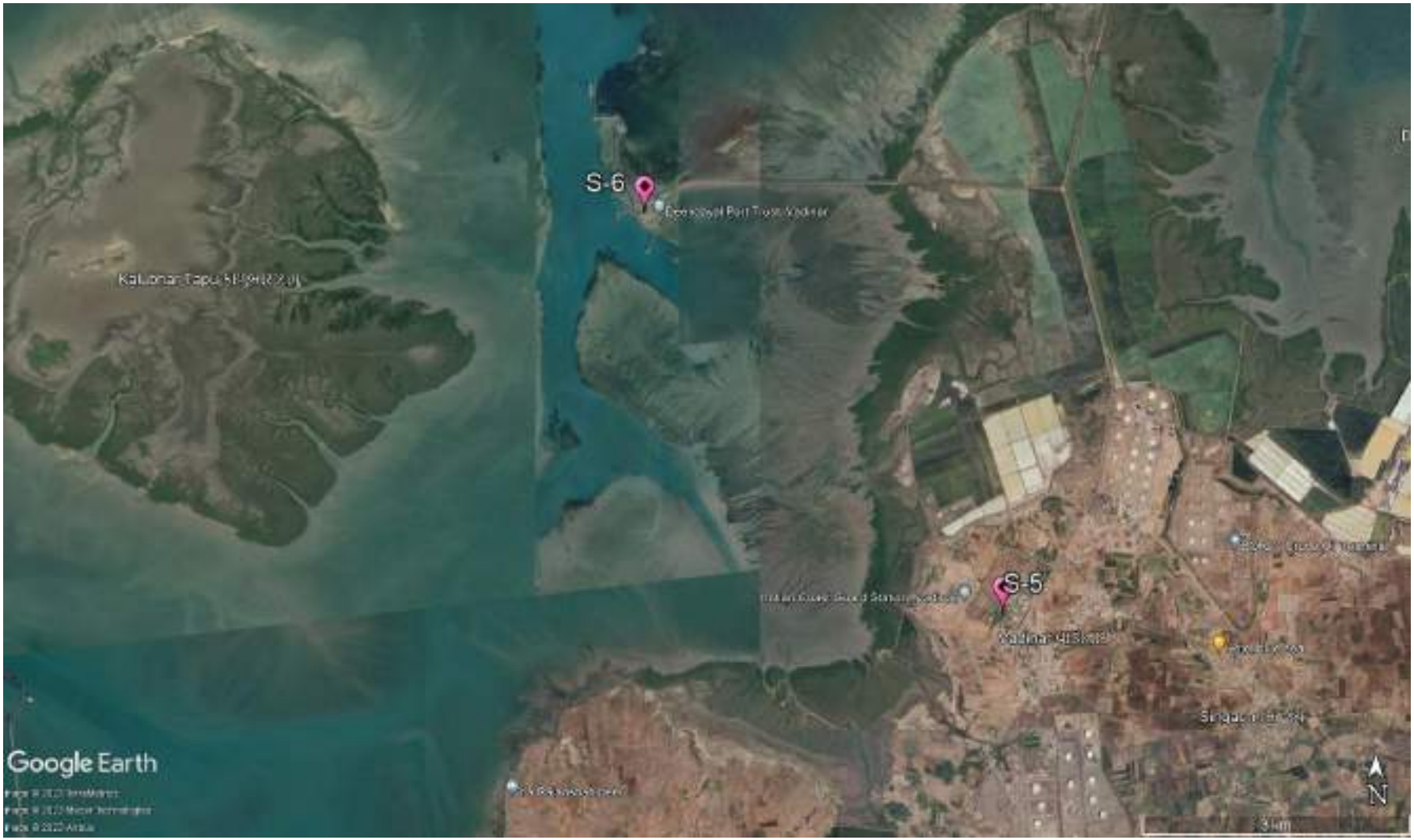

Figure 13: Location Map for Soil Quality Monitoring at Vadinar

7.2 Result and Discussion

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

Table 19: Soil Quality for the sampling period

Sr. No	Location / Parameters	Unit	Kandla				Vadinar	
			S-1 (Oil Jetty 7)	**S-2** IFFCO Plant)	**S-3** (Khori Creek)	**S-4** (Nakti Creek)	**S-5** (Near SPM)	**S-6** (Near Vadinar Jetty)
1	pH		9.39	8.8	7.54	8.64	8.32	8.4
2	Conductivity	µS/cm	1847	4380	75700	704	94	127
3	Inorganic Phosphate	Kg/ha	1.92	1.7	1.24	3.15	0.95	0.77
4	Organic Carbon	%	0.06	0.14	0.98	0.49	0.25	0.65
5	Organic Matter	%	0.10	0.24	1.69	0.84	0.431	1.12
6	SAR	meq/L	5.29	6.14	29.26	0.67	0.11	0.09
7	Aluminium	mg/Kg	812.75	830.95	840.71	916.40	735.77	754.58
8	Chromium	mg/Kg	60.76	57.44	42.48	46.75	76.06	60.93
9	Nickel	mg/Kg	14.92	14.38	11.91	16.54	29.15	26.73
10	Copper	mg/Kg	78.66	74.40	62.62	16.84	102.62	70.50
11	Zinc	mg/Kg	101.93	76.19	44.26	23.57	46.12	29.32
12	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	4.67	3.27	1.29	3.46	BQL	BQL
14	Arsenic	mg/Kg	BQL	BQL	BQL	2.377	0.099	BQL
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	36	38	50.8	46	42	62
17	Sand	%	73.52	73.52	51.52	73.52	54.24	64.24
18	Silt	%	23.28	21.28	33.28	11.28	33.44	25.44
19	Clay	%	3.2	5.2	15.2	15.2	12.32	10.32
20	Texture	-	Loamy Sand	Loamy Sand	Loam	Sandy loam	sandy loam	Sandy loam

7.3 Data Interpretation and Conclusion

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

- The value of **pH** ranges from 7.54 to 9.39, highest at location S-1 (Oil Jetty 7) and lowest at S-3 (Khori Creek); while the average pH for Kandla was observed to be 8.59.

Whereas, at Vadinar the pH value observed at S-5 i.e., Near SPM (8.32) and at S-6 i.e., Near Jetty Area (8.4). 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 704 to 75700 µs/cm, highest at location S-3 (Khori Creek) with the average as 20657.75 µs/cm. Whereas, at Vadinar the range of conductivity was between the range of 94 to 127 µs/cm with an average value of 110.5 µs/cm.

- At Kandla, the concentration of **Inorganic Phosphate** varied from 1.24 to 3.15 Kg/ha, with average 2 Kg/ha. Whereas, at the locations of Vadinar, the Inorganic Phosphate was observed at S-5 i.e., Near SPM (0.95 Kg/ha) and detected at S-6 i.e., near Jetty Area (0.77 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 0.06 to 0.98% while the average TOC at Kandla was detected as 0.42%. Whereas, at Vadinar the average TOC was found to be 0.45% where the observed TOC value found at S-5 and S-6 to be 0.25 and 0.65 respectively.

- The concentration of **Water Holding Capacity** in the soil samples of Kandla and Vadinar varies from 36 to 50.8% and 42 to 62% respectively.

- The concentration of **Sodium Adsorption Ratio** ranges from 0.67 to 29.26 meq/L with an average value 10.34 meq/L at Kandla. Whereas, at Vadinar, the average SAR was found to be 0.1 meq/L where the observed SAR value found at S-5 (0.11 meq/L) and S-6 (0.09 meq/L).

- Loam to Sandy Loam **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 812.75 to 916.40 mg/kg at Kandla and 735.77 to 754.58 mg/kg at Vadinar and the average value was observed to be 850.20 and 745.18 mg/kg at Kandla and Vadinar monitoring station, respectively.
- The concentration of **Chromium** varied from 42.48 to 60.76 mg/kg at Kandla and 60.93 to 76.06 mg/kg at Vadinar and the average value was observed to be 51.86 and 68.496 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Nickel** varied from 11.91 to 16.54 mg/kg at Kandla and 26.73 to 29.15 mg/kg at Vadinar and the average value was observed to be 14.43 and 27.94 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Zinc** varied from 23.57 to 101.93 mg/kg at Kandla and 29.32 to 46.12 mg/kg at Vadinar and the average value was observed to be 61.48 and 37.72 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Copper** varied from 16.84 to 78.66 mg/kg at Kandla and 70.50 and 102.62 mg/kg at Vadinar and the average value was observed to be 58.13 and 86.56 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Lead** varied from 1.29 to 4.67 mg/kg at Kandla with average value 3.17 mg/Kg, whereas for Vadinar, the value recorded below the detection limit.

- The concentration of **Arsenic** found to be BQL at Kandla except for location S-4 i.e. 2.38 mg/kg. Whereas for Vadinar the value recorded for location S-5 to be 0.09 mg/kg and BQL at S-6.

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

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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 details of the drinking water sampling stations have been mentioned in **Table 20** and the locations have been depicted through Google map in **Figure 14 and 15.**

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	Port & Custom Building	23.009033N 70.222047E
3.		DW-3	North Gate	23.007938N 70.222411E
4.		DW-4	Workshop	23.009372N 70.222236E
5.		DW-5	Canteen Area	23.003707N 70.221331E
6.		DW-6	West Gate 1	23.006771N 70.217340E
7.		DW-7	Sewa Sadan -3	23.009779N 70.221838E
8.		DW-8	Nirman Building	23.009642N 70.220623E
9.		DW-9	Custom Building	23.018930N 70.214478E
10.		DW-10	Port Colony Kandla	23.019392N 70.212619E
11.		DW-11	Wharf Area/ Jetty	22.997833N 70.223042E
12.		DW-12	Hospital Kandla	23.018061N 70.212328E
13.		DW-13	A.O. Building	23.061914N 70.144861E
14.		DW-14	School Gopalpuri	23.083619N 70.132061E
15.		DW-15	Guest House	23.078830N 70.131008E
16.		DW-16	E- Type Quarter	23.083306N 70.132422E
17.		DW-17	F- Type Quarter	23.077347N 70.135731E
18.		DW-18	Hospital Gopalpuri	23.081850N 70.135347E
19.	Vadinar	DW-19	Near Vadinar Jetty	22.440759N 69.675210E
20.		DW-20	Near Port Colony	22.401619N 69.716822E

Figure 14: Location Map for Drinking Water Monitoring at Kandla

Figure 15: Location Map 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	-	7.38	6.77	6.75	7.37	7.83	7.94	7.42	7.82	6.62	6.82	8.12	6.62	7.81	8.03	7.45	7.08	7.42	7.19	7.27	7.87
2.	Colour	Hazen	5	15	1	1	1	1	5	5	1	5	1	1	5	1	1	1	1	1	1	1	1	1
3.	EC	µS/cm	-	-	260	165.2	205	42.7	1257	1181	55.7	1156	117.7	194.5	1183	194.9	81.5	818	147.3	63.2	246	63.4	178.3	132.5
4.	Salinity	mg/L	-	-	0.13	0.08	0.10	0.03	0.62	0.59	0.03	0.57	0.06	0.10	0.59	0.10	0.11	0.58	0.7	0.05	0.31	0.04	0.09	0.34
5.	Turbidity	NTU	1	5	1.20	1.48	0.93	0.90	1.6	1.1	1.13	1.14	0.97	1.23	3.4	1.02	BQL	7.01	BQL	BQL	BQL	BQL	1.5	0.7
6.	Chloride	mg/L	250	1000	57.98	42.49	37.99	12.50	262.42	259.92	16	244.92	28.99	48.98	244.92	45.99	35.47	285.40	45.4	22.1	65.2	16.3	27.49	19.1
7.	Total Hardness	mg/L	200	600	8	10	12	4	230	230	4	210	8	3	210	20	12	170	8	5	12	4	38	30
8.	Ca Hardness	mg/L	-	-	4	7	8	3	110	120	2	110	4	2	90	12	6	90	5	3	7	3	18	18
9.	Mg Hardness	mg/L	-	-	4	3	4	1	120	110	2	100	4	1	120	8	6	80	3	2	5	1	20	12
10	Free Residual Chlorine	mg/L	0.2	1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
11	TDS	mg/L	500	2000	132	84	104	22	630	598	28	580	60	98	600	98	BQL	512	73	33	185	34	90	81
12	TSS	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	2	BQL	BQL	8	BQL	BQL	BQL	BQL	BQL	BQL
13	Fluoride	mg/L	1.0	1.5	BQL	BQL	0.36	BQL	0.89	0.91	0.42	BQL	BQL	BQL	1.06	BQL	BQL	0.15	BQL	BQL	BQL	BQL	BQL	BQL
14	Sulphate	mg/L	200	400	BQL	BQL	BQL	BQL	93.16	93.24	BQL	BQL	BQL	BQL	93.38	BQL	BQL	88.2	10.3	BQL	11.48	BQL	BQL	25.4
15	Nitrate	mg/L	45	-	12.04	BQL	4.08	BQL	6.68	5.69	BQL	4.53	BQL	4.23	6.47	BQL	BQL	1.78	BQL	BQL	2.51	BQL	BQL	3.44
16	Nitrite	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
17	Sodium	mg/L	-	-	46.24	28.73	32.72	11.54	135.8	117.01	10.47	109.5	18.28	34.08	115.72	24.85	21.25	88.2	15.3	BQL	46.4	9.05	20.56	35.7

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
18	Potassium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
19	Hexavalent Chromium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20	Odour	TON	Agreeable		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	Arsenic	mg/L	0.01	0.05	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.08	BQL
22	Cadmium	mg/L	0.003	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23	Copper	mg/L	0.05	1.5	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
24	Iron	mg/L	0.3	-	BQL	BQL	0.16	BQL	0.14	0.16	BQL	BQL	BQL	BQL	0.17	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
25	Lead	mg/L	0.01	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.002	BQL	BQL	BQL	BQL	BQL
26	Manganese	mg/L	0.1	0.3	BQL	BQL	BQL	BQL	BQL	0.04	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	5	10	5	160	120	5	145	190	81	39	140	52	102	11	48	40	120	BQL	10

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)

*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 6.62 to 8.12, with an average pH of 7.35. In Vadinar, its values ranged from 7.27 to 7.87, with an average pH of 7.57. Notably, the pH levels at both project sites fall within the acceptable range of 6.5 to 8.5, as specified under IS:10500:2012.
- **Turbidity:** At the drinking water locations of Kandla, the turbidity was found in range from 0.9 to 7.01 NTU with average value 1.77 NTU. Whereas, at Vadinar the value of turbidity was reported 1.5 NTU at DW-19 and 0.7 NTU at DW-20 with average at 1.10 NTU.
- **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 22 to 630 mg/L, with an average concentration of 227.71 mg/L. while in Vadinar, it ranged from 81 to 90 mg/L, with average at 85.50 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 except for location DW-5, DW-11, DW-14.
- **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 42.7 to 1257 µS/cm, with an average value of 412.89 µS/cm. In Vadinar, the EC values showed variation from 132.5 to 178.3 µS/cm, with an average value of 155.40 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 12.5 to 285.4 mg/L, with an average value of 98.49 mg/L. In Vadinar, it ranged from 19.1 to 27.49 mg/L, with an average value of 23.30 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, DW-14.
- **Total Hardness (TH):** Total Hardness varied from 3 to 230 mg/L, with the average value as 64.44 mg/L. While at Vadinar, the variation was observed from 30 to 38 mg/L; with the average conc. at 34 mg/L. which was found to be within the acceptable norm of 200 mg/L as specified by IS:10500:2012 and is not harmful for local inhabitants.
- **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 10.3 to 93.38

mg/L, with an average value of 64.96 mg/L. In Vadinar, the sulphate concentration was observed BQL at location DW-19 and 25.4 mg/L at DW-20.

- **Sodium:** During the monitoring period, at Kandla variation in the concentration of sulphate was observed to be in the range of 9.05 to 135.8 mg/L, with the average concentration of 50.89 mg/L. While at Vadinar, the concentration recorded 20.56 mg/L at DW-19 and 35.7 mg/L at DW-20.
- **Nitrate:** During the monitoring period, at Kandla & Vadinar variation in the concentration of Nitrate was observed to be in the range of 1.78 to 12.03 mg/L, with the average concentration of 5.34 mg/L also majority of the location recorded as "BQL". While at Vadinar, the concentration recorded BQL at DW-19 and 3.44 mg/L at DW-20, with average concentration of 3.44 mg/L.
- **Fluoride:** The concentration was found to be BQL in majority of the monitoring location except for location DW-3 (North Gate) i.e. 0.36 mg/L, DW-5 (Canteen Area) i.e. 0.89 mg/L, DW-6 (West Gate 1) i.e. 0.91 mg/L, DW-7 (Sewa Sadan-3) i.e. 0.42, DW-11 (Wharf area/Jetty) i.e. 1.06 mg/L, DW-14 (School Gopalpuri) i.e. 0.15 mg/L at Kandla. While at Vadinar its value also reported to be BQL for both the monitoring location.
- The parameters such as **Potassium, Free Residual Chlorine, Total Suspended Solids, Nitrite, Hexavalent Chromium**, and **the metals Arsenic, Cadmium, Copper, Iron, Lead, Manganese, Mercury, Total Chromium and Zinc** were all observed to have concentrations "Below the Quantification Limit (BQL)" at majority of the locations during the monitoring period.
- Bacteriological Analysis of the drinking water reveals that Total Coliforms were detected in small concentration at majority of the monitoring locations of Kandla and Vadinar. Reporting such concentration of Coliforms indicates certain external influx may contaminate the source. Hence, it should be checked at every distribution point.

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.

Furthermore, a regular monitoring 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.

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: Norms of treated effluent 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 16 and 17** as follows:

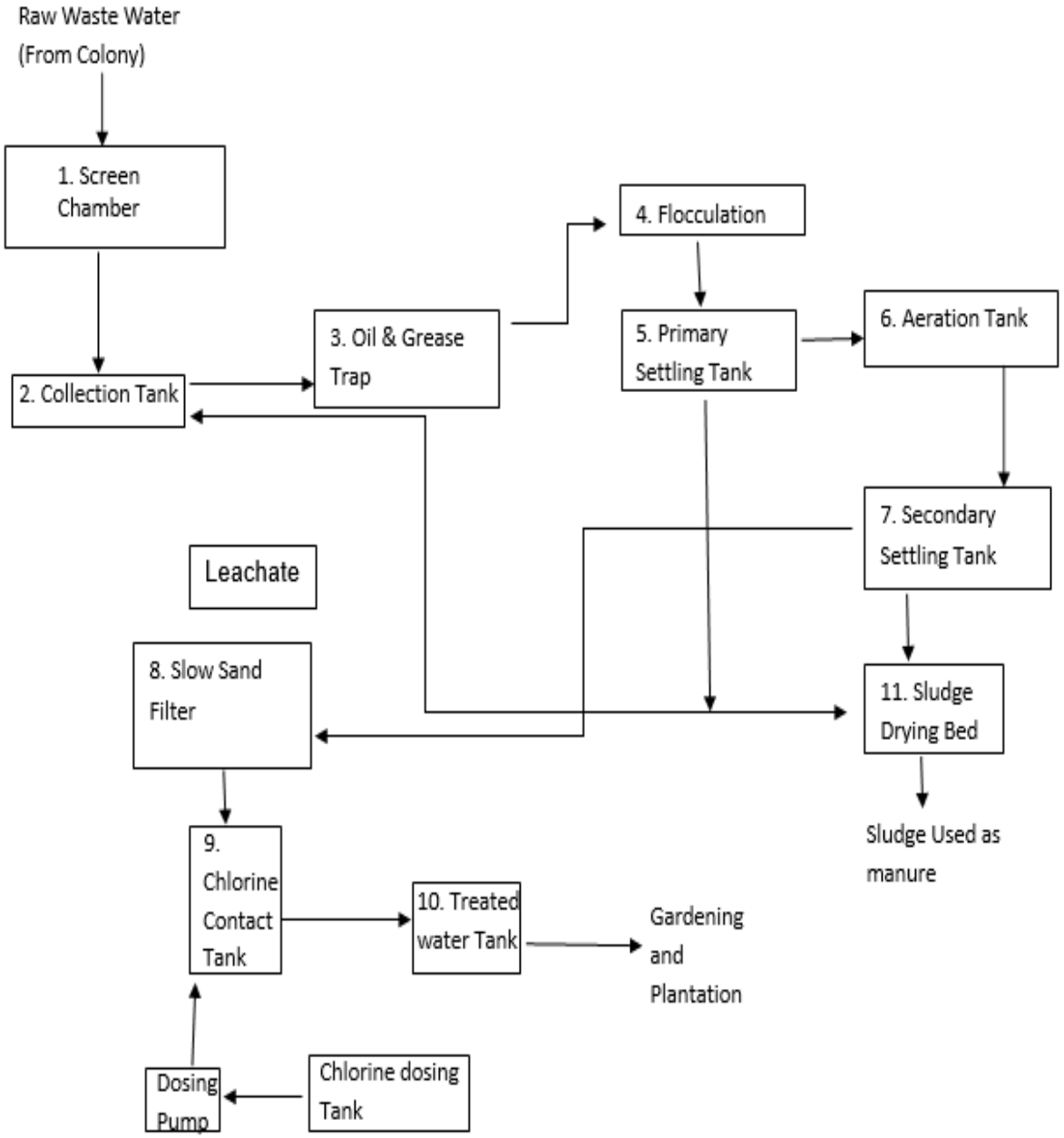

Figure 16: Process flow diagram of Kandla STP

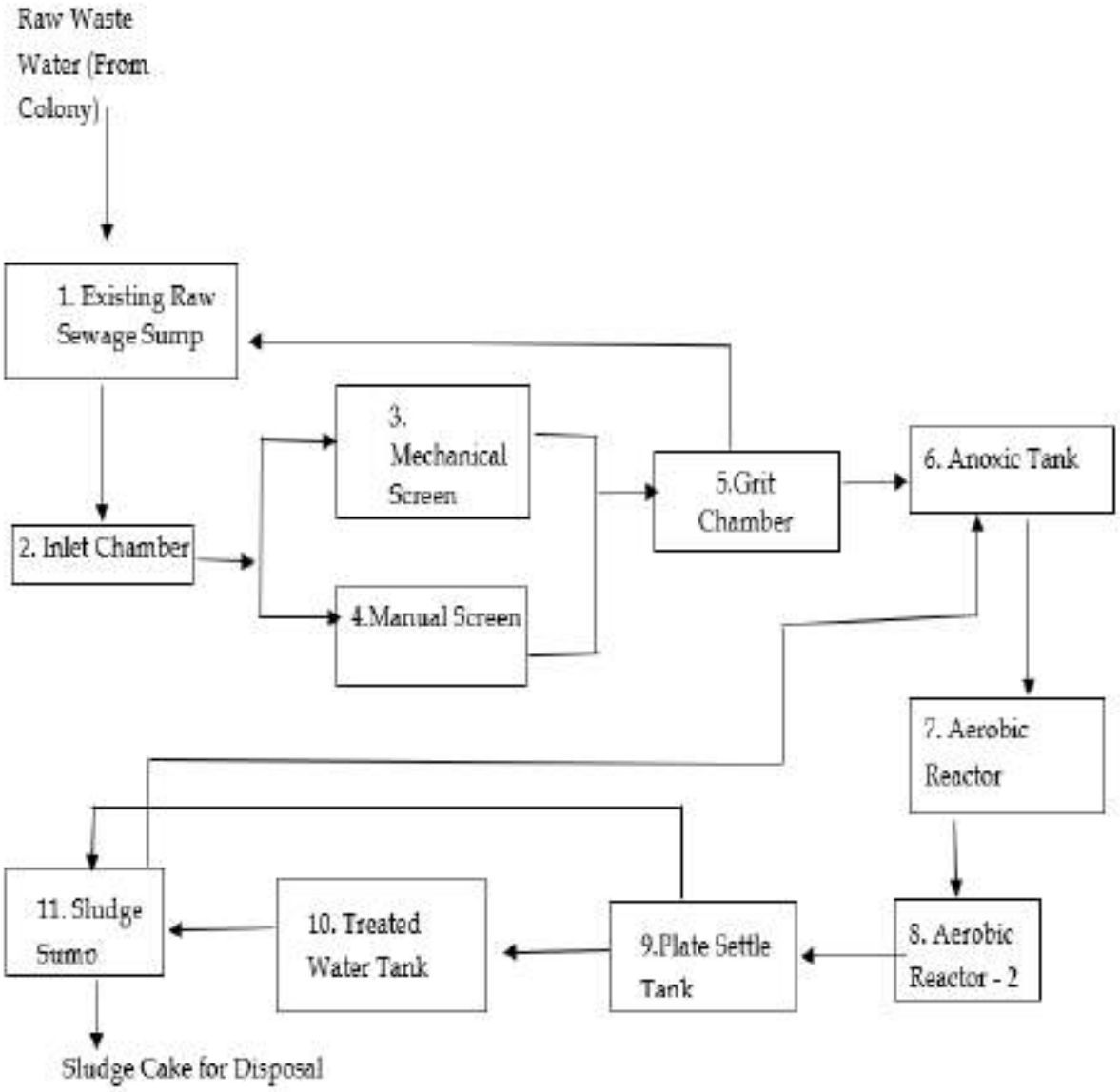

Figure 17: Process flow diagram of Gopalpuri STP

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 18** as follows:

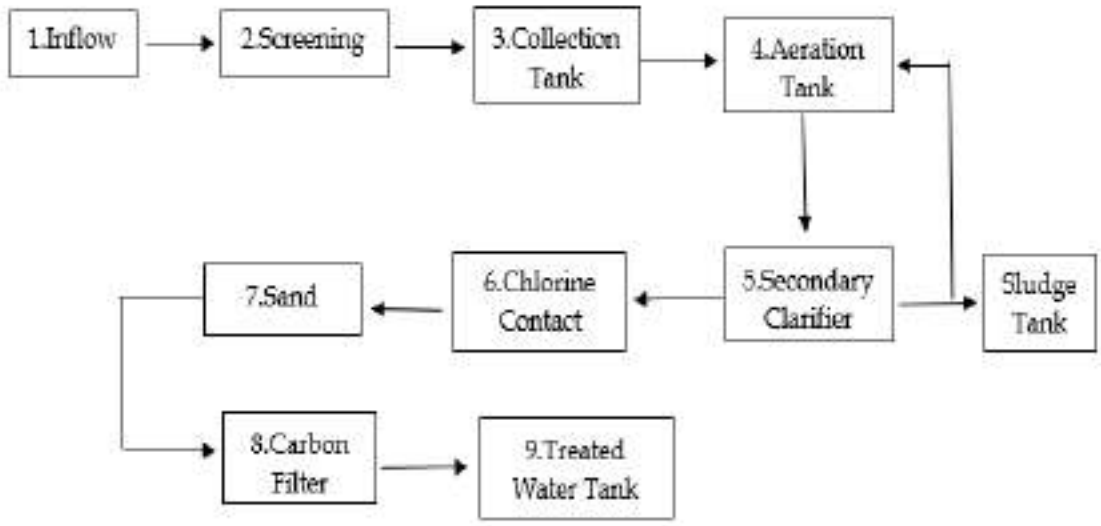

Figure 18: Process flowchart for the Vadinar STP

The map depicting the locations of STP to be monitored in Kandla and Vadinar have been shown in **Figure 19 and 20** as follows:

Figure 19: Location Map for STP Monitoring at Kandla

Figure 20: Location Map 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

The quality of the water samples collected from the inlet and the outlet of the STP's of Kandla and Vadinar has been summarized in **Table 27 & 28**. The said water quality has been represented in comparison with the standard values 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 October				Week 4 of October				Week 1 of November				Week 2 of November			
				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**	7.09	7.42	7.45	7.11	7.43	7.12	7.12	7.55	7.70	7.34	7.13	7.59	7.40	7.52	7.16	7.45
2.	TDS	mg/L	-	1652	1128	1563	1074	1376	954	1554	1468	8702	4208	1232	1046	8668	1954	1138	1084
3.	TSS	mg/L	**100**	59	21	59	21	83	33	106	16	58	26	46	28	344	82	58	22
4.	DO	mg/L	-	0.65	6.25	BQL	7.41	0.94	5.36	BQL	2.8	BQL	2.8	BQL	3.8	BQL	6.9	BQL	4.1
5.	COD	mg/L	-	175	43.1	82.37	44.92	76.11	36.48	192	36	130.95	83.33	170.63	43.82	436.51	79.37	162.70	47.62
6.	BOD	mg/L	**30**	76.21	6.52	53.14	2.01	69.16	3.44	57.6	5.4	40.92	15.62	53.32	8.22	136.41	14.88	40.67	8.93
7.	SAR	meq/L	-	6.32	5.17	7.56	7.12	6.84	5.11	7.51	7.21	21.56	15.52	6.97	6.20	21.27	8.88	5.73	5.64
8.	Total Coliforms	MPN/ 100ml	**<1000**	1600	1600	1600	1600	1600	1600	1600	1600	1600	130	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)	Vadinar							
				Week 3 of October		Week 4 of October		Week 1 of November		Week 2 of November	
				STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)	STP-3 (Inlet)	STP-3 (Outlet)
1.	pH	-	**5.5-9**	7.12	7.24	7.15	7.20	7.26	7.00	7.26	7.17
2.	TDS	mg/L	-	424	352	420	354	428	354	486	372
3.	TSS	mg/L	**20**	26	16	46	4	18	10	18	12
4.	DO	mg/L	-	BQL	6.2	BQL	5.9	BQL	5.3	BQL	2.8
5.	COD	mg/L	**50**	171.31	35.86	157.48	19.69	115.08	27.78	158.73	27.78
6.	BOD	mg/L	**10**	53.53	4.48	47.24	4.92	35.96	3.47	49.60	5.21
7.	SAR	meq/L	-	2.19	2.22	2.23	2.15	2.72	2.53	2.54	2.24
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 conform to the standard of 6.5-8.5. Whereas, pH for STP-3 at Vadinar conforms the norm of 5.5-9 as specified in the CCA.
- The **TSS** for the STP-1 and STP-2 of Kandla and STP-3 of Vadinar falls within the stipulated norms of 100 and 20 mg/L for outlet of Kandla and Vadinar, respectively and hence conforms to the norms specified.
- As per the norms, the **Chemical Oxygen Demand** falls within the CCA norms (50 mg/L) for the STP-3 of Vadinar.
- The **BOD** of the outlet for the STPs of Kandla and Vadinar falls within the stipulated norms.
- The **Total Coliforms** were exceeding the norms at the locations of the STP-1 & STP-2 outlets of Kandla and STP-3 outlet of Vadinar.

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 of 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 treatment parameters such as retention time, Mixed Liquor Suspended Solids (MLSS), Mixed liquor volatile suspended solids (MLVSS), Recirculation rate, sludge generation, etc should be monitored timely.
- During the treatment, the required retention time and rate of aeration should be maintained, so that the efficiency of the treatment plant is maintained.
- The dosage of chemicals administered during the treatment should be reviewed and alterations in the dosage should be done.
- The results show the presence of total coliforms; hence the method of disinfection (Chlorination) sodium or calcium Hypochlorite can be used.
- Effectiveness of any technology depends on factors such as the specific pollutants in the wastewater, plant size, local regulations, and available resources. There are several processes that may be implemented such as - Advanced oxidation process involve using strong oxidants to break down complex organic compounds. Methods like Fenton's reagent (hydrogen peroxide and iron catalyst) and UV/H_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.
- Enhanced biological treatment processes, such as Moving Bed Biofilm Reactors (MBBR), Integrated Fixed-film Activated Sludge (IFAS) systems, and Membrane Bio-Reactors (MBRs) are utilised to improve the efficiency of organic matter and nutrient removal from wastewater.

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CHAPTER 10: MARINE WATER QUALITY MONITORING

10.1 Marine Water

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

Major water quality concerns at ports include wastewater and leakage of toxic substances from ships, stormwater runoff, etc. This discharge of wastewater, combined with other ship wastes which includes sewage and wastewater from other on-board uses, is a serious threat to the water quality as well as to the marine life. As defined in the scope by 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 21 and 22** as follows:

Figure 21: Location Map for Marine Water Monitoring at Kandla

Figure 22: Location Map 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	1.022	1.022	1.021	1.022	1.022	1.022	1.022
2.	pH	-	6.5-9.0	8.05	8.17	8.14	8.13	8.16	8.21	8.07	8.18
3.	Color	Hazen	No Noticeable	5	5	10	5	5	5	10	10
4.	EC	µS/cm	-	51,600	52,000	51,300	51,900	52,000	51,900	54,400	55,200
5.	Turbidity	NTU	-	56.4	33.9	61.8	69.0	94.5	70.1	7.8	7.12
6.	TDS	mg/L	-	33,960	34,146	33,724	34,038	33,882	34,368	31,490	33,540
7.	TSS	mg/L	-	44	26	52	58	80	58	307	309
8.	COD	mg/L	-	45.58	40.47	40.0	40.0	38.14	37.67	43.7	33.5
9.	DO	mg/L	3.0 mg/L	6.2	6.4	4.5	6.2	6.3	6.7	5.2	6.3
10.	BOD	mg/L	5.0 mg/L	BQL	BQL	5.00	5.00	BQL	BQL	6.2	4.2
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	2860.6	2897.7	2925.2	3029.2	2916.8	2862.6	2547.1	3016.4
13.	Nitrate	mg/L	-	4.93	4.36	5.13	5.24	6.92	6.84	4.14	4.21
14.	Nitrite	mg/L	-	0.12	BQL	BQL	BQL	0.11	0.13	BQL	BQL
15.	Phosphate	mg/L		0.54	BQL	0.69	0.61	0.70	0.65	BQL	BQL
16.	Silica	mg/L	-	2.13	2.47	2.47	2.58	4.00	2.48	0.47	0.62
17.	Sodium	mg/L	-	10,625	10,341	10,308	10,323	10,278	10,722	5376.25	8472
18.	Potassium	mg/L	-	311.40	310.40	311.10	306	313.50	289.70	298.3	342.2
19.	Hexavalent Chromium	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	-	-	1	1	1	1	1	1	1	1
21.	Arsenic	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	0.11	0.085
22.	Cadmium	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

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
24.	Iron	mg/L	-	0.88	0.77	0.90	1.05	1.57	1.19	BQL	BQL
25.	Lead	µg/L	-	BQL	BQL	BQL	BQL	3.85	BQL	BQL	BQL
26.	Manganese	µg/L	-	BQL	BQL	BQL	BQL	47.74	BQL	BQL	BQL
27.	Total Chromium	µg/L	-	BQL	BQL	BQL	BQL	5.82	BQL	BQL	BQL
28.	Zinc	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Mercury	µg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Particulate Organic Carbon	mg/L	-	1.17	0.61	0.59	1.88	1.51	1.43	BQL	BQL
31.	Total Coliforms	MPN/ 100ml	500/100 ml	23	50	52	2	14	22	20	17
32.	Floating Material (Oil grease scum, petroleum products)	mg/L	10 mg/L	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

BQL- Below Quantification Limit; Turbidity (DL=50 NTU), Biochemical Oxygen Demand (QL=3 mg/L), Oil & Grease (QL=1 mg/L), Nitrate as NO_3 (QL=1 mg/L), Nitrite as No_2 (QL=0.1 mg/L), Phosphorous (QL=0.5 mg/L), Silica (QL=0.05 mg/L), Sodium as Na (QL=10,000 mg/L), Hexavalent Chromium (QL=0.01 µg/L), Arsenic (QL=5 µg/L), Cadmium (QL=2 µg/L), Copper (QL=5 µg/L), Iron (QL=0.1 mg/L), Lead (QL=2 µg/L), Manganese (QL=40 µg/L), Total Chromium (QL=5 µg/L), Zinc (QL=0.5 mg/L), Mercury (QL=0.5 µg/L)

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 2023 at high tide. The detailed interpretation of the parameters in comparison to the Class SW-IV for Harbour Waters is as follows:

- **pH** at Kandla was observed in the range of 8.05 to 8.21, with the average pH as 8.14. Whereas for the locations of Vadinar, it was observed in the range of be 8.07 to 8.18, with the average pH as 8.13. For the monitoring location of both the study areas, pH was found to comply with the norms of 6.5-8.5.
- **Color** was observed to be 5 Hazen at all the six-monitoring location of Kandla, whereas the value observed 10 Hazen at both the monitoring locations of Vadinar.
- For all monitoring locations of Kandla the value of **Turbidity** was observed in range of 33.9 to 94.5 NTU and for Vadinar it ranges from 7.12 to 7.8 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.
- **Electrical conductivity (EC)** was observed in the range of 51,300 to 52,000 µS/cm, with the average EC as 51,783.33 µS/cm for the locations of Kandla, whereas for the locations of Vadinar, it was observed in the range of 54,400 to 55,200 µS/cm, with the average EC as 54,800 µS/cm.
- For the monitoring locations at Kandla the value of **Total Dissolved Solids (TDS)** ranged from 33,724 to 34,368 mg/L, with an average value of 34019.67 mg/L. Similarly, at Vadinar, the TDS values ranged from 31,490 to 33,540 mg/L, with an average value of 32,515 mg/L.
- **TSS** values in the studied area during high Tide varied between 26 to 80 mg/L at Kandla and 168 to 307 mg/L at Vadinar, with the average value of 53 mg/L and 237.5 mg/L respectively for Kandla and Vadinar.
- **COD** varied between 37.67 to 45.58 mg/L at Kandla and 33.5 to 43.7 mg/L at Vadinar, with the average value as 40.31 mg/L and 38.6 mg/L respectively for Kandla and Vadinar.
- **DO** level in the studied area varied between 4.5 to 6.7 mg/L at Kandla and 5.2 to 6.3 mg/L at Vadinar, which represents that the marine water is suitable for marine life.
- **BOD** observed "below the detection limit" in the studied area of Kandla except for location MW-4 (Khori Creek) i.e. 5 mg/L, whereas at Vadinar the value observed 6.2 mg/L at MW-7 and at MW-8 recorded as 4.2 mg/L.
- **Sulphate** concentration in the studied area during high Tide varied between 2860.6 to 3029.2 mg/L at Kandla and 2547.1 to 3016.4 mg/L at Vadinar. A high variation in the sulphate concentration is observed at Kandla. Sulphate is naturally formed in inland waters by mineral weathering or the decomposition and combustion of organic matter.
- **Phosphate** in the studied area varied between 0.54 to 0.7 mg/L at Kandla, while at Vadinar, the concentration of Phosphate was recorded BQL.

- In the study area of Kandla the value **Potassium** during high Tide varied between 289.7 to 313.5 mg/L and 298.3 to 342.2 mg/L at Vadinar, with the average value as 307.01 mg/L and 320.25 mg/L respectively for Kandla and Vadinar.
- **Sodium** in the study area varied between 10,278 to 10,722 mg/L at Kandla whereas at Vadinar its value recorded 5376.25 mg/L at MW-7 and 8472 mg/L at MW-8.
- **Silica** in the studied area varied between 2.13 to 4 mg/L at Kandla and 0.47 to 0.62 mg/L for Vadinar.
- **Arsenic** in the study area of Kandla recorded below the quantification while at Vadinar the value observed to be 0.11 µg/L at MW-7 and 0.08 µg/L at MW-8.
- **Iron** in the study area varied between 0.77 to 1.57 mg/L at Kandla whereas at Vadinar its value recorded BQL at both the monitoring locations (MW-7 and MW-8).
- **Manganese** recorded BQL at all the monitoring location of Kandla and Vadinar excepts MW-5 i.e. 47.74 µg/L.
- **Oil & Grease, Copper, Nitrite, Hexavalent and Total Chromium, Cadmium, Zinc, and Mercury, Floating Material (Oil grease scum, petroleum products)** were observed to have concentrations **"Below the Quantification Limits (BQL)"** for all the locations of Kandla and Vadinar.
- **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 **Figure 23 and 24** as follows:

Figure 23: Location Map of Marine Sediment Monitoring at Kandla

Figure 24: Locations Map of Marine Sediment Monitoring at Vadinar

The list of parameters to be monitored under the projects for the Marine Sediment sampling been mentioned in **Table 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	4.02	9.47	19.32	7.82	18.36	16.81	5.39	4.48
2.	Phosphate	mg/Kg	994.23	1246.4	813.7	581.3	763.24	886.36	402.3	519.3
3.	Organic Matter	mg/Kg	0.42	BQL	BQL	0.77	0.93	0.53	0.15	0.17
4.	Sulphate as SO^{4-}	mg/Kg	183.25	113.50	246.90	165.50	113.65	108.30	86.36	143.40
5.	Calcium as Ca	mg/Kg	1963.62	2251.40	1463.80	2343	2347	2164	2896	2637.90
6.	Magnesium as Mg	mg/Kg	1383.23	1843.60	1573.20	1521.60	1568	1402.63	926.80	1623.80
7.	Silica	g/Kg	481.3	347.8	336.1	255.12	375.6	305.8	346.7	373.9
8.	Nitrite	mg/Kg	0.51	0.31	0.36	0.75	0.29	0.53	0.15	0.2
9.	Nitrate	mg/Kg	19.84	12.79	14.86	14.31	15.93	16.24	14.84	8.04
10.	Sodium	mg/Kg	3813	2707	3645	2643	3571	4123.95	5231.7	9291.4
11.	Potassium	mg/Kg	1823.3	1247.6	2943.5	2943.62	1546.4	3025.68	1236.7	3271.6
12.	Aluminium	mg/Kg	2442.3	2324.56	2168.9	2261.3	1316.2	1533.65	1584.3	1826.7
13.	Chromium	mg/Kg	62.13	43.9	48.32	43.5	50.23	53.65	27.9	56.72
14.	Copper	mg/Kg	2.73	3.83	3.12	4.02	5.12	3.63	3.12	5.12
15.	Nickel	mg/Kg	39.42	20.49	28.45	29.34	23.83	25.38	16.84	27.95
16.	Zinc	mg/Kg	60.76	63.26	46.3	55.53	57.36	56.64	25.89	88.74
17.	Cadmium	mg/Kg	BQL	0.60	0.87	BQL	BQL	0.15	BQL	BQL
18.	Lead	mg/Kg	5.86	5.92	4.56	5.37	4.32	3.67	5.49	8.21
19.	Arsenic	mg/Kg	3.22	2.58	3.81	3.13	2.86	2.35	2.04	3.20
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 2023. The detailed interpretation of the parameters is given below:

- **Inorganic Phosphate** for the sampling period was observed in range of 4.02 to 19.32 Kg/ha for Kandla. Whereas for Vadinar the value observed at location MS-7 i.e., Nakti creek (5.39 Kg/ha) and MS-8, i.e., Near Vadinar Jetty (4.48 Kg/ha). For Kandla and Vadinar the average value of Inorganic Phosphate was observed 12.63 and 4.94 Kg/ha respectively.
- The value of **Phosphate** was observed in range of 581.3 to 1246.4 mg/Kg for Kandla and for Vadinar the value observed at location MS-7 i.e., Nakti creek (402.3 mg/Kg)

and MS-8, i.e., Near Vadinar Jetty (519.3 mg/Kg). For Kandla and Vadinar the average value of Phosphate was observed 880.87 and 460.8 mg/Kg respectively.

- The value of **Organic Matter** for the sampling period was observed in the range of 0.42 to 0.93 % for Kandla with the average value of 0.66% and for Vadinar the value recorded at location MS-7 and MS-8 was observed 0.15% & 0.17% respectively.
- The value of **Sulphate** was observed in the range of 108.3 to 246.9 mg/Kg for Kandla and for Vadinar the value observed at MS-7 is 86.36 mg/Kg and at MS-8, is 143.40 mg/Kg. For Kandla and Vadinar the average value of Sulphate was observed 155.18 and 114.88 mg/Kg respectively.
- The value of **Calcium** was observed in the range of 1463.8 to 2347 mg/Kg for Kandla and for Vadinar the value observed at MS-7 is 2896 mg/Kg and at MS-8, is 2637.90 mg/Kg. The average value of Calcium for the monitoring period was observed 2088.80 mg/Kg and 2766.95 mg/Kg at Kandla and Vadinar, respectively.
- The value of **Magnesium** for the sampling period was observed in the range of 1383.23 to 1843.6 mg/Kg for Kandla and for Vadinar the value observed at MS-7 is 926.80 mg/Kg and at MS-8, is 1623.80 mg/Kg. For Kandla and Vadinar the average value of Magnesium was observed 1548.71 mg/Kg and 1275.3 mg/Kg respectively.
- The value of **Nitrate** was observed in the range of 12.79 to 19.84 mg/Kg for Kandla with average value 15.66 mg/Kg and for Vadinar the value observed to be 14.84 and 8.04 mg/Kg at MS-7 and MS-8, respectively with average 11.44 mg/Kg.
- The value of **Nitrite** was observed in the range of 0.29 to 0.75 mg/Kg for Kandla with average value 0.45 mg/Kg and for Vadinar the value observed to be 0.15 and 0.2 mg/Kg at MS-7 and MS-8, respectively with average 0.18 mg/Kg.
- The value of **Sodium** was observed in the range of 2643 to 4123.95 mg/Kg for Kandla with average value 3417.16 mg/Kg and for Vadinar the value observed to be 5231.7 and 9291.4 mg/Kg at MS-7 and MS-8, respectively with average 7261.55 mg/Kg.
- For the sampling period **Silica** was observed in the range of 255.12 to 481.3 mg/Kg for Kandla with average value 350.28 mg/Kg and for Vadinar the value observed to be 346.7 and 373.9 mg/Kg at MS-7 and MS-8, respectively with average 360.3 mg/Kg
- The value of **Potassium** was observed in the range of 1247.6 to 3025.68 mg/Kg for Kandla with average value 2255.01 mg/Kg and for Vadinar the value observed to be 1236.7 and 3271.6 mg/Kg at MS-7 and MS-8, respectively with average 2254.15 mg/Kg.
- The value of **Aluminium**, was observed in the range of 1316.2 to 2442.3 mg/Kg for Kandla with average value 2007.82 mg/Kg and for Vadinar the value observed to be 1584.3 and 1826.7 mg/Kg at MS-7 and MS-8, respectively with average 1705.5 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 Loamy**" in both Kandla and Vadinar the sampling period, except location MS-8 which is Loamy soil.

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	3.22	2.58	3.81	3.13	2.86	2.35	2.04	3.20
2.	Copper	mg/Kg	2.73	3.83	3.12	4.02	5.12	3.63	3.12	5.12
3.	Chromium	mg/Kg	62.13	43.9	48.32	43.5	50.23	53.65	27.9	56.72
4.	Nickel	mg/Kg	39.42	20.49	28.45	29.34	23.83	25.38	16.84	27.95
5.	Lead	mg/Kg	5.86	5.92	4.56	5.37	4.32	3.67	5.49	8.21
6.	Zinc	mg/Kg	60.76	63.26	46.3	55.53	57.36	56.64	25.89	88.74
7.	Cadmium	mg/Kg	BQL	0.60	0.87	BQL	BQL	0.15	BQL	BQL

- **Arsenic** was observed in the range of 2.35 to 3.81 mg/Kg for Kandla with average value 2.9 mg/Kg and for Vadinar the value observed to be 2.04 and 3.20 mg/Kg at MS-7 and MS-8, respectively with average 2.62 mg/Kg.
- **Copper** was observed in the range of 2.73 to 5.12 mg/Kg for Kandla with average value 3.74 mg/Kg and for Vadinar the value observed to be 3.12 and 5.12 mg/Kg at MS-7 and MS-8, respectively with average 4.12 mg/Kg.
- **Chromium** was observed in the range of 43.5 to 62.13 mg/Kg for Kandla with average value 50.28 mg/Kg and for Vadinar the value observed to be 27.9 and 56.72 mg/Kg at MS-7 and MS-8, respectively with average 42.31 mg/Kg.
- **Nickel** was observed in the range of 20.49 to 39.42 mg/Kg for Kandla with average value 27.82 mg/Kg and for Vadinar the value observed to be 16.84 and 27.95 mg/Kg at MS-7 and MS-8, respectively with average 22.39 mg/Kg.

- **Lead** was observed in the range of 3.67 to 5.92 mg/Kg for Kandla with average value 4.95 mg/Kg and for Vadinar the value observed to be 5.49 and 8.21 mg/Kg at MS-7 and MS-8, respectively with average 6.85 mg/Kg.
- **Zinc** was observed in the range of 46.3 to 63.26 mg/Kg for Kandla with average value 56.64 mg/Kg and for Vadinar the value observed to be 25.89 and 88.74 mg/Kg at MS-7 and MS-8, respectively with average 57.32 mg/Kg.
- **Cadmium** was observed BQL for majority of locations at Kandla and Vadinar during sampling period except for location except MS-2 (0.6), MS-3 (0.87 mg/L) and MS-6 (0.15 mg/L).

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

CHAPTER 12: MARINE ECOLOGY MONITORING

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 **Figure 25 and 26** as follows:

Figure 25: Locations Map of Marine Ecological Monitoring at Kandla

Figure 26: Locations Map of Marine Ecological Monitoring at Vadinar

The various parameters to be monitored under the study for Marine Ecological Monitoring are mentioned in **Table 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.

- **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:

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

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

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

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

5. 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	135	184	122	211	149	124	102	94
2.	Net Primary Productivity (NPP)	mg/L/hr	0.19	BQL	0.84	1.29	BQL	BQL	BQL	1.05
3.	Gross Primary Productivity (GPP)	mg/L/hr	1.57	BQL	1.2	2.31	BQL	0.22	1.52	2.61
4.	Pheophytin	mg/m^3	0.22	BQL	0.25	BQL	0.51	BQL	1.02	1.11
5.	Chlorophyll-a	mg/m^3	1.34	0.235	1.02	0.87	1.41	0.99	2.14	1.74
6.	Particulate Oxidisable Organic Carbon	mg/L	1.17	0.61	0.59	1.88	1.51	1.43	BQL	BQL
7.	Secchi Depth	ft	0.85	1.18	0.8	0.75	0.61	0.74	3.01	3.19

- **Biomass:**

  With reference to the **Table 39**, the value of **Biomass** reported from location ME-1 to ME-6 in range between 122-211 mg/L where lowest biomass presents in ME-3 (Near Coal Berth) and highest biomass present in ME-4 (Khori Creek) during sampling period. In Vadinar, the value of biomass was observed 102 mg/L at ME-7 (Near SPM) and 94 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 0.22 to 2.31 mg/L/48 Hr where the highest value recorded for Khori Creek (ME-4) and lowest recorded at Nakti creek, near to NH-8A i.e. ME-6. In Vadinar, the value of **GPP** was observed was observed 1.52 mg/L/48 Hr at ME-7 (Near SPM) and 2.61 mg/L/48 Hr in 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 estimated to be between 0.19 to 1.29 mg/L/48 Hr. While in Vadinar, the value of **NPP** was observed BQL at ME-7 and 1.05 mg/L/48 Hr at ME-8 monitoring station.

- **Pheophytin**

  The level of Pheophytin was detected in the range from 0.22 to 0.51 mg/m^3 where the highest value observed at ME-5 (Nakti creek) and the lowest or below quantification limit observed at ME-2, ME-4 and ME-6. While in Vadinar, the value of Pheophytin was observed 1.12 at ME-7 and 1.01 mg/L/48 Hr at ME-8 monitoring station.

- **Chlorophyll-a**

  In the sub surface water, the value of Chlorophyll-a reported in range from 0.24 to 1.41 mg/m^3. The highest value observed at ME-5 (Nakti creek) while the lowest value observed at ME-2 (Kandla Creek, near to KPT Colony). In Vadinar, the value of chlorophyll-a was observed 2.14 mg/m^3 at ME-7 (Near SPM), monitoring station and 1.74mg/m^3 in ME-8 (Near Vadinar Jetty).

- **Particulate Oxidisable Organic Carbon**

  During the sampling period, the particulate oxidisable organic carbon falls within the range of 0.61 to 1.18 mg/L from monitoring location ME-1 to ME-6 at Kandla, whereas for Vadinar it recorded BQL at both the monitoring station (ME-7 and ME-8).

- **Secchi Depth**

  In monitoring station of Kandla (ME-1 to ME-6) the level of Secchi Depth was observed between 0.61 to 1.18 ft whereas at Vadinar, the value recorded at ME-7 i.e. Near SPM is 3.01 ft and in Near Vadinar Jetty is 3.19 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.	300	40	150	184	250	-	-	-
Chaetoceros sp.	-	-	110	75	210	-	130	-
Chlamydomonas sp.	-	113	-	130	-	120	-	-
Cyclotella sp.	140		250	-	-	350	98	260
Ditylum sp	-	-	-	140	-	160	110	255
Coscinodiscus sp.	423	354		64	120	-	-	-
Fragilaria sp.	-	-	320	-	-	-	250	
Bacteriastrum sp.	-	-	-	260	-	310	220	210
Pleurosigma sp.	230	140	45	-	60	-	-	-
Navicula sp.	-	-	-	-	-	145	350	4167
Nitzschia sp.	245	120	260	-	120	42	-	-
Synedra sp.	-	-	-	75	-	-	150	100
Planktothrix sp.	170	40	130	-	-	180	-	-
Oscillatoria sp.	174	-	340	280	-	-	70	156
Thallassiosira	-	250	-	-	120	70	-	-
Density-Units/L	**1682**	**1057**	**1495**	**1133**	**670**	**1377**	**1378**	**5148**
No. of genera	**7**	**7**	**7**	**7**	**5**	**8**	**8**	**6**

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

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from 670 to 1682 units/L, while for Vadinar its density of phytoplankton observed 1378 units/L at ME-7 and 5148 units/L at ME-8. During the sampling, phytoplankton communities were dominated by *Coscinodiscus sp.* and *Bacillaria sp.* in Kandla, while *Navicula 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	12	12	14	13	16	13	12	14
Individuals	7450	8745	9155	9100	10310	7990	8025	9650
Shannon diversity	1.88	1.37	1.90	1.64	1.23	1.73	1.77	1.02
Simpson 1-D	0.84	0.79	0.84	0.84	0.80	0.83	0.84	0.34
Species Evenness	0.97	0.70	0.91	0.79	0.69	0.83	0.85	0.57
Margalef richness	0.81	0.86	0.95	0.99	0.74	0.97	0.97	0.59
Berger-Parker	0.25	0.33	0.21	0.23	0.28	0.25	0.25	0.81
Relative abundance	0.42	0.66	0.50	0.66	0.68	0.58	0.58	0.12

- **Shannon- Wiener's Index (H)** of phytoplankton communities was in the range of 1.23 to 1.90 between selected sampling stations from ME-1 to ME-6 with an average value of 1.63 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of phytoplankton communities recorded to be 1.77 at ME-7 and 1.02 at ME-8 with an average value of 0.38. 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 0.79 to 0.84 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.82. Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was 0.84 at ME-7 and 0.34 at ME-8 with an average of 0.59.

- **Margalef's diversity index** (Species Richness) of phytoplankton communities in Kandla and nearby creeks sampling stations was varying from 0.74 to 0.99 with an average of 0.89 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of phytoplankton communities observed 0.97 at ME-7 and 0.59 at ME-8 with an average value of 0.78.

- **Berger-Parker Index (d)** of phytoplankton communities was in the range of 0.21 to 0.33 between selected sampling stations from ME-1 to ME-6 with an average value of 0.26 at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of 0.25 to 0.81 with an average value of 0.53. 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 0.69 to 0.97 for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of 0.57 to 0.85, during the monitoring month. This indicates varying degrees of evenness or unevenness in the distribution of individuals among the studied species.

- During the sampling period, **Relative Abundance** of phytoplankton communities was in range of 0.42 to 0.68 between selected sampling stations from ME-1 to ME-6 with an average value of 0.58 at Kandla creek and nearby creeks. Whereas for Vadinar the Index

value 0.58 at ME-7 and 0.12 at ME-8 with an average value 0.35, 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	2	1	-	2	-	-	1
Acrocalanus	-	-	-	-	-	2	-	-
Amoeba	2	-	3	4	2	-	4	1
Brachionus sp.	-	1	-	-	-	2	-	-
Calanus sp.	-	-	6	-	-	-	-	-
Cladocera sp.	6	1	-	1	-	2	1	2
Cyclopoid sp.	-	-	2		-	6	-	-
Copepod larvae	-	-	2	2	-	1	-	2
Diaptomus sp.	5	1	-	-	2	-	5	-
Eucalanus sp.	-	-	8	-	-	9	-	1
Mysis sp.	2	-	-	1	-	-	1	-
Paracalanus sp.		2	5	-	-	2	-	2
Density Unit/L	**16**	**7**	**27**	**8**	**6**	**24**	**11**	**9**
No. of genera	**5**	**5**	**7**	**4**	**3**	**7**	**4**	**6**

A total of 12 groups/taxa of zooplankton were recorded in Kandla and Vadinar during the study period which mainly constituted by copepods, branchiopoda, monogononata, fish and shrimp larval forms. *Eucalanus sp.* 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 6 to 27 units/L, while for Vadinar its density of zooplankton observed 11 units/L at ME-7 and 9 units/L at ME-8. During the sampling, zooplankton communities were dominated by *Eucalanus sp.* and *Cladocera sp.* in Kandla, while *Amoeba* in both the monitoring location of Kandla and 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	5	5	7	4	3	7	4	6
Individuals	16	7	27	8	6	24	11	9
Shannon diversity	1.42	1.55	1.76	1.21	1.1	1.33	1.16	1.74
Simpson (1-D)	0.78	0.9	0.83	0.75	0.8	0.86	0.71	0.92
Species Evenness	0.88	0.96	0.9	0.87	1	0.68	0.84	0.97
Margalef	1.44	2.06	1.82	1.44	1.12	1.89	1.25	2.28
Berger-Parker	0.38	0.29	0.3	0.5	0.33	0.38	0.45	0.22
Relative abundance	31.25	71.43	25.93	50	50	29.17	36.36	66.67

- **Shannon- Wiener's Index (H)** of zooplankton communities was in the range of 1.1 to 1.76 between selected sampling stations from ME-1 to ME-6 with an average value of 1.39 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of zooplankton communities recorded to be 1.16 at ME-7 and 1.74 at ME-8 with an average value of 1.45. 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 0.75 to 0.9 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.82. Similarly, for Vadinar Simpson diversity index (1-D) of zooplankton communities was 0.71 at ME-7 and 0.92 at ME-8 with an average of 0.88.

- **Margalef's diversity index** (Species Richness) of zooplankton communities in Kandla and nearby creeks sampling stations was varying from 1.12 to 2.06 with an average of 1.63 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of zooplankton communities observed 1.25 at ME-7 and 2.28 at ME-8 with an average value of 1.76.

- **Berger-Parker Index (d)** of zooplankton communities was in the range of 0.29 to 0.5 between selected sampling stations from ME-1 to ME-6 with an average value of 0.36 at Kandla creek and nearby creeks. Berger-Parker Index (d) of zooplankton communities in the sampling stations of Vadinar, was in the range of 0.22 to 0.45 with an average value of 0.34. 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 0.68 to 1 for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of 0.84 to 0.97, during monitoring month, indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of 29.17 to 71.43 between selected sampling stations from ME-1 to ME-6 with an average value of 42.96 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 36.36 at ME-7 and 66.67 at ME-8 with an average value 51.52, 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

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Thiaridae	2	1	-	5	-	4	1	2
Mollusca sp.	2	2	2	1	-	1	2	-
Odonata sp.	5	1	-	2	1	1	-	-
Lymnidae	1	4	5	3	2	-	5	-
Planorbidae	-	-	2	-	-	3	-	1
Atydae	1	2	-	1	-	2	-	1
Gammaridae	-	1	1	-	-	-	2	4
Turbinidae	1	-	3	-	1	1	-	2
Palaemonidae	-	-	-	2	-	-	-	-
Density-m^3	**12**	**11**	**13**	**14**	**4**	**12**	**10**	**10**
No of genera	**6**	**6**	**5**	**6**	**3**	**6**	**4**	**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 *Lymnidae sp, Thiaridae, Mollusca sp.* etc. The density of benthic fauna was varying from 4 to 14 m^2. The dominating benthic communities at Kandla Creek and nearby creek (Nakti and Khori creek) were represented *Lymnidae sp.* 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	6	6	5	6	3	6	4	5
Individuals	12	11	13	14	4	12	10	10
Shannon diversity	1.58	1.64	1.48	1.63	1.04	1.63	1.17	1.42
Simpson 1-D	0.82	0.85	0.81	0.84	0.83	0.85	0.73	0.82
Species Evenness	0.88	0.92	0.92	0.91	0.95	0.91	0.84	0.88
Margalef	2.01	2.09	1.56	1.89	1.44	2.01	1.3	1.74
Berger-Parker	0.42	0.36	0.38	0.36	0.5	0.33	0.5	0.4
Relative abundance	50	54.55	38.46	42.86	75	50	40	50

- **Shannon- Wiener's Index (H)** of benthic organism was in the range of 1.04 to 1.64 between selected sampling stations from ME-1 to ME-6 with an average value of 1.5 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of benthic organism recorded to be 1.17 at ME-7 and 1.42 at ME-8 with an average value of 1.29. 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 0.81 to 0.85 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.83.

Similarly, for Vadinar Simpson diversity index (1-D) of benthic organism was 0.73 at ME-7 and 0.82 at ME-8 with an average of 0.78.

- **Margalef's diversity index** (Species Richness) of benthic organism in Kandla and nearby creeks sampling stations was varying from 1.44 to 2.09 with an average of 1.83 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of benthic organism observed to be 1.3 at ME-7 and 1.74 at ME-8.

- **Berger-Parker Index (d)** of benthic organism was in the range of 0.33 to 0.5 between selected sampling stations from ME-1 to ME-6 with an average value of 0.39 at Kandla creek and nearby creeks. Berger-Parker Index (d) of benthic organism in the sampling stations of Vadinar, was in the range of 0.4 to 0.5 with an average value of 0.45. 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 0.88 to 0.95 for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of 0.84 to 0.88, during monitoring month, indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of 38.46 to 75 between selected sampling stations from ME-1 to ME-6 with an average value of 51.81 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 40 at ME-7 and 50 at ME-8 with an average value 45.29, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla

STP Monitoring

Noise Monitoring

Soil Monitoring

Marine Monitoring

Air Monitoring

Drinking Water Monitoring

Annexure 2: Photographs of the Environmental Monitoring conducted at Vadinar

Air Monitoring

Noise Monitoring

STP Monitoring

Drinking water Monitoring

Marine Monitoring

Soil Monitoring

Source : GEMI

Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

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

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