# DEENDAYAL PORT AUTHORITY
## (Erstwhile: DEENDAYAL PORT TRUST)

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

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

www.deendayalport.gov.in

**Ref: -** EG/WK/4684(EC)/Part VII/ 362

Date: 18/09/2023

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) DPT Letter No. EG/WK/4684(EC)/PartVII/29 dated 29/06/2021
3) DPT Letter No. EG/WK/4684(EC)/PartVII/141 dated 08/02/2022
4) DPA letter No. EG/WK/4684(EC)/PartVII/129 dated 30/06/2022
5) DPA letter No. EG/WK/4684(EC)/PartVII/297 dated 05/05/2023

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. 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 May, 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,

Manager(Env.)
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 – I

**Point wise compliance of Conditions stipulated in the NOC/CTE**

**Annexure 1**

**Compliance Report (for the period upto May, 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

<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".<br>DPA vide its letter dated 24.07.2018 and reminders letters dated 28.11.2020, 21.04.2021, 09.11.2021, 23.12.2021 and 06.06.2022 had requested GPCB to amend the said condition. However, the same is still awaited.</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.<br><br>Copy of monitoring report is attached herewith as Annexure i</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 is 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><th>Parameters</th><th>Time Weighted Average</th><th>Concentration in Ambient air in µg/m$^3$</th></tr>
<tr><td>Sulphur Dioxide ($SO_2$)</td><td>Annual<br>24 Hours</td><td>50<br>80</td></tr>
<tr><td>Nitrogen Dioxide ($NO_2$)</td><td>Annual<br>24 Hours</td><td>40<br>80</td></tr>
<tr><td>Particulate Matter (Size less than 10µm)</td><td>Annual<br>24 Hours</td><td>60<br>100</td></tr>
<tr><td>Particulate Matter (Size less than 2.5µm) or $PM_{2.5}$</td><td>Annual<br>24 Hours</td><td>40<br>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.<br><br>Copy of monitoring report is attached herewith as Annexure i</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:;<br>Between 6 A.M and 10 P.M : 75 dB(A)<br>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.<br><br>Copy of monitoring report is attached herewith as Annexure i</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.<br><br>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.<br>In the operation phase, DPA shall regularly submit the returns in prescribed form regarding water consumption. |

# ANNEXURE – i

## Monitoring Report

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

**Monitoring period (17th April-16th May, 2023)**

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

**Submitted to:**

**Deendayal Port Authority (DPA), Kandla**


## Gujarat Environment Management Institute (GEMI)

**(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 at Kandla and Vadinar for a period of 3 years" by Deendayal Port Authority, Kandla. Under the said project the report titled *"Environment Monitoring Report (17April-16May 2023)"* is prepared.

- **Name of the Report:** *Environment Monitoring Report (April-May 2023)*
- **Date of Issue:** 21/08/2023
- **Version:** 2.0
- **Report Ref.:** GEMI/DPA/782(2)/2023-24/18

## Table of Contents

## List of Tables

# List of Figures

# List of Graphs

# List of Abbreviations

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

# CHAPTER 1: INTRODUCTION

## 1.1 Introduction

Kandla Port, also known as the Deendayal Port is a seaport in Kachchh District of Gujarat state in the western India, near the city of Gandhidham. Located on the Gulf of Kachchh, it is one of major ports on the western coast. The Port is located on the Gulf of Kachchh on the north-western coast of India, 256 nautical miles southeast of the Port of Karachi in Pakistan and over 430 nautical miles north-northwest of the Port of Mumbai (Bombay). It is the largest port of India by volume of cargo handled. Deendayal Port's journey began in 1931 with the construction of RCC Jetty by Maharao Khengarji. Kandla was constructed in the 1950s as the chief seaport serving western India, after the independence of India. In the year 2007-08 and has retained the top position for the 14$^{th}$ consecutive year since then. On 31st March 2016, Deendayal Port created history by handling 100 MMT cargo in a year and became the first Major Port to achieve this milestone. It is the largest port of India by volume of cargo handled. Deendayal Port Authority, India's busiest major port in recent years, is gearing up to add substantial cargo handling capacity with private sector participation. Deendayal port Authority creates a new record by handling 137 MMTPA (at Kandla and Vadinar) during the financial year 2022-23. The Deendayal Port Authority (DPA) had commissioned the Off-shore Oil Terminal facilities at Vadinar in the year 1978, for which M/s. Indian Oil Corporation Limited (IOCL) provided Single Bouy Mooring (SBM) system, having a capacity of 54 MMTPA, which was first of its kind in India. Further, significant Quantum of infrastructural upgradation has been carried out & excellent maritime infrastructure has been created at Vadinar for the 32MMTPA Essar Oil Refinery in Jamnagar District. DPA, Kandla crossed the landmark 100 MMT in cargo throughput for FY 2022-23 on December 28, 2022, thereby becoming the first Major Port to reach three figures in cargo handling, that too in only 3 quarters of a fiscal year.

## 1.2 Green Ports Initiative

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

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

Deendayal Port Authority had also appointed Gujarat Environment Management Institute (GEMI) as an Advisor for "Making Deendayal Port a Green Port - Intended Sustainable Development under the Green Port Initiatives.

Deendayal Port Authority has also signed MoU with Gujarat Forest Department in August 2019 for Green Belt Development in an area of 31.942 Ha of land owned by Deendayal Port Authority. The plantation is being carried out by the Social Forestry division of Kachchh.

## 1.3 Importance of EMP

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

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

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

It identifies the principles, approach, procedures and methods that will be used to control and minimize the environmental and social impacts of operational activities associated

with the port. An EMP is a required part of environmental impact assessment of a new port project but could also be evolved for existing ports. It is useful both during the construction and operational phases of the new port but only for operation of existing ports to ensure the effectiveness of the mitigation measures and to give guidance as to the most appropriate way of dealing with any unforeseen effects.

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

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

This document presents the environmental monitoring report (EMR) for Kandla and Vadinar for the month of April -May 2023.

## 1.4 Objectives and scope of the Study

In line with the work order, the key objective of the study is Environmental Monitoring and preparation the Management Plan at Kandla and Vadinar for a period of 3 years". Environmental monitoring refers to systematic sampling of air, water, soil, noise and ecology in order to monitor the performance/ compliance of a project compliance with Environmental quality standards, and any applicable Statutory Compliance and the effectiveness of mitigation measure in EMP.

The scope of work includes not limited to following:

1. To review the locations of Ambient Air, Ambient Noise, drinking water, and Marine Water, Soil and Sediments monitoring stations within the impacted region in and around DPA establishment, in view of the developmental projects.
2. To assess the Ambient Air quality, quality at 6 stations at Kandla and 2 at Vadinar in terms of gases and particulate matter.
3. To assess the DG stack emissions (gases and particulate matter).
4. To assess Drinking water quality at twenty stations in terms of Physical, Chemical and Biological parameters viz., Color, Odor, turbidity, conductivity, pH, Total Dissolved Solids, chlorides, Hardness, total iron, sulfate, $NH_4$, $PO_4$, and bacterial count on a monthly basis.
5. To assess the Marine water quality in terms of aquatic Flora and Fauna and Sediment quality in terms of benthic flora and fauna.
6. To assess Marine Water Quality and sediment in term of physical and chemical parameter.

7. To assess the trends of water quality in terms of Marine ecology by comparing the data collected over a specified time period.
8. Every week a sample (Treated wastewater) of the Sewage Treatment Plant (STP) shall be analyzed to see the water quality being discharged by DPA.
9. Noise monitoring will be carried out twice a day at the representative stations for a period of 24 hours.
10. Meteorological parameters are very important from air pollution point of view and precise and continuous data collection is of utmost importance. The data collected is analyzed as per the standards. Meteorological data on wind speed, wind direction, temperature, relative humidity, solar radiation and rainfall will be collected from one permanent station at DPA and one permanent station at Vadinar.
11. To suggest incorporates, mitigation measures, based on the findings of this study and also check compliance with Environmental quality standards, green port initiatives, MIV 2030, and any applicable Statutory Compliance.
12. To recommend Environment management plans on Monitoring programme based on findings of study.

This page is intentionally left blank

# CHAPTER 2: METHODOLOGY

## 2.1 Study Area:

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

### a. Kandla:

Deendayal Port (Erstwhile Kandla Port) is one of the twelve major ports in India and is located on the West Coast of India, in the Gulf of Kutch at 23001'N and 70013'E in the state of Gujarat in India. Deendayal port primarily services the Northern India hinterland, including the land locked states of Jammu & Kashmir, Uttar Pradesh, Madhya Pradesh and Gujarat. Now, the Major Port Authorities Act 2021 is the governing statute for Administration of Major Ports. Now, on 18 February 2021, Major Port Authorities, (MPA) Act 2021 notified in the Gazette of India same has come into force from 3 November 2021. Under, MPA 2021, Deendayal Port Trust (DPT) have become Deendayal Port Authority (DPA). At Kandla, Deendayal Port has sixteen (16) cargo berths for handling various types of Dry Bulk Cargo viz, fertilizer, food grains, Coal, sulphur, timber, salt, ores etc. and Containers. Apart from dry bulk, DPA has seven (7) oil for handling all types of Liquid Cargo viz. POL, Chemicals etc. at Kandla. Deendayal Port Authority has handled total 135 MMTPA cargo (at Kandla & Vadinar) during the financial year 2022-23.

- **Climatic conditions of Kandla**

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

### b. Vadinar:

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

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

- **Climatic conditions of Vadinar**

Vadinar has a hot semi-arid climate, there are three defined seasons. The summer season lasts from March to May and is extremely hot, humid, but dry. The climatic conditions in Vadinar are quite similar to that recorded in its district head quarter in Jamnagar. The yearly mean temperature is 26.7 °C. Rainy season with extremely erratic monsoonal rainfall that averages around 630 millimetres. Tropical cyclones sometimes affect the region during this period. The winter season is from October to February remains hot during the day but has negligible rainfall, low humidity and cool nights to be by far the most comfortable time of year.

The locations of Kandla Port and Vadinar port have been depicted in the **Figure 1** as follows:

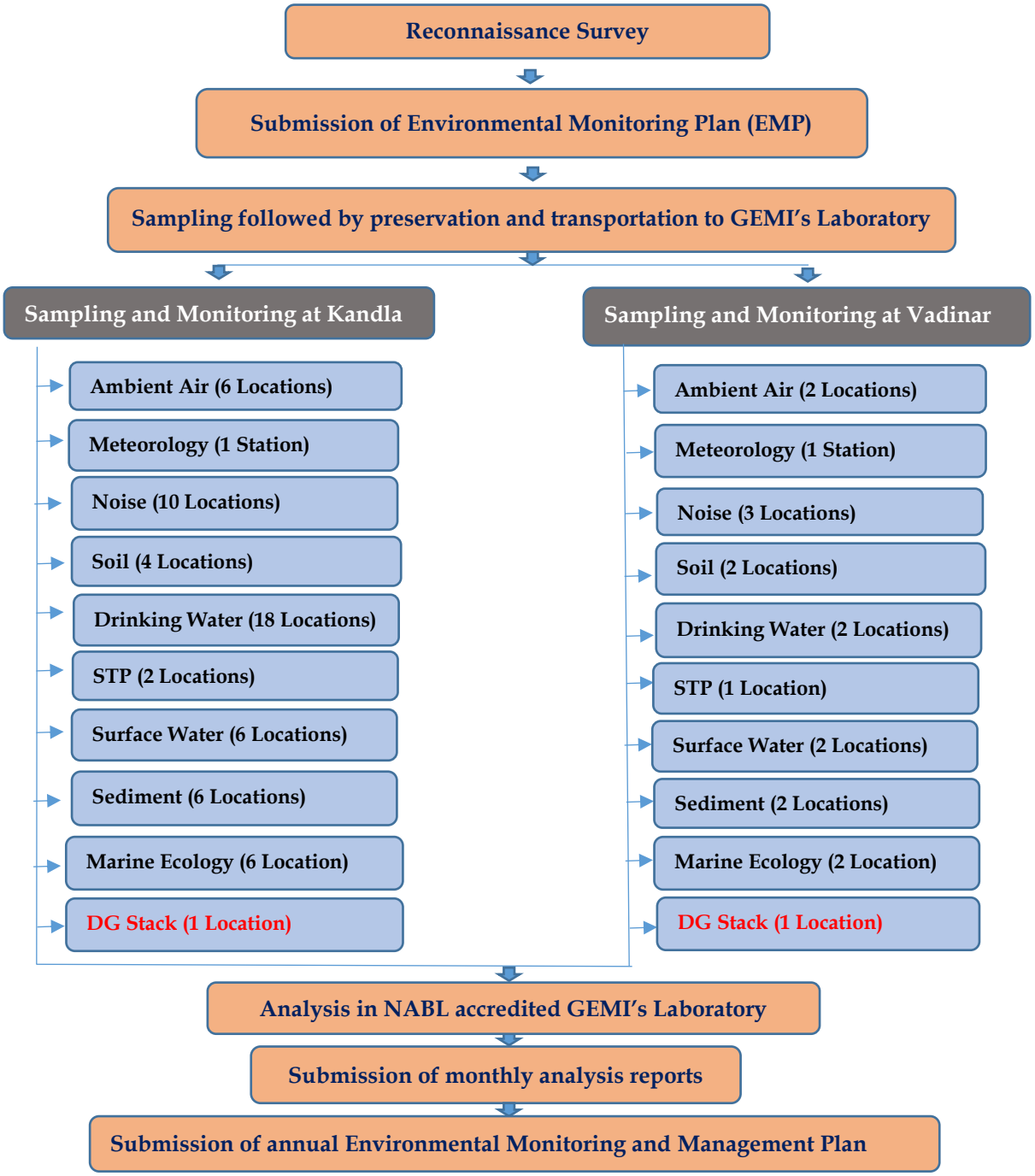

**Figure 1: Locations Map of Kandla and Vadinar**


**Figure 2: Map of Kandla Port**


**Figure 3: Map of Vadinar Port**

## 2.2 Methodology adopted for the study

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



## 2.3 Environmental Monitoring at Kandla and Vadinar

Regular monitoring of environmental parameters is of immense importance to assess the status of environment during project operation. With the knowledge of baseline conditions, the monitoring programme will serve as an indicator for any deterioration in environmental conditions due to operation of the project, to enable taking up suitable mitigatory steps in time to safeguard the environment. Monitoring is as important as that of control of pollution since the efficiency of control measures can only be determined by monitoring.

Environmental Monitoring Plan (EMP) is very important for monitoring the environmental status of the port for sustainable development. The list of main elements for which Environmental monitoring is to be carried out is mentioned below:

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

Gujarat Environment Management Institute (GEMI) has been entrusted by Deendayal Port Authority to carry out the monitoring of the various aforementioned environmental aspects of the port, so as to verify effectiveness of Environment management plan; confirm statutory and legal compliance; and identify any unexpected changes. Standard methods and procedures have been strictly adhered to in the course of this study. QA/QC procedures were strictly followed which covers all aspects of the study, and includes sample collection, handling, laboratory analyses, data coding, statistical analyses, presentation and communication of results. All analysis was carried out in GEMI's NABL/MoEF accredited/recognized laboratory.

Under the present study, the details of various sectors of Environment monitoring are described in subsequent chapters.

# CHAPTER 3: METEOROLOGY MONITORING

## 3.1 Meteorology Monitoring

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

**Table 1: Details of Automatic Weather Station**

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

## 3.2 Methodology

During the study, a continuous automatic weather monitoring station was installed at both the sites to record climatological parameters such as Wind speed, Wind Direction, Relative Humidity, Solar Radiation, Rainfall and Temperature to establish general meteorological regime of the study area. The stations (observatory) were installed at Kandla and Vadinar on 19/04/2023. The methodology adopted for monitoring meteorological data shall be as per the standard norms laid down by Bureau of Indian Standards (BIS) and the India Meteorological Department (IMD).

The details of Automatic Weather Monitoring Station have been mentioned in **Table 2**.

**Table 2: Automatic Weather Monitoring Station details**

| Sr. No. | Details of Meteorological Data | Unit of Measurement | Instrument | Frequency |
|---|---|---|---|---|
| 1. | Wind Direction | degree | Automatic Weather Monitoring Station (Envirotech WM280) | Hourly Average |
| 2. | Wind Speed | Km/hr | | |
| 3. | Rainfall | mm/hr | | |
| 4. | Relative Humidity | % RH | | |
| 5. | Temperature | $^{o}C$ | | |
| 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 period of April and May 2023 at both the observatory site.

### 3.3 Results:

The summary of hourly climatological observations recorded at observatory, Kandla during 19th April – 16st May 2023, with respect to significant parameters has been mentioned in **Table 2**. Monthly average of maximum and minimum daily observed values summarized in **Table 3** have been discussed as follows:

**Table 3: Meteorological data for Kandla and Vadinar**

| **Details of micro-meteorological data at Kandla Observatory** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Wind Speed (Km/h)** | | | **Temperature (°C)** | | | **Relative humidity (%)** | | | **Solar Radiation (W/m²)** | **Wind Direction (°)** | **Rainfall (mm)** |
| **Stat.** | **Mean** | **Max.** | **Min** | **Mean** | **Max** | **Min** | **Mean** | **Max** | **Min** | | | |
| April-May 23 | 8.78 | 27.02 | 1.54 | 31.31 | 32.21 | 30.40 | 61.07 | 64.12 | 57.76 | 105.42 | South-south East | 0.05 |
| **Details of micro-meteorological data at Vadinar Observatory** | | | | | | | | | | | | |
| **Date** | **Wind Speed (Km/h)** | | | **Temperature (°C)** | | | **Relative humidity (%)** | | | **Solar Radiation (W/m²)** | **Wind Direction (°)** | **Rainfall (mm)** |
| **Stat.** | **Mean** | **Max.** | **Min** | **Mean** | **Max** | **Min** | **Mean** | **Max.** | **Min** | | | |
| April-May 23 | 13.24 | 26.33 | 7.78 | 28.17 | 28.74 | 28.04 | 71.08 | 73.47 | 70.00 | 110.76 | west and south | 0.02 |

- **Temperature**
  a. Kandla: The ambient Temperature from April to May varies between the range of 26.75-35.23°C for Kandla, with average temperature of 31.31°C.
  b. Vadinar: The ambient temperature for the month of April varies between the range of 25.04-30.62°C for Vadinar, with average temperature of 28.17°C.
- **Relative Humidity**
  a. Kandla: The Relative Humidity recorded between the range of 43.77-69.65%, with average Humidity of 61.07%.
  b. Vadinar: During the study period, the Relative Humidity varies between 64.53-76.05%, with average Humidity of 71.08%.
- **Rainfall**
  a. Kandla: It is observed that, the average Rainfall in the monitoring period was found to be 0.05 mm
  b. Vadinar: The average Rainfall was recorded as 0.02 mm,
- **Wind Speed**

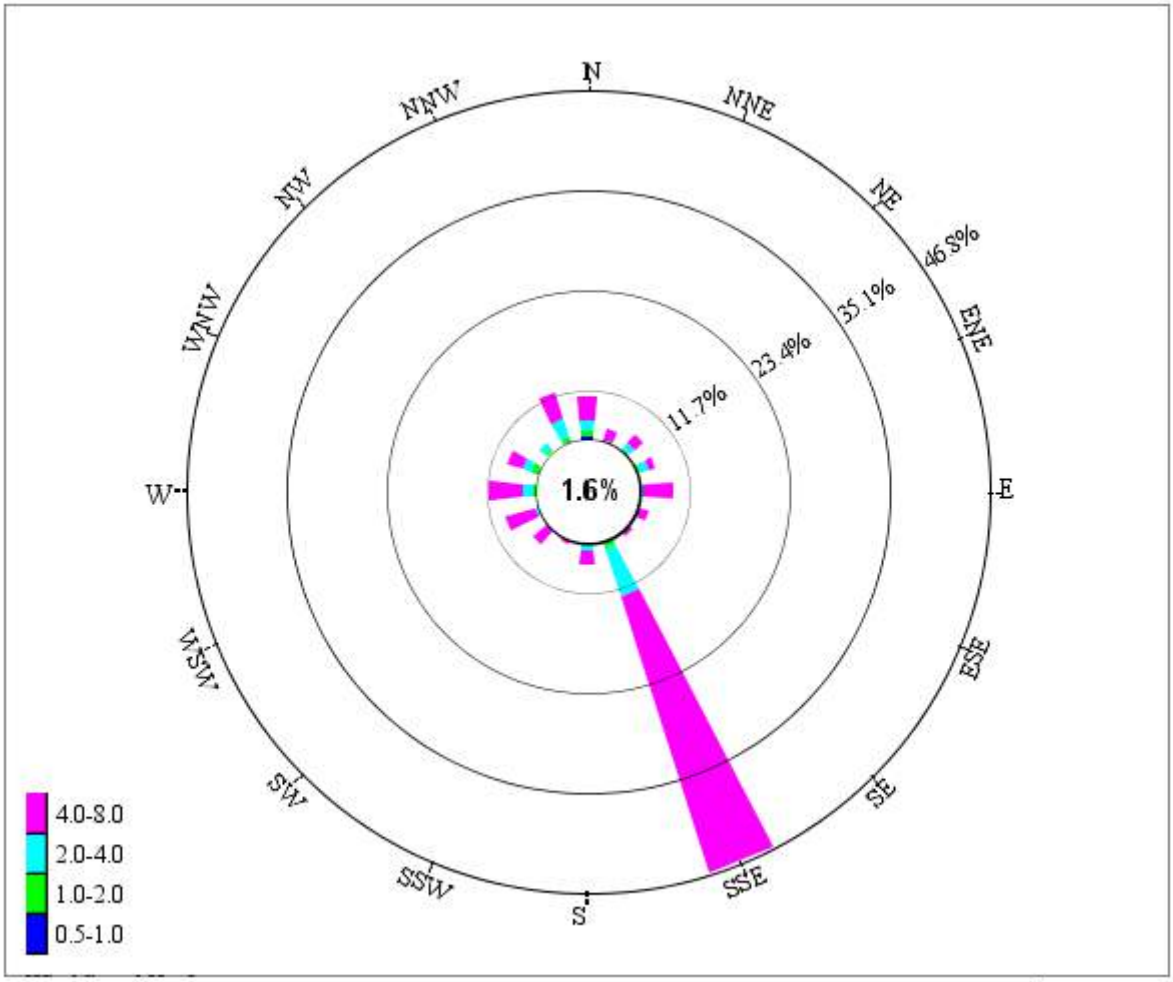
  Wind speed and Direction play a significant role in transporting the pollutants and thus decides the air quality.

  a. Kandla: Wind speed recorded ranges between 3.98-18.42 Km/hr
  b. Vadinar: During the study period, the Wind speed recorded, ranges between 6.23-18.08 Km/hr.
- **Solar Radiation:**
  a. Kandla: The average Solar Radiation for the monitoring period was recorded as 105.42 W/$m^2$.
  b. Vadinar: The average Solar Radiation was recorded as 110.76 W/$m^2$
- **Wind rose diagram -**

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

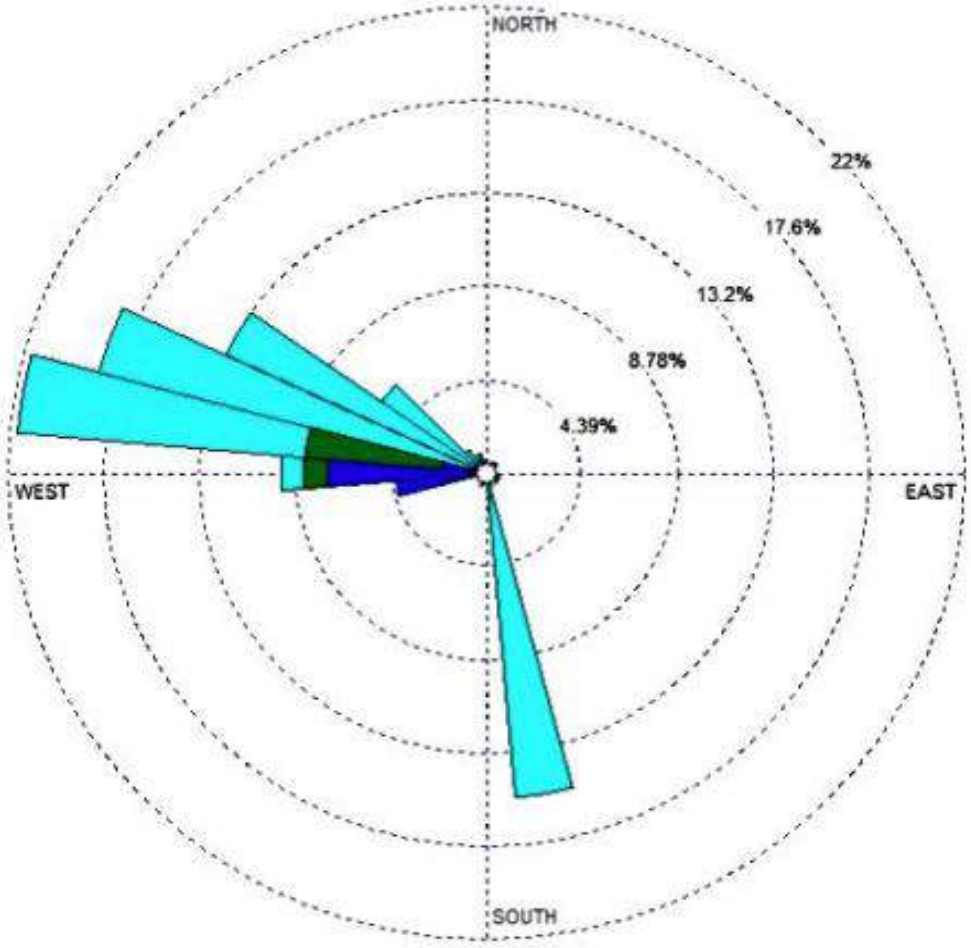
This wind rose reveals that the prevailing winds in Kandla during the given period predominantly blow from the northwest direction. The wind rose diagram represents that the wind flow at Kandla for the monitoring month towards South-South east. Whereas the winds at Vadinar were observed to flow from west directions.

| | |
|---|---|
| **Wind Rose Plot (April)**<br>**M/s Deendayal Port Authority**<br>**Site: Kandla Port (Environment Laboratory)** | **Display: Wind Direction**<br>**Wind Speed** |




| | |
|---|---|
| Data Period: 21/04/2023 to 16/05/2023 | Modeler: Envirotech Instruments Pvt. Ltd. Delhi. |

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




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

# CHAPTER 4: AMBIENT AIR QUALITY MONITORING

## 4.1 Ambient Air Quality

To determine the impact of the shipping activities and port operations on the ambient air quality, it is necessary to monitor the ambient air quality of the study area The prime objective of ambient air quality monitoring with respect to is to assess the present air quality and its conformity to ambient air quality standards (NAAQS, 2009). Ambient air quality in terms of (parameters) are monitored from 17th April- 15th May 2023 covering 6 weeks.

## 4.2 Methodology adopted for the Study

The study area represents the area occupied by Deendayal port authority and its associated Port area, facilities, as well as the surrounding area comprising of few villages. The sources of air pollution in the region are mainly vehicular traffic, fuel burning, loading & unloading of dry cargo, fugitive emissions from storage area and dust arising from unpaved village roads, eight locations within the study area were scientifically selected and are based on the following considerations:

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

The description of various stations monitored at Kandla and Vadinar are given in **Table 4**.

**Table 4: Details of Ambient Air monitoring locations**

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

The monitoring locations at Kandla and Vadinar have been depicted in **Figure 4 and 5** respectively follows:


**Figure 4: Location Map for Ambient Air Monitoring at Kandla**

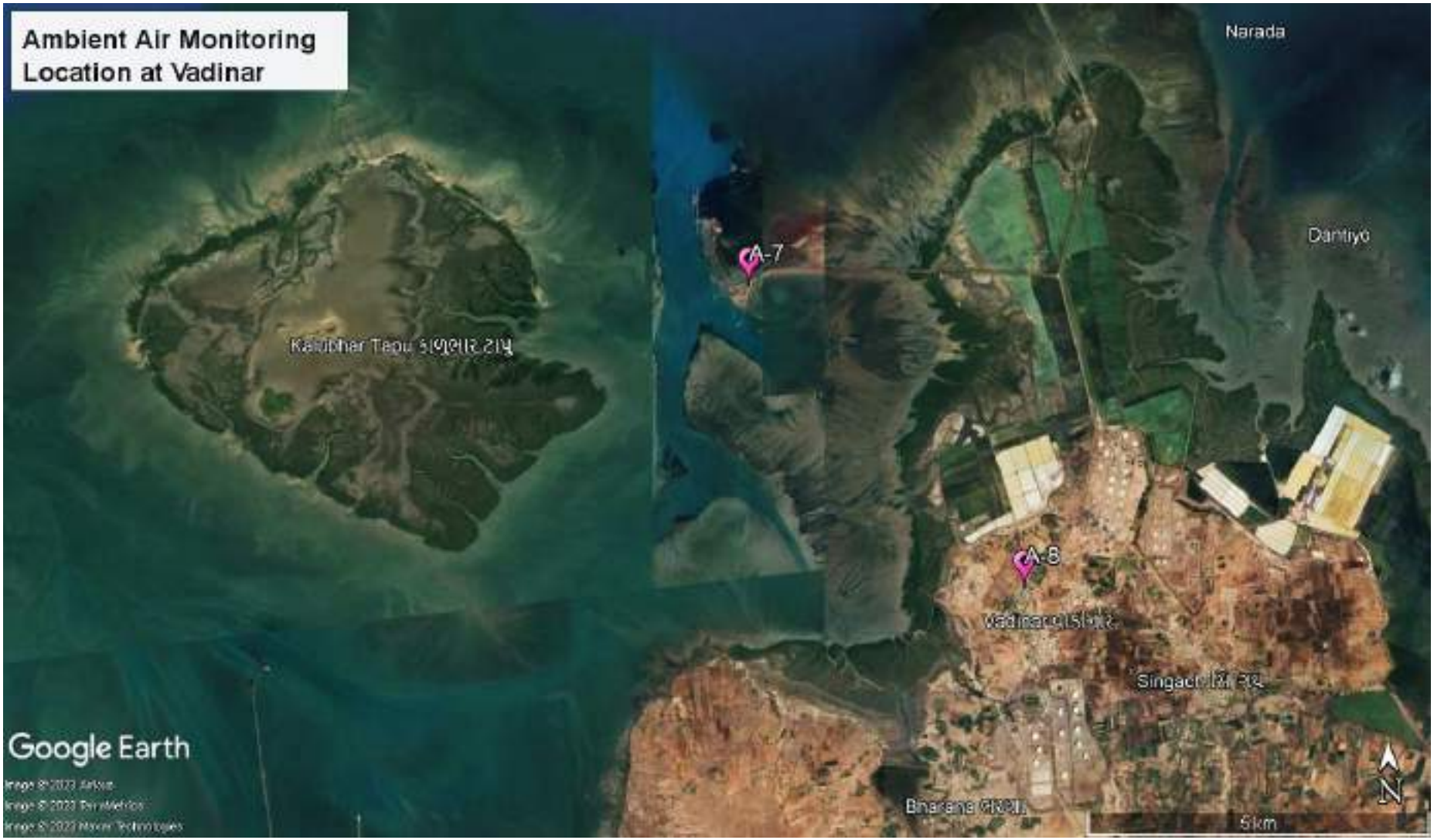



**Figure 5: Location Map for Ambient Air Monitoring at Vadinar**

**Frequency of AAQ Monitoring**

The sampling for Particulate matter ($PM_{10}$, $PM_{2.5}$) and gaseous like $SO_x$, $NO_x$, CO and Total VOCs were monitored twice in a week for a duration of 24 hours a day. Whereas, the samples of PAH, Benzene and non-Methane VOCs were collected on monthly basis.

**Method of sampling and analysis:**

The Sampling of the Ambient Air Quality parameters and analysis is done as per CPCB guidelines of National Ambient Air Quality monitoring. The sampling was performed at a height of 3.5 m (approximately) from the ground level.

For the sampling of $PM_{10}$, calibrated 'Respirable Dust Samplers' were used, where Whatman GF/A microfiber filter paper (size: 8" X 10") was used for the collection of $PM_{10}$. APM- air sampler of the make Envirotech instrument was attached with Respirable Dust Sampler $PM_{2.5}$ sampler for monitoring particulate matter of size <2.5 microns. A known volume of ambient air is passed through the cyclone to the initially pre-processed filter paper. The centrifugal force in cyclone acts on particulate matter to separate them into two parts and collected as following: -

Particles <10 µ size (Respirable): GF/A Filter Paper

Particles <2.5 µ size (Respirable): Polytetrafluoroethylene (PTFE)

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

Data has been compiled for $PM_{10}$, $PM_{2.5}$, $SO_x$ and $NO_x$ samples of 24-hour duration on two days a week (i.es., 8 samples were collected at each location). In case of CO, one hourly sample were taken on selected monitoring days using the sensor-based CO Meter. For the parameters Benzene, Methane & Non-methane and Volatile Organic Carbons (VOCs) the Low Volume Sampler is used, where the charcoal tubes are used as sampling media. The sampling in the Low Volume Sampler is carried out as per IS 5182 (Part 11): 2006 RA: 2017, where the ambient air flow rate is maintained at 200 cc/min, the volume of air that passes through the low volume sampler during two hours monitoring is approx. 24 L. Whereas the sampling of PAHs is carried out as per IS: 5182 (Part 12): 2004. Where, the EPM 2000 Filter papers are utilized in the Respirable Dust Sampler (RDS). For the parameters, PAH & Non-methane VOC's, monthly monitoring is carried out. The details of the parameters with their frequency monitored are mentioned in **Table 5:**

**Table 5: Parameters for Ambient Air Quality Monitoring**

| Sr. No. | Parameters | Units | Reference method | Instrument | Frequency |
|---|---|---|---|---|---|
| 1. | $PM_{10}$ | µg/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 | |
| 7. | Benzene | µg/m³ | IS 5182 (Part 11): 2006 RA: 2017 | 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 |
| 9. | Non-methane VOC | µg/m³ | IS 5182 (Part 11): 2006 | Low Volume Sampler | |

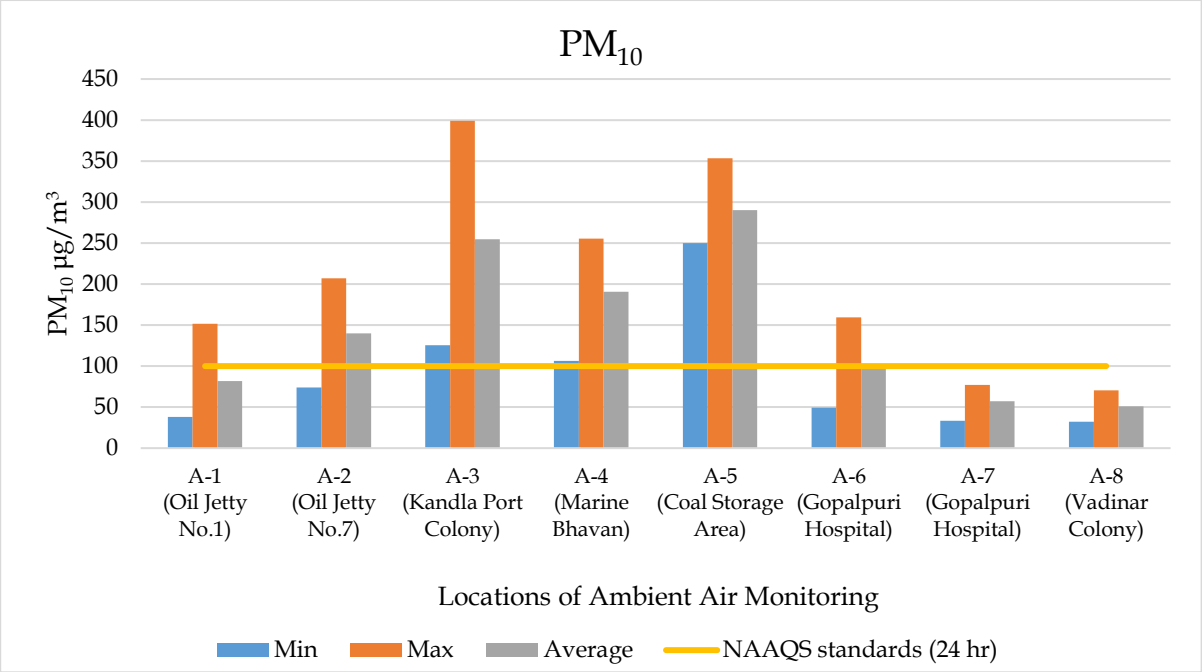
## 4.3 Result and Discussion:

The summarized results of ambient air quality monitoring for the period from 17th April to 15th May 2023 are presented in **Table-6 to 15** along with the graphical representation depicted in **Graph 1 to Graph 6.** Various parameters monitored during the study have been presented by their maximum, minimum, average and standard deviation.

**Table 6: Summarized results of $PM_{10}$ for Ambient Air quality monitoring**

| $PM_{10}$ (µg/m³) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sr No | Location / Sampling Date | Kandla | | | | | | Vadinar | | |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 | NAAQS standards (24 hr) |
| 1 | 17-Apr-2023 | 86.35 | 144.87 | 341.95 | 255.59 | 211.81 | 89.13 | 56.62 | 42.63 | 100 µg/m³ |
| 2 | 19-Apr-2023 | 69.35 | 135.52 | 349.89 | 106.41 | 305.36 | 115.90 | 59.78 | 56.55 | |
| 3 | 24-Apr-2023 | 72.27 | 121.69 | 399.25 | 155.37 | 260.08 | 159.38 | 74.25 | 56.50 | |
| 4 | 26-Apr-2023 | 151.72 | 149.37 | 271.07 | 185.15 | 216.88 | 73.34 | 76.96 | 70.37 | |
| 5 | 1-May-2023 | 81.83 | 124.52 | 182.54 | 156.01 | 219.18 | 56.78 | 33.42 | 43.40 | |
| 6 | 3-May-2023 | 58.16 | 74.14 | 125.42 | 252.46 | 323.61 | 124.93 | 33.97 | 32.10 | |
| 7 | 8-May-2023 | 72.81 | 207.10 | 287.49 | 207.14 | 249.87 | 109.62 | 56.42 | 59.48 | |

| $PM_{10}$ (µg/m³) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sr No | Location / Sampling Date | Kandla | | | | | | Vadinar | | NAAQS standards (24 hr) |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 | |
| 8 | 10-May-2023 | 104.33 | 154.22 | 204.48 | 207.03 | 267.24 | 128.82 | 63.83 | 49.15 | |
| 9 | 15-May-2023 | 37.94 | 149.14 | 128.12 | 189.98 | 353.42 | 49.35 | 57.77 | 46.17 | |
| | **Minimum** | 37.94 | 74.14 | 125.42 | 106.41 | 249.87 | 49.35 | 33.42 | 32.10 | |
| | **Maximum** | 151.72 | 207.10 | 399.25 | 255.59 | 353.42 | 159.38 | 76.96 | 70.37 | |
| | **Average** | 81.64 | 140.06 | 254.47 | 190.57 | 290.18 | 100.81 | 57.00 | 51.02 | |
| | **Std Dev** | 32.07 | 35.06 | 99.61 | 47.63 | 55.45 | 36.37 | 15.16 | 12.38 | |




**Graph 1: Spatial trend in $PM_{10}$ Concentration at Monitoring locations**

**Interpretation:**

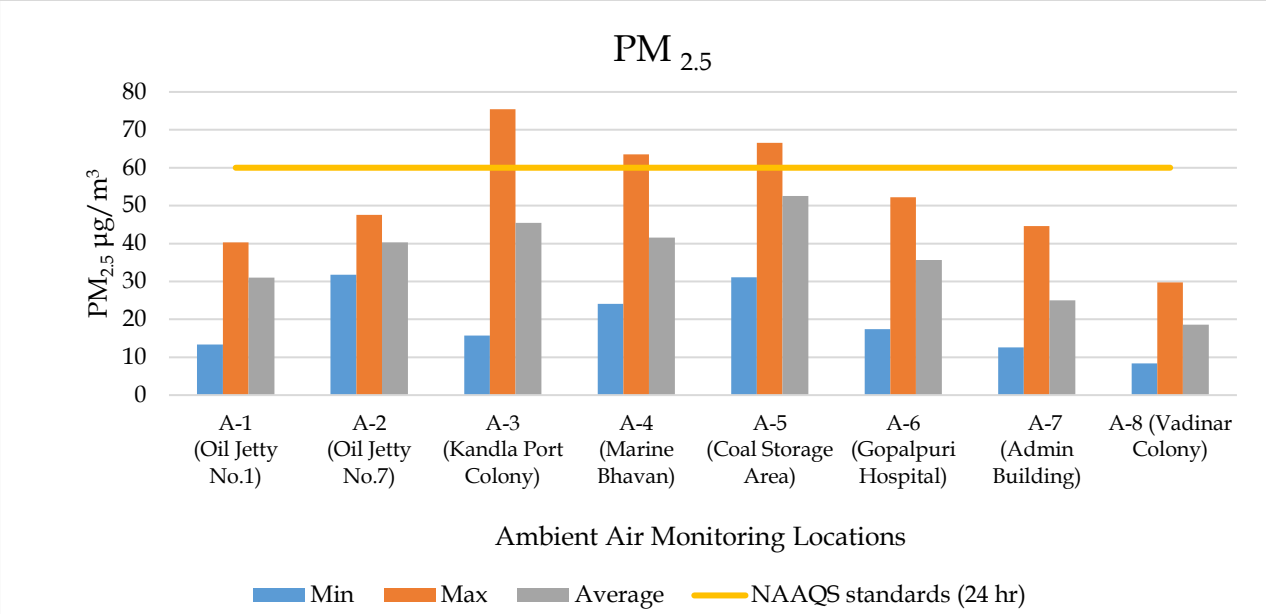
The results were compared with National Ambient Air Quality Standards (NAAQS), 2009 of Central Pollution Control Board (CPCB). Particulate Matter ($PM_{10}$) exceeded the norms at locations (Oil jetty 1, KPT colony, Marine Bhavan, Coal storage area). The highest concentration of $PM_{10}$ was observed at location A-3 i.e., Kandla Port Colony (399.25 µg/m³), whereas the lowest was observed at A-1 i.e., Oil Jetty No.1 (37.94 µg/m³). All the monitored values of $PM_{10}$ at station A-2, A-3, A-4 and A5 are exceeding the specified limit of 100 µg/m³.

The higher reporting of $PM_{10}$ could be due to heavy vehicular traffic, loading and unloading of cargo, dust from construction activities. Emissions and dispersion from construction equipment, work vessels, trucks and other vehicles used in construction work could be a source of Particulate matter. The unloading of coal directly in the truck, using grabs cause coal to disperse in air as well as coal dust to fall and settle on ground. This settled coal dust again mixes with the air while trucks travel through it. Also, the coal loaded trucks were not always covered with tarpaulin sheets and these results in increased

suspension of coal from trucks/dumpers during its transit from vessel to yard or storage site. This also increases the PM values around marine Bhavan & Coal storage area. Whereas for the Ambient Air locations of Vadinar, the concentration of $PM_{10}$ falls within the stipulated norm of 100 µg/m³. Kandla Port is a coastal area with extensive salt pans on the western side. Some of these salt pans are temporarily not in use and the hence this barren area is source of fugitive dust. Wind speeds also contribute to increased dispersion of pollutants in the area. Apart from this, dust storms are also common.

**Table 7: Summarized results of $PM_{2.5}$ for Ambient Air quality monitoring**

| $PM_{2.5}$ (µg/m³) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sr. No | Location / Sampling date | Kandla | | | | | | Vadinar | | NAAQS standards (24 hr) |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 | |
| 1 | 17-Apr-2023 | 40.32 | 31.73 | 60.77 | 49.96 | 68.52 | 35.99 | 40.63 | 35.08 | 60 µg/m³ |
| 2 | 19-Apr-2023 | 28.39 | 38.62 | 41.03 | 45.23 | 88.51 | 35.27 | 42.74 | 30.15 | |
| 3 | 24-Apr-2023 | 31.31 | 47.55 | 67.13 | 47.27 | 56.75 | 35.27 | 44.65 | 28.31 | |
| 4 | 26-Apr-2023 | 39.87 | 42.70 | 32.14 | 31.82 | 71.62 | 36.21 | 32.58 | 29.76 | |
| 5 | 1-May-2023 | 22.23 | 34.23 | 28.33 | 24.06 | 38.84 | 34.46 | 12.61 | 11.05 | |
| 6 | 3-May-2023 | 38.73 | 47.58 | 38.22 | 36.51 | 89.04 | 25.32 | 14.52 | 8.35 | |
| 7 | 8-May-2023 | 26.60 | 42.51 | 75.44 | 39.65 | 66.58 | 48.62 | 26.09 | 19.25 | |
| 8 | 10-May-2023 | 38.44 | 37.28 | 50.47 | 63.55 | 60.03 | 52.18 | 25.99 | 22.94 | |
| 9 | 15-May-2023 | 13.32 | 40.22 | 15.73 | 35.86 | 31.09 | 17.39 | 18.87 | 10.49 | |
| | Minimum | 13.32 | 31.73 | 15.73 | 24.06 | 31.09 | 17.39 | 12.61 | 8.35 | |
| | Maximum | 40.32 | 47.58 | 75.44 | 63.55 | 66.58 | 52.18 | 44.65 | 29.76 | |
| | Average | 31.02 | 40.27 | 45.47 | 41.55 | 52.57 | 35.63 | 25.04 | 18.59 | |
| | Std Dev | 9.33 | 5.46 | 19.54 | 11.53 | 18.89 | 10.51 | 11.16 | 8.81 | |



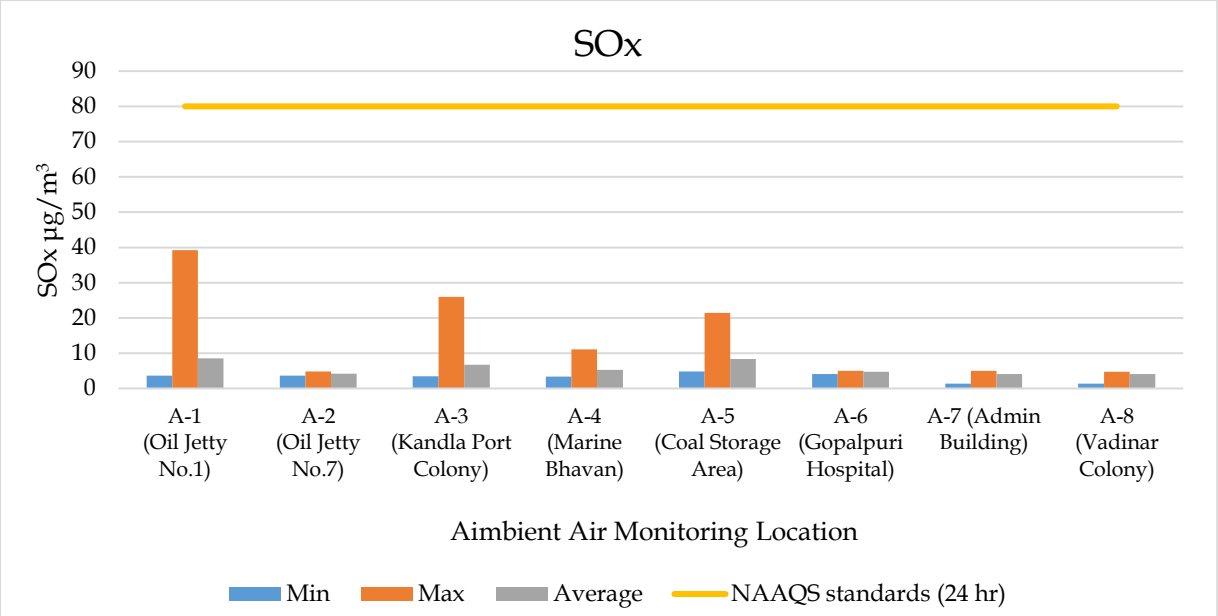

**Graph 2: Spatial trend in $PM_{2.5}$ Concentration at Monitoring locations**

The highest $PM_{2.5}$ concentration (75.44 µg/m³) was recorded at station A-3, Kandla Port Colony which is above the limit prescribed by NAAQS. Whereas majority of the monitored values of $PM_{2.5}$ at Kandla were reported well below the specified limit of 60 µg/m³. While for Vadinar monitoring station the maximum value for $PM_{2.5}$ observed is,

44.65 µg/m³ at Admin Building (A-7). Similar to values detected for the Respirable Dust i.e., $PM_{10}$, higher concentration of $PM_{2.5}$ was also observed at the Locations A-3 to A-5. This may be attributed to emissions from combustion of gasoline, oil, diesel fuel or wood produce.

**Table 8: Summarized results of $SO_x$ for Ambient Air quality**

| $SO_x$ (µg/m³) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sr. No | Location / Sampling date | Kandla | | | | | | Vadinar | | |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 | NAAQS standards (24 hr) |
| 1 | 17-Apr-2023 | 5.98 | 4.8 | 4.1 | 3.6 | 5.33 | 4.9 | 4.6 | 4.6 | 80 µg/m³ |
| 2 | 19-Apr-2023 | 4.3 | 4.2 | 4.9 | 3.8 | 7.53 | 4.6 | 4.3 | 4.2 | |
| 3 | 24-Apr-2023 | 3.9 | 4.5 | 4.6 | 3.7 | 9.21 | 4.1 | 4.51 | 4.58 | |
| 4 | 26-Apr-2023 | 7.44 | 3.6 | 3.6 | 3.4 | 4.8 | 4.9 | 1.39 | 4.69 | |
| 5 | 1-May-2023 | 39.19 | 3.8 | 5.16 | 3.9 | 8.65 | 4.98 | 3.12 | 1.4 | |
| 6 | 3-May-2023 | 4.2 | 3.9 | 3.5 | 8.27 | 5.15 | 4.85 | 4.99 | 4.67 | |
| 7 | 8-May-2023 | 3.6 | 4.6 | 26.01 | 11.13 | 21.47 | 4.67 | 4.6 | 4.25 | |
| 8 | 10-May-2023 | 4.1 | 4.0 | 4.6 | 4.9 | 7.97 | 4.58 | 4.2 | 4.36 | |
| 9 | 15-May-2023 | 3.6 | 3.6 | 3.5 | 3.4 | 4.8 | 4.1 | 1.39 | 1.4 | |
| | Minimum | 3.6 | 3.6 | 3.5 | 3.4 | 4.8 | 4.1 | 1.39 | 1.4 | |
| | Maximum | 39.19 | 4.8 | 26.01 | 11.13 | 21.47 | 4.98 | 4.99 | 4.69 | |
| | Average | 8.57 | 4.18 | 6.74 | 5.28 | 8.34 | 4.72 | 4.06 | 4.11 | |
| | Std Dev | 11.55 | 0.40 | 7.25 | 2.66 | 5.21 | 0.27 | 1.13 | 1.04 | |




**Graph 3: Spatial trend in SOx Concentration at Monitoring locations**

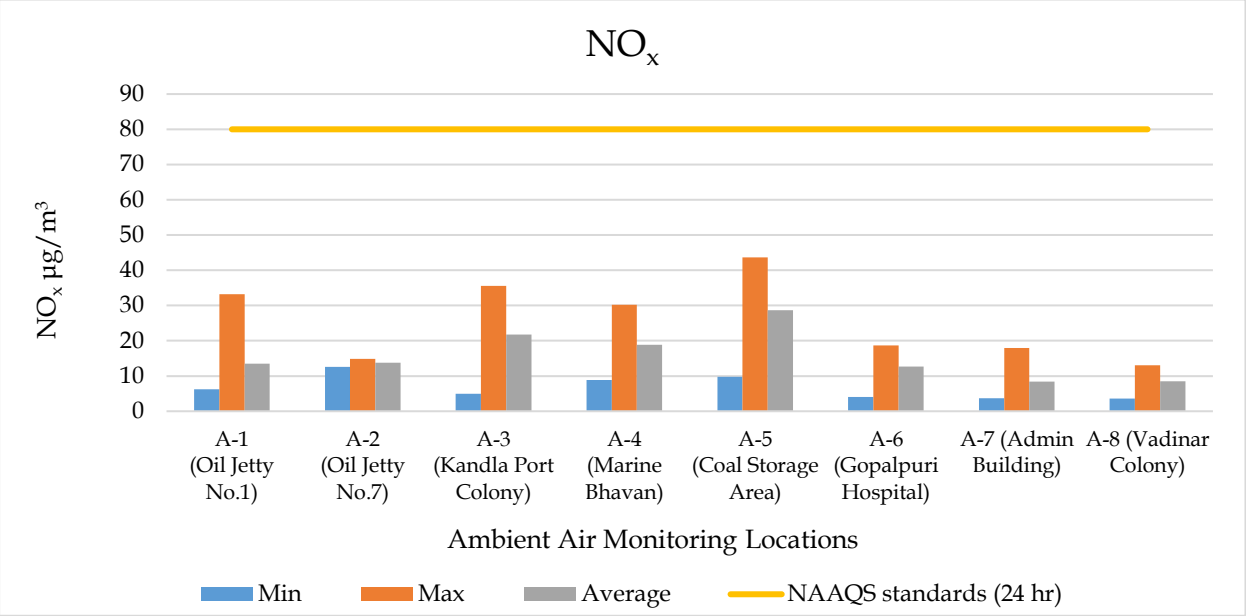
The highest $SO_x$ concentration (39.19 µg/m³) was recorded at station A-1, Oil Jetty No.1 area while the lowest $SO_x$ concentration was found to be 3.4 µg/m³ at A-4, Marine Bhavan. From the observed value it is seen that the concentration of $SO_x$ falls within the limit prescribed by NAAQS.

Whereas for Vadinar monitoring station the maximum and minimum value for $SO_x$ observed is, 4.99 µg/m³ and 1.39 µg/m³ at Admin Building (A-7) at different month. The

majority of the monitored values of $SO_x$ at Vadinar were reported well below the specified limit of 80 µg/m³.

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

| $NO_x$ (µg/m³) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sr No | Location / Sampling date | Kandla | | | | | | Vadinar | | |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 | NAAQS standards (24 hr) |
| 1 | 17-Apr-2023 | 9.20 | 12.85 | 21.94 | 19.41 | 27.76 | 8.70 | 8.14 | 9.72 | 80 µg/m³ |
| 2 | 19-Apr-2023 | 10.02 | 12.55 | 19.88 | 8.90 | 31.22 | 10.24 | 7.64 | 11.25 | |
| 3 | 24-Apr-2023 | 6.20 | 14.87 | 35.54 | 18.80 | 32.57 | 17.38 | 17.94 | 12.81 | |
| 4 | 26-Apr-2023 | 33.24 | 13.40 | 30.12 | 25.04 | 20.64 | 13.24 | 10.00 | 10.58 | |
| 5 | 1-May-2023 | 18.72 | 14.89 | 21.27 | 19.81 | 21.84 | 18.68 | 7.47 | 13.06 | |
| 6 | 3-May-2023 | 7.52 | 14.33 | 5.00 | 13.18 | 25.84 | 4.08 | 6.43 | 6.48 | |
| 7 | 8-May-2023 | 12.28 | 13.37 | 23.49 | 21.98 | 32.60 | 14.12 | 7.85 | 7.77 | |
| 8 | 10-May-2023 | 13.99 | 13.55 | 27.64 | 30.18 | 43.64 | 12.00 | 5.45 | 5.12 | |
| 9 | 15-May-2023 | 10.65 | 14.36 | 11.05 | 12.57 | 9.78 | 15.61 | 3.66 | 3.61 | |
| | Minimum | 6.20 | 12.55 | 5.00 | 8.90 | 9.78 | 4.08 | 3.66 | 3.61 | |
| | Maximum | 33.24 | 14.89 | 35.54 | 30.18 | 43.64 | 18.68 | 17.94 | 13.06 | |
| | Average | 13.54 | 13.80 | 21.77 | 18.87 | 28.67 | 12.67 | 8.40 | 8.49 | |
| | Std Dev | 8.26 | 0.85 | 9.33 | 6.60 | 17.27 | 4.55 | 4.65 | 3.73 | |

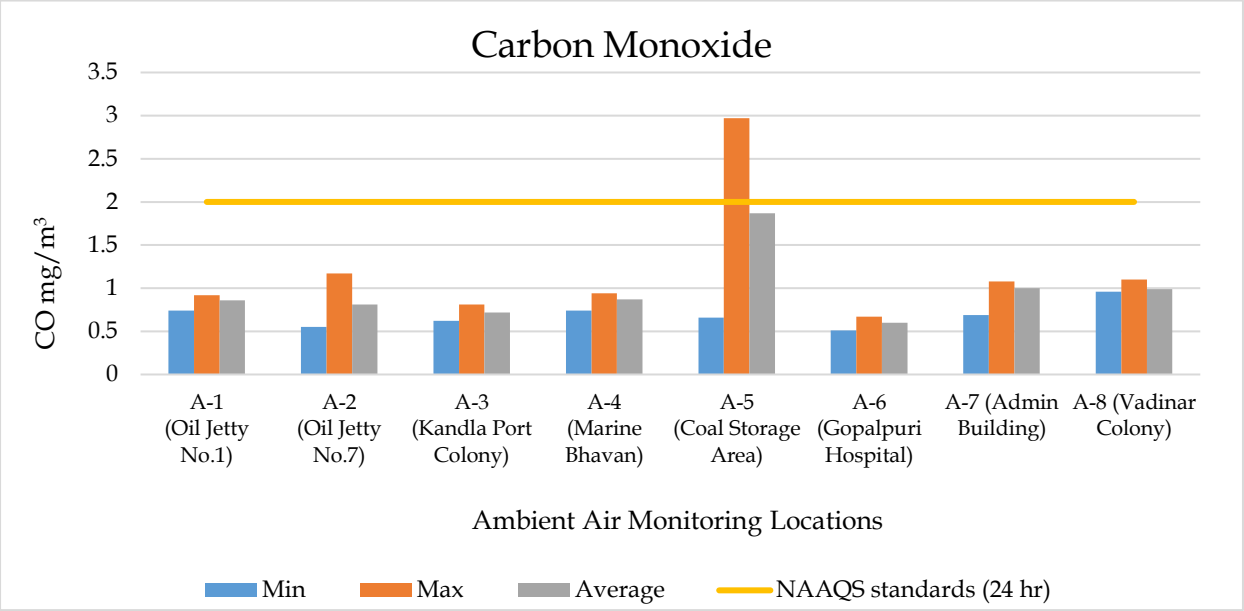



**Graph 4: Spatial trend in NOx Concentration at Monitoring locations**

The highest $NO_x$ concentration 43.64 µg/m³ was recorded at station A-5, Coal Storage Area. All the monitored values of $NO_x$ are found well below the specified limit of 80 µg/m³. At Vadinar, the concentration of $NO_x$ was found to be below the NAAQS limit for both the monitoring stations.

**Table 10: Summarized results of Carbon Monoxide for Ambient Air quality monitoring**

| Carbon Monoxide (mg/m³) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sr No | Location / Sampling date | Kandla | | | | | | Vadinar | | |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 | NAAQS standards (8 hr) |
| 1 | 17-Apr-2023 | 0.90 | 0.76 | 0.62 | 0.89 | 1.13 | 0.66 | 0.88 | 0.97 | 2 mg/m³ |
| 2 | 19-Apr-2023 | 0.86 | 1.06 | 0.65 | 0.86 | 1.16 | 0.64 | 0.94 | 0.89 | |
| 3 | 24-Apr-2023 | 0.89 | 1.17 | 0.63 | 0.87 | 1.98 | 0.65 | 1.08 | 1.10 | |
| 4 | 26-Apr-2023 | 0.91 | 0.55 | 0.71 | 0.92 | 2.01 | 0.67 | 0.69 | 0.99 | |
| 5 | 1-May-2023 | 0.91 | 0.77 | 0.67 | 0.91 | 0.54 | 0.66 | 1.01 | 0.96 | |
| 6 | 3-May-2023 | 0.74 | 0.71 | 0.79 | 0.94 | 1.68 | 0.52 | 1.03 | 0.98 | |
| 7 | 8-May-2023 | 0.92 | 0.76 | 0.80 | 0.83 | 1.97 | 0.51 | 1.04 | 0.99 | |
| 8 | 10-May-2023 | 0.75 | 0.56 | 0.79 | 0.87 | 2.97 | 0.58 | 1.08 | 0.97 | |
| 9 | 15-May-2023 | 0.84 | 0.92 | 0.81 | 0.74 | 0.66 | 0.54 | 1.04 | 0.96 | |
| | **Minimum** | 0.74 | 0.55 | 0.62 | 0.74 | 0.66 | 0.51 | 0.69 | 0.96 | |
| | **Maximum** | 0.92 | 1.17 | 0.81 | 0.94 | 2.97 | 0.67 | 1.08 | 1.10 | |
| | **Average** | 0.86 | 0.81 | 0.72 | 0.87 | 1.87 | 0.60 | 1.00 | 0.99 | |
| | **Std Dev** | 0.07 | 0.21 | 0.08 | 0.06 | 1.16 | 0.07 | 0.14 | 0.05 | |



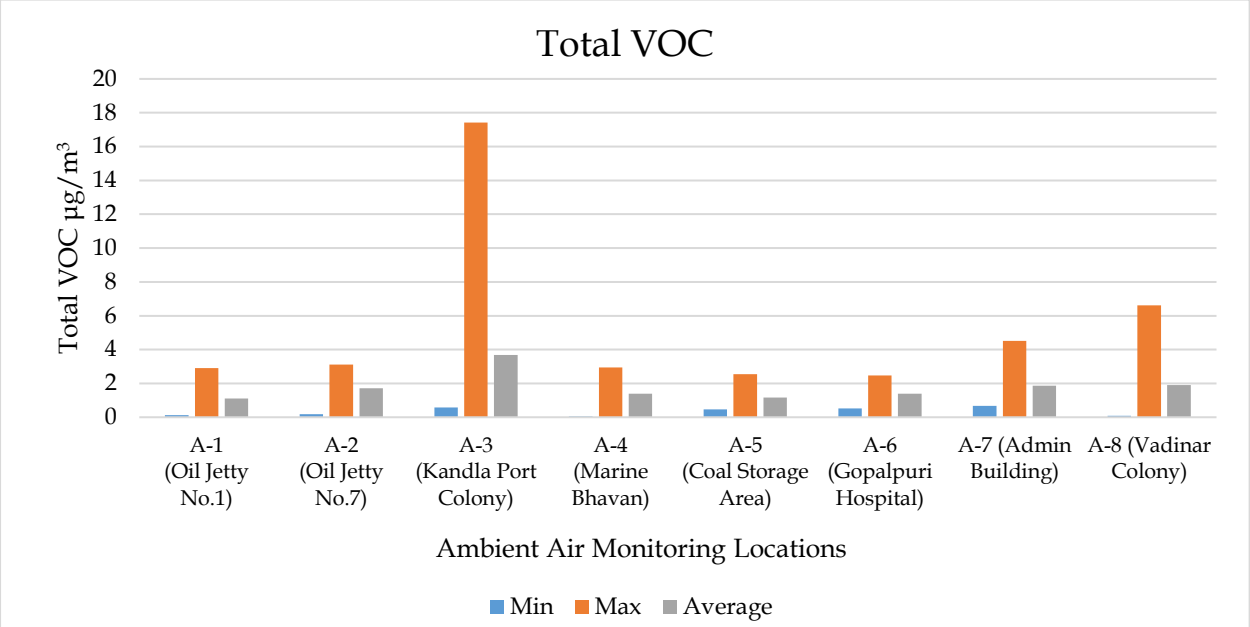

**Graph 5: Spatial trend in CO Concentration at Monitoring locations**

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

The levels of CO at monitoring station of Vadinar were found well within the permissible limit. The mean concentration of CO was found 1.00 and 0.99 mg/m³, in A-7 (Admin building) and A-8 (Vadinar Colony) respectively. In the coal storage area, as the moisture in the coal is liberated and the coal oxidizes, both heat and carbon monoxide are created. This might be attributed to the higher concentration of Carbon Monoxide in the Coal Storage Area as compared to the other monitored locations.

**Table 11: Summarized results of Total VOC for Ambient Air quality monitoring**

| Total VOCs (µg/m³) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sr. No | Locations / Sampling date | Kandla | | | | | | Vadinar | |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 |
| 1 | 17-Apr-2023 | 0.13 | 2.54 | 17.43 | 2.36 | 2.54 | 2.48 | 4.52 | 6.62 |
| 2 | 19-Apr-2023 | 1.32 | 0.67 | 2.21 | 0.04 | 1.14 | 2.06 | 2.6 | 2.4 |
| 3 | 24-Apr-2023 | 0.69 | 2.45 | 1.97 | 0.94 | 0.47 | 1.84 | 2.76 | 2.98 |
| 4 | 26-Apr-2023 | 2.91 | 1.99 | 2.85 | 1.58 | 1.85 | 0.81 | 0.87 | 2.45 |
| 5 | 1-May-2023 | 1.08 | 2.07 | 1.83 | 2.95 | 0.49 | 0.52 | 1.28 | 0.25 |
| 6 | 3-May-2023 | 0.97 | 3.11 | 2.92 | 1.74 | 1.52 | 2.10 | 2.09 | 1.08 |
| 7 | 8-May-2023 | 1.04 | 0.19 | 1.91 | 0.99 | 0.58 | 1.00 | 1.06 | 0.08 |
| 8 | 10-May-2023 | 1.05 | 2.11 | 1.47 | 0.85 | 0.96 | 0.85 | 0.95 | 0.27 |
| 9 | 15-May-2023 | 0.65 | 0.28 | 0.57 | 1.09 | 1.02 | 0.87 | 0.68 | 1.09 |
| | **Minimum** | 0.13 | 0.19 | 0.57 | 0.04 | 0.47 | 0.52 | 0.68 | 0.08 |
| | **Maximum** | 2.91 | 3.11 | 17.43 | 2.95 | 2.54 | 2.48 | 4.52 | 6.62 |
| | **Average** | 1.10 | 1.71 | 3.68 | 1.39 | 1.17 | 1.39 | 1.87 | 1.91 |
| | **Std Dev** | 0.76 | 1.06 | 5.20 | 0.87 | 0.69 | 0.72 | 1.26 | 2.06 |




**Graph 6: Spatial trend in Total VOCs Concentration at Monitoring locations**

During the monitoring period, the highest total VOC concentration was observed (17.43 µg/m³) at A-3, Kandla Port Colony. While at Vadinar monitoring station the highest total VOC concentration was observed 6.62 µg/m³ at A-8 with mean value 1.91 µg/m³. VOCs emitted from an urban source to the atmosphere may cause pollution on a local scale. VOCs are present mainly due to motor vehicles emissions. Gasoline and natural gas are a major source of VOCs that impact outdoor air quality. Vehicle exhaust and burning fossil fuels, wood, and garbage all release VOCs into the atmosphere.

**Table 12: Summarized results of Benzene for Ambient Air quality monitoring**

| Benzene (µg/m³) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sr. No | Location / Sampling date | Kandla | | | | | | Vadinar | | |
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 | NAAQS standards (24 hr) |
| 1 | 17-Apr-2023 | 3.5 | 1.01 | 1.43 | 0.04 | 1.08 | 1.08 | 0.48 | 0.37 | 5 µg/m³ |

The Ambient air Monitoring location of Kandla recorded the highest Benzene concentration i.e., 1.43 µg/m³ at A-3, Kandla Port Colony. While at Vadinar monitoring station the highest Benzene concentration was found to be 0.77 µg/m³ at A-7, Admin Building. Thus, all monitoring station at Kandla and Vadinar recorded the Benzene concentration well below the specified limit of 5 µg/m³.

**Table 13: Summarized results of Polycyclic Aromatic Hydrocarbon**

| Sr No | | Kandla | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|
| | Location / Components | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 |
| | | 26-Apr-2023 | | 24-Apr-2023 | | | | 24-Apr-2023 | |
| 1 | Napthalene | 0.41 | 17.31 | 0.49 | 0.32 | 1.92 | 39.82 | 0.39 | 0.32 |
| 2 | Acenaphthylene | 0.03 | 0.48 | 0.34 | 0.53 | 0.03 | 0.05 | 0.005 | 0.005 |
| 3 | Acenaphthene | 0.01 | 0.45 | 15.10 | 119.08 | 0.02 | 11.80 | 0.14 | 0.12 |
| 4 | Fluorene | 0.04 | 0.33 | 22.99 | 178.72 | 0.07 | 27.22 | 0.05 | 0.03 |
| 5 | Anthracene | 0.23 | 0.47 | 0.88 | 5.05 | 0.35 | 3.78 | 0.32 | 0.27 |
| 6 | Phenanthrene | 0.34 | 0.13 | 0.08 | 0.55 | 0.51 | 0.78 | 0.29 | 0.22 |
| 7 | Fluoranthene | 0.34 | 0.26 | 1.43 | 15.67 | 0.26 | 20.36 | 0.36 | 0.30 |
| 8 | Pyrene | 0.40 | 0.26 | 2.40 | 42.23 | 0.33 | 51.22 | 0.21 | 0.01 |
| 9 | Chrycene | 0.39 | 0.15 | 0.58 | 6.27 | 0.36 | 5.82 | 0.22 | 0.25 |
| 10 | Banz(a)anthracene | 1.17 | 0.38 | 1.64 | 15.42 | 0.92 | 16.73 | 0.32 | 0.21 |
| 11 | Benzo[k]fluoranthene | 0.98 | 0.38 | 0.71 | 0.64 | 0.64 | 4.25 | 0.31 | 0.03 |
| 12 | Benzo[b]fluoranthene | 0.89 | 0.35 | 0.47 | 3.97 | 0.61 | 6.52 | 0.25 | 0.07 |
| 13 | Benzopyrene | 0.75 | 0.29 | 0.52 | 2.85 | 0.70 | 3.40 | 0.32 | 0.03 |
| 14 | Indeno[1,2,3-cd] fluoranthene | 2.39 | 0.69 | 0.80 | 2.46 | 1.68 | 4.61 | 0.35 | 0.1 |
| 15 | Dibenz(ah)anthracene | 1.00 | 0.19 | 0.21 | 1.04 | 0.31 | 0.46 | 0.29 | 0.05 |
| 16 | Benzo[ghi]perylene | 2.34 | 0.47 | 0.97 | 6.07 | 1.90 | 6.38 | 0.27 | 0.21 |

Higher concentration of the PAH was observed the period of 17th April to 16th May 2023. Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous pollutants in urban atmospheres. Anthropogenic sources of total PAHs in ambient air emissions are greater than those that come from natural events. Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, etc. Six sources can be identified such as road dust, oil, coal, vehicles, incineration, and road salt. The road dust and emissions from traffic are the main outdoor source for the PAH concentration. Other outdoor sources of PAHs are industrial plants in and around the DPA premises.

**Table 14: Summarized results of Non-methane VOCs (µg/m³)**

| Sr No | Location / Sampling date | Kandla | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|
| | | A-1 | A-2 | A-3 | A-4 | A-5 | A-6 | A-7 | A-8 |
| 1 | 17-Apr-2023 | 0.12 | 0.15 | 0.16 | 0.17 | 0.13 | 0.19 | 0.15 | 0.15 |

The Ambient air Monitoring location of Kandla recorded the highest Non-methane VOC concentration i.e., 0.19 µg/m³ at A-6, Gopalpuri Hospital while the lowest Non-methane VOC concentration was found 0.12 µg/m³ at A-1, Oil Jetty No.1. While at Vadinar monitoring station, the lowest Non-methane VOC concentration was observed 0.09 µg/m³ at A-7, Admin Building. Thus, all monitoring station at Kandla and Vadinar recorded the Benzene concentration well below the specified limit of 5 µg/m³.

## 4.4 Conclusion:

From the ambient monitoring study conducted for a period (17th April-15th May 2023), it may be concluded that the particulate matter ($PM_{10}$), were reported in higher concentrated and apparently were exceeding the NAAQS particularly at 4 locations in Kandla (Oil Jetty No 7, Coal storage area, Kandla port colony and Marine bhavan) while gaseous pollutants ($NO_x$, $SO_x$, CO, VOCs etc.) falls within the permissible limit. The probable reason contributing to these emissions of pollutants into the atmosphere in and around the port area are summarized as follows-

1. **Ship Emissions:** Ships primarily emit air pollutants through their exhaust stacks. These emissions include sulfur oxides ($SO_x$), nitrogen oxides ($NO_x$), particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), and greenhouse gases (GHGs) such as carbon dioxide ($CO_2$). The type of fuel used by ships greatly influences the amount and type of emissions produced.
2. **Port Machinery:** Port activities involve the use of various machinery and equipment, including cranes, forklifts, tugboats, and cargo handling equipment. These machines often rely on diesel engines, which can emit pollutants such as $NO_x$, PM, and CO. Older or poorly maintained equipment tends to generate higher emissions.
3. **Port Vehicles:** Trucks and other vehicles operating within port and port area contributes to air pollution. Similar to port machinery, diesel-powered vehicles can emit $NO_x$, PM, CO, and other pollutants such as (PAH), VOCs etc. Vehicle traffic and congestion in and around port areas can exacerbate the air quality issues.
4. While docked or at anchor, ships may use auxiliary engines to power onboard systems such as lighting, heating, and refrigeration. These engines can emit pollutants and contribute to air pollution, particularly in port areas with significant vessel traffic.

## 4.5 Suggestive Measures to control the air pollution:

Efficient mitigation strategies need to be implementation for substantial environmental and health co-benefits. To improve air quality the port has adopted a number of precautionary measures, such as maintained a wide expanse of Green zone, initiated Inter-Terminal Transfer (ITT) of tractor-trailers, Centralized Parking Plaza, providing shore power supply to tugs and port crafts, the use of LED lights at DPA area helps in

lower energy consumption and decreases the carbon foot prints in the environment, time to time cleaning of paved and un paved roads, use of tarpaulin sheets to cover dumpers at project sites etc. are helping to achieve the cleaner and green future at port. To address air pollution from port shipping activities, various measures can be implemented including:

- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle-Mask advised in sensitive areas.
- Covering vehicles with tarpaulin during transportation of construction material to site.
- Ensuring that contractors are maintaining engines and that machinery deployed during construction are complying with emission standards.
- Ensuring frequent water sprinkling on roads to reduce dust vehicular movement on land. The water sprinkling should be use at each and every stage of transporting coal up the loading of truck to avoid generation of coal dust.
- Use of proper transport methods, such as a conveyor belt, for excavated material and screens around the construction site.
- Temporary pavement of roads in a construction site could considerably reduce dust emission.
- Prohibition of the use of heavy diesel oil as fuel could be a possible means to reduce pollutants Use of Cleaner Fuels: Encouraging or mandating the use of low-sulfur fuels, such as marine gas oil (MGO) or liquefied natural gas (LNG), can significantly reduce sulfur and particulate matter emissions from ships.
- Retrofitting and Engine Upgrades: Retrofitting ships with exhaust gas cleaning systems, also known as scrubbers, can help reduce sulfur emissions. Engine upgrades, such as optimizing fuel combustion and improving engine efficiency, can reduce overall emissions.
- Shore Power Infrastructure: Investing in infrastructure for cold ironing allows ships to connect to the electrical grid while docked, reducing the need for auxiliary engines and associated emissions.
- Improved Port Operations: Implementing efficient cargo-handling processes, optimizing logistics to reduce congestion and idling times, and encouraging use of cleaner port machinery and vehicles can all contribute to reducing air pollution in port areas.
- Inspection of condition of contractor's barges and equipment before start of work and ensuring a maintenance schedule is followed for the equipment used.
- Minimization of movement of project vehicles at night and especially during peak hour traffic (9-11am, 2-3 pm and 5-6pm).
- Regular maintenance of diesel generators engines However, continued efforts are needed to improve air quality and mitigate the impact of port shipping activities on the environment and public health.

This page is intentionally left blank

# CHAPTER 5: NOISE MONITORING

## 5.1 Noise Monitoring

Noise can be defined as an unwanted sound. It is, therefore, necessary to measure both the quality as well as the quantity of environmental noise in and around the study area. Noise produced during operation stage and thereafter activities may affect surrounding environment impacting the fauna and also the human population working and residing not only at site but also in the nearby areas. Under the scope, the noise monitoring is required to be carried out at 10 locations in Kandla and 3 locations in Vadinar. The sampling locations for noise are confined to commercial areas of DPA. The details of the noise monitoring stations are mentioned in **Table 15** and locations have been depicted in the **Figure 6 and 7** as follow:

**Table 15: Details of noise monitoring locations**

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


**Figure 6: Location Map for Noise Monitoring at Kandla**


**Figure 7: Location Map for Noise Monitoring at Vadinar**

**Frequency of Noise Monitoring**

Monitoring was carried out at each noise monitoring station for Leq. noise level (Day and Night), which was recorded for 24 hours continuously for once in a month with the help of Class-1 Sound/Noise Level Meter.

## 5.2 Method of sampling and analysis:

The intensity of sound energy in the environment is measured in a logarithmic scale and is expressed in a decibel (dB(A)) scale. Ordinary sound level meter measures the sound energy that reaches the microphone by converting it into electrical energy and then measures the magnitude in dB(A). In a sophisticated type of sound level meter, an additional circuit (filters) is provided, which modifies the received signal in such a way that it replicates the sound signal as received by the human ear and the magnitude of sound level in this scale is denoted as dB(A). The sound levels are expressed in dB(A) scale for the purpose of comparison of noise levels, which is universally accepted by the international community.

Noise levels were measured using an integrated sound level meter of the make Casella Sound Level Meter (Class-I). It has an indicating mode of Lp and Leq. Keeping the mode in Lp for few minutes and setting the corresponding range and the weighting network in "A" weighting set the sound level meter was run for one-hour time and Leq was measured at all locations.

The day noise levels have been monitored during 6.00am to 10.00pm and night noise levels, during 10.00pm to 6.00am at all the thirteen locations monthly.

**Table 16: Details of the Noise Monitoring that carried out at Kandla and Vadinar**

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

**Standard for Noise**

Ministry of Environment & Forests (MoEF) has notified the noise standards vide gazette notification dated February 14, 2000 for different zones under the Environment Protection Act (1986). The specified standards are as mentioned in **Table 17** as follows:

**Table 17: Ambient Air Quality norms in respect of Noise**

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

**Note:**

1 Day time shall mean from 6.00 am to 10.00 pm.
2 Night time shall mean from 10.00 pm to 6.00 am.
3 Silence zone is defined as area comprising not less than 100 meters around hospitals, educational institutions, courts, religious places or any other area, which is declared as such by the competent authority.

## 5.3 Result and Discussion

The details of the Noise monitoring conducted for the months of April-May 2023 have been summarized in the **Table 18** as below. The day noise levels have been monitored during 6.00am to 10.00pm and night noise levels, during 10.00pm to 6.00am at all the thirteen locations monthly.

**Table 18: The results of Ambient Noise Quality**

| Sr. No. | Station Code | Station Name | Category of Area | Standard | Day Time | | | Standard | Night Time | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Max. | Min. | Leq dB(A) Total | | Max | Min | Leq dB(A) Total |
| 1 | N-1 | Oil Jetty 7 | A | 75 | 64.5 | 38.4 | 53.7 | 70 | 56.3 | 36.9 | 48.4 |
| 2 | N-2 | West Gate No.1 | A | 75 | 66.3 | 46.1 | 57.2 | 70 | 51.3 | 39.6 | 46.6 |
| 3 | N-3 | Canteen Area | B | 65 | 66.2 | 38.0 | 54.8 | 55 | 51.2 | 38.6 | 46.4 |
| 4 | N-4 | Main Gate | A | 75 | 60.8 | 37.1 | 52.2 | 70 | 50.8 | 38.6 | 46.3 |
| 5 | N-5 | Main Road | A | 75 | 64.9 | 41.4 | 54.9 | 70 | 51.0 | 33.6 | 43.5 |
| 6 | N-6 | Marin Bhavan | B | 65 | 60.7 | 39.0 | 52.1 | 55 | 52.3 | 44.3 | 48.5 |
| 7 | N-7 | Port & Custom Building | B | 65 | 66.3 | 37.6 | 54.5 | 55 | 53.2 | 37.9 | 45.7 |
| 8 | N-8 | Nirman Building | B | 65 | 58.7 | 42.1 | 51.3 | 55 | 58.9 | 38.5 | 50.8 |
| 9 | N-9 | ATM Building | B | 65 | 64.5 | 35.1 | 54.2 | 55 | 53.4 | 37.3 | 49.0 |
| 10 | N-10 | Wharf Area/ Jetty | A | 75 | 74.5 | 42.1 | 63.1 | 70 | 52.7 | 38.7 | 48.9 |
| 11 | N-11 | Near Main Gate | A | 75 | 67.7 | 35.7 | 56.7 | 70 | 54.3 | 34.3 | 46.8 |
| 12 | N-12 | Near Vadinar Jetty | A | 75 | 65.3 | 39.2 | 54.5 | 70 | 54.1 | 34.7 | 46.2 |
| 13 | N-13 | Port Colony Vadinar | C | 55 | 58.7 | 41.8 | 50.7 | 45 | 55.7 | 36.3 | 47.8 |

## 5.4 Data Interpretation:

With reference to the Table 18, during the monitoring period at Kandla highest day time noise was observed at N-10 i.e., Wharf Area/Jetty (74.5 dB(A)). The day time noise levels were observed to be within the prescribed limit of 75 dB(A).

While considering the Night time, highest noise was observed at N-8 i.e., Nirman Building (58.9 dB(A)), whereas lowest noise was observed at N-5 i.e., Main Road area (33.6 dB(A). The night time noise levels were observed to be within the prescribed limit of 70 dB(A).

For the locations of Vadinar highest and lowest day time noise was observed at N-11 i.e., Near Main Gate as 67.7 dB(A) and 35.7 dB(A) respectively. The day time noise levels were observed to be within the prescribed limit of 75 dB(A).

While considering the Night time, highest noise was observed at N-13 i.e., Port Colony Vadinar (55.7 dB(A)), whereas lowest noise was observed at N-11 i.e., Near Main Gate (34.3 dB(A)). The night time noise levels were observed to be within the prescribed limit of 70dB(A).

## 5.5 Conclusion

Transportation systems are the main source of noise pollution in urban areas. Construction of buildings, highways, and roads cause a lot of noise, due to the usage of air compressors, bulldozers, loaders, dump trucks, and pavement breakers. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. The Day Time Noise Level in all 10 locations at Deendayal Port Authority ranged from 51.3 dB(A) to 63.1 dB(A) while at Vadinar port 3 location ranged from 50.7 dB(A) to 56.7 dB(A) and for The Night Time Average Noise Level in all locations of Deendayal Port Authority ranged from 43.5 dB(A) to 50.8 dB(A) while at Vadinar port ranged from 46.2 dB(A) to 47.8 dB(A) which falls within the permissible limits set for the industrial, commercial and residential area for the daytime.

Transportation systems are the main source of noise pollution in project areas. Noise sources in port operations include cargo handling, vehicular traffic, and loading / unloading containers and ships. Construction activities may create a problem of noise generated by construction equipment, truck traffic, work vessels and other similar sources. Sources of noise can be individuated in port areas in the following three main areas:

- Passenger car and heavy vehicle (trucks) road traffic (the most important one);
- Goods movement (from machinery such as quay-crane, pumps, etc.);
- Rail traffic noise: rail movement in port and in surrounding areas are prevalent to low speed and of consequence the noise level is not so high, however in highly trafficked areas the problem can be relevant.

## 5.6 Measures against adverse effects

Transmission of noise may reduce with the distance from their sources. Noise could be considerably reduced by adoption of low noise equipment or installation of sound insulation fences. Green belt of plants can be a good barrier. Limitation of working hours may be a possible means to mitigate the nuisances of construction activities.

# CHAPTER 6: DRINKING WATER MONITORING

## 6.1 Drinking Water Monitoring

It is necessary to check with the drinking water sources regularly so as to know whether water quality meets the prescribed standards for drinking. Monitoring the drinking water quality is essential to protect human health and the environment. A total of 20 locations (18 at Kandla and 2 at Vadinar) were monitored for Drinking Water. The location map has been depicted in the **Figure 8 and 9** and the details of the drinking water monitoring locations within the premises of DPA have been mentioned in **Table 19**.

**Table 19: Details of Drinking Water Sampling Locations**

| Sr. No. | Location Code | | Location Name | Latitude/ Longitude |
|---|---|---|---|---|
| 1. | Kandla | DW-1 | Oil Jetty 7 | 23.043527N 70.218456E |
| 2. | | DW-2 | Port & Custom Building | 23.009033N 70.222047E |
| 3. | | DW-3 | North Gate | 23.007938N 70.222411E |
| 4. | | DW-4 | Workshop | 23.009372N 70.222236E |
| 5. | | DW-5 | Canteen Area | 23.003707N 70.221331E |
| 6. | | DW-6 | West Gate 1 | 23.006771N 70.217340E |
| 7. | | DW-7 | Sewa Sadan -3 | 23.009779N 70.221838E |
| 8. | | DW-8 | Nirman Building | 23.009642N 70.220623E |
| 9. | | DW-9 | Custom Building | 23.018930N 70.214478E |
| 10. | | DW-10 | Port Colony Kandla | 23.019392N 70.212619E |
| 11. | | DW-11 | Wharf Area/ Jetty | 22.997833N 70.223042E |
| 12. | | DW-12 | Hospital Kandla | 23.018061N 70.212328E |
| 13. | | DW-13 | A.O. Building | 23.061914N 70.144861E |
| 14. | | DW-14 | School Gopalpuri | 23.083619N 70.132061E |
| 15. | | DW-15 | Guest House | 23.078830N 70.131008E |
| 16. | | DW-16 | E- Type Quarter | 23.083306N 70.132422E |
| 17. | | DW-17 | F- Type Quarter | 23.077347N 70.135731E |
| 18. | | DW-18 | Hospital Gopalpuri | 23.081850N 70.135347E |
| 19. | Vadinar | DW-19 | Near Vadinar Jetty | 22.440759N 69.675210E |
| 20. | | DW-20 | Near Port Colony | 22.401619N 69.716822E |


**Figure 8: Location Map for Drinking Water Monitoring for Kandla**


**Figure 9: Location Map for Drinking Water Monitoring at Vadinar**

## 6.2 Methodology of Monitoring:

The water samples were collected from the finalized sampling locations and analyzed for physico-chemical and microbiological parameter. The analysis of these samples collected was carried out as per APHA, 23rd Edition and Indian Standard method in GEMI's NABL Accredited Laboratory, Gandhinagar. GEMI has followed the CPCB guideline as well as framed its own guidelines for the collection of water/wastewater samples, under the provision of Water (Preservation and Control of Pollution) Act 1974, titled as '**Sampling Protocol for Water & Wastewater'**; approved by the Government of Gujarat vide letter no. ENV-102013-299-E dated 24-04-2014. The samples under the study were collected and preserved as per the said Protocol. The samples were analyzed for selected parameters to establish the existing water quality of the study area. The parameters finalized to assess the drinking water quality have been mentioned in **Table 20** as follows:

**Table 20: List of parameters for Drinking Water Quality monitoring**

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

| Sr. No. | Parameters | Units | Reference method | Instrument |
|---|---|---|---|---|
| 16. | Nitrate | mg/L | APHA, 23rd Edition, 4500 NO3- B: 2017 | UV- Visible Spectrophotometer |
| 17. | Nitrite | mg/L | APHA, 23rd Edition, 4500 NO2-B: 2017 | |
| 18. | Hexavalent Chromium | mg/L | APHA, 23rd Edition, 3500 Cr B: 2017 | |
| 19. | Manganese | mg/L | APHA,23rd Edition, ICP Method 3120 B: 2017 | ICP-OES |
| 20. | Mercury | mg/L | EPA 200.7 | |
| 21. | Lead | mg/L | APHA ICP 23rd Edition (Section-3120 B):2017 | |
| 22. | Cadmium | mg/L | APHA ICP 23rd Edition (Section-3120 B):2017 | |
| 23. | Iron | mg/L | APHA ICP 23rd Edition (Section-3120 B):2017 | |
| 24. | Total Chromium | mg/L | APHA ICP 23rd Edition (Section-3120 B):2017 | |
| 25. | Copper | mg/L | APHA,23rd Edition, ICP Method 3120 B: 2017 | ICP-OES |
| 26. | Zinc | mg/L | APHA ICP 23rd Edition (Section-3120 B):2017 | |
| 27. | Arsenic | mg/L | APHA ICP 23rd Edition (Section-3120 B):2017 | |
| 28. | Colour | mg/L | APHA, 23rd Edition, 2120 B:2017 | Color Comparator |
| 29. | Total Coliforms | MPN/ 100ml | IS 15185: 2016 | LAF/ Incubator |

## 6.3 Conclusion Result and discussion:

The drinking water quality of the locations at Kandla and Vadinar and its comparison with the to the standard (Drinking Water Specifications i.e., IS: 10500:2012) have been summarized in **Table 21**.

**Table 21: Summarized Result of Drinking Water quality**

| Sr. No. | Parameters | Units | Standard values as per IS | | Kandla | | | | | | | | | | | | | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | P | DW-1 | DW-2 | DW-3 | DW-4 | DW-5 | DW-6 | DW-7 | DW-8 | DW-9 | DW-10 | DW-11 | DW-12 | DW-13 | DW-14 | DW-15 | DW-16 | DW-17 | DW-18 | DW-19 | DW-20 |
| 1. | pH | - | 6.5-8.5 | - | 7.35 | 7.15 | 7.36 | 7.26 | 7.27 | 7.31 | 7.45 | 7.42 | 7.24 | 7.23 | 7.33 | 7.19 | 7.62 | 7.65 | 7.55 | 7.53 | 7.6 | 7.28 | 7.46 | 7.45 |
| 2. | Colour | Hazen | 5 | 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 5 | 1 | 1 | 1 | 1 | 5 | 20 |
| 3. | EC | µS/cm | - | - | 198 | 38 | 138 | 36 | 42 | 48 | 36 | 40 | 315 | 138 | 55 | 62 | 24 | 551 | 58 | 146 | 150 | 38 | 115 | 683 |
| 4. | Salinity | mg/L | - | - | 0.10 | 0.02 | 0.07 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.15 | 0.07 | 0.02 | 0.03 | 0.02 | 0.27 | 0.03 | 0.07 | 0.07 | 0.02 | 0.06 | 0.33 |
| 5. | Turbidity | NTU | 1 | 5 | BQL | BQL | 0.7 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 5.3 |
| 6. | Chloride | mg/L | 250 | 1000 | 46.9 | 7.50 | 30.99 | 8.5 | 10.32 | 12.59 | 7.5 | 10.50 | 72.48 | 25.99 | 13.54 | 12.50 | 7.50 | 80.97 | 12.50 | 25.99 | 26.49 | 11.5 | 19.99 | 90.47 |
| 7. | Total Hardness | mg/L | 200 | 600 | 15 | 10 | 10 | 15 | 10 | 15 | 10 | 15 | 15 | 10 | 15 | 15 | 10.0 | 160 | 15 | 20 | 20 | 10 | 20 | 160 |
| 8. | Ca Hardness | mg/L | - | - | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5.0 | 90 | 5 | 10 | 10 | 5 | 5 | 80 |
| 9. | Mg Hardness | mg/L | - | - | 10 | 5 | 5 | 10 | 5 | 10 | 5 | 10 | 10 | 5 | 10 | 10 | 5.0 | 70 | 10 | 10 | 10 | 5 | 15 | 80 |
| 10. | Free Residual Chlorine | mg/L | 0.2 | 1 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 11. | TDS | mg/L | 500 | 2000 | 100 | 20 | 72 | 20 | 22 | 25 | 20 | 22 | 158 | 70 | 29 | 30 | 28 | 278 | 32 | 76 | 78 | 20 | 62 | 346 |
| 12. | TSS | mg/L | - | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 12 |
| 13. | Fluoride | mg/L | 1.0 | 1.5 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 14. | Sulphate | mg/L | 200 | 400 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 25.84 | BQL | BQL | BQL | BQL | BQL | 40.57 |

| Sr. No. | Parameters | Units | Standard values as per IS | | Kandla | | | | | | | | | | | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | P | DW-1 | DW-2 | DW-3 | DW-4 | DW-5 | DW-6 | DW-7 | DW-8 | DW-9 | DW-10 | DW-11 | DW-12 | DW-13 | DW-14 | DW-15 | DW-16 | DW-17 | DW-18 | DW-19 | DW-20 |
| 15. | Nitrate | mg/L | 45 | - | 9.59 | 1.09 | 3.27 | BQL | BQL | BQL | BQL | BQL | 3.615 | 7.458 | BQL | BQL | BQL | 3.564 | 1.223 | 1.097 | 1.191 | BQL | 15.79 | 18.54 |
| 16. | Nitrite | mg/L | - | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 17. | Sodium | mg/L | - | - | 24.1 | BQL | 13.00 | BQL | 12 | 13.6 | BQL | BQL | 41.55 | 13 | 12.8 | BQL | BQL | 50.93 | BQL | 16.83 | 17.51 | BQL | 7.55 | 54.55 |
| 18. | Potassium | mg/L | - | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 19. | Hexavalent Chromium | mg/L | - | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 0.041 | 0.015 |
| 20. | Odour | TON | Agreeable | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 21. | Arsenic | mg/L | 0.01 | 0.05 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 22. | Cadmium | mg/L | 0.003 | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 23. | Copper | mg/L | 0.05 | 1.5 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 16.25 | BQL |
| 24. | Iron | mg/L | 0.3 | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 1.478 | BQL |
| 25. | Lead | mg/L | 0.01 | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 10.53 | BQL |
| 26. | Manganese | mg/L | 0.1 | 0.3 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | 139.03 | 93.717 |
| 27. | Mercury | mg/L | 0.001 | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |

| Sr. No. | Parameters | Units | Standard values as per IS | | Kandla | | | | | | | | | | | | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | P | DW-1 | DW-2 | DW-3 | DW-4 | DW-5 | DW-6 | DW-7 | DW-8 | DW-9 | DW-10 | DW-11 | DW-12 | DW-13 | DW-14 | DW-15 | DW-16 | DW-17 | DW-18 | DW-19 | DW-20 |
| 28. | Total Chromium | mg/L | 0.05 | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 29. | Zinc | mg/L | 5 | 15 | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 30. | Total Coliform* | CFU/ 100ml | Shall not be detected | | 5 | 390 | BQL | 25 | 5 | 5 | BQL | BQL | BQL | BQL | 5 | 5 | BQL | 135 | BQL | 7650 | 2350 | 5 | 2850 | 130000 |

A: Acceptable, P:Permissible, BQL: Below Quantification limit Turbidity (QL=0.5), Free Residual Chlorine (QL=2), Total Suspended Solids (QL=2), Fluoride (QL=0.3), Sulphate (QL=10), Nitrate as NO3 (QL=1), Nitrite as No2 (QL=0.1), Sodium as Na (QL=5), Potassium as K (QL=5), Hexavalent Chromium (QL=0.01), Arsenic (QL=5), Cadmium (QL=2), Copper (QL=5), Iron (QL=0.1), Lead (QL=2), Manganese (QL=40), Mercury (QL=0.5), Total Chromium (QL=5), Zinc (QL=0.5)

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

## 6.4 Data Interpretation:

- **pH:** The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion in water. At Kandla, the pH values for drinking water samples ranged from 7.15-7.65 and mean value was 7.37 while at Vadinar pH ranged from 7.45-7.46 and mean value was 7.45.
- **Turbidity:** Turbidity measurements are used to determine how clear and clean a water sample is. Small particles like clay, silt, algae, and microorganisms can be suspended in water and cause light scattering, giving water a milky or cloudy appearance. At the drinking water locations of Kandla, the turbidity was observed to be "Below the detection Limit" for majority of the locations, except location DW-3 (0.7 NTU). Whereas, for Vadinar the turbidity was observed to be "Below the detection Limit" for DW-19 and 5.3 NTU for DW-20.
- **Total Dissolved Solids (TDS):** Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. During the study period, TDS values at Kandla varied between 20 to 278 mg/L. The average TDS value was found 114.8 mg/L. The minimum value for TDS was 20 mg/L at DW-2, DW-4, DW-7 and DW-18 and maximum was 278 mg/L at DW-14. The average TDS was 61.11 mg/L. Whereas, at Vadinar TDS ranged from 62-346 mg/L and mean was 204 mg/L.
- **Electrical Conductivity** is the ability of a solution to transfer (conduct) electric current. Conductivity is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water. The conductivity in the samples collected ranged from 24-551 µS/cm with the average value as 117.38 µS/cm. While at Vadinar, the value of EC ranged from 115-683 µS/cm with the average value as 399 µS/cm.
- **Chlorides:** Excessive chloride concentration increase rates of corrosion of metals in the distribution system. The Chloride concentration varied from 7.5-80.97 mg/L, with the average value as 23.57 mg/L. The lowest concentration was observed at DW-2, DW-7 and DW-13, while the highest was observed at DW-14. While at Vadinar, the concentration varied from 19.99-90.47 mg/L. With the average chloride concentration as 55.23 mg/L. The lowest concentration was observed at DW-19, while the highest was observed at DW-20.
- **Total Hardness:** Hardness is caused by compounds of calcium and magnesium, and by a variety of other metals. The Total Hardness concentration varied from 10-160 mg/L, with the average value as 21.66 mg/L. The highest was observed at DW-14. While at Vadinar, the concentration varied from 20-160 mg/L. With the average Total Hardness concentration as 90 mg/L. Hardness at all the locations was observed to have concentrations within the norms specified. The hardness of water is according to the IS standards and it is not harmful for local inhabitants.
- The parameters Free Residual Chlorine, Total Suspended Solids, Fluoride, Sulphate, Nitrate, Nitrite, Sodium, Hexavalent Chromium, Potassium, and the metals Arsenic, Cadmium, Copper, Iron, Lead, Manganese, Mercury, Total Chromium and Zinc were all observed to have concentrations "Below the Quantification Limit (BQL)" at majority of the locations for both the monitoring period.

- Bacteriological Analysis of the drinking water at Kandla and Vadinar reveals that the Total Coliforms were detected at majority of the locations of Kandla and Vadinar. This shows that drinking water samples is unfit for human consumption. Reporting such high concentration of Coliforms indicates certain external influx may contaminate the source. Hence, it should be checked at every distribution point.

### 6.5 Conclusion

- These results were compared with permissible limits as prescribed in IS 10500:2012 – Drinking Water Specification. It may be concluded from the analysis data that amongst the drinking water parameters so monitored, the parameters such as TDS, Total hardness, chloride, fluoride were observed to be well below the acceptable limit of IS standard at all the 20 monitoring locations. Whereas Total Coliforms were found to be present in all the drinking water samples collected from both the locations.
- Low TDS water shall contain lower mineral content, Normal drinking water provides about 20% of your dietary intake of dissolved minerals. So, which means by consuming such water may result in mineral deficiency. Further, it may increase the metal leaching.
- Bacteriological Analysis of the drinking water at Kandla and Vadinar reveals that the drinking water samples is unfit for human consumption.
- Appropriate water treatment processes should be implemented to remove or inactivate coliform bacteria that include disinfection with chlorine, ultraviolet (UV) light, or ozone etc. Filtration systems can also help remove bacteria, sediment, and other impurities.
- Further, a regular monitoring program to test the quality of drinking water at various stages, including the source, purification plants, distribution network, and consumer endpoints would help in early detection of coliform bacteria or other microbial contaminants.

This page is intentionally left blank

# CHAPTER 7: DG STACK MONITORING

## 7.1 DG Stack Monitoring

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

As defined in scope by Deendayal Port Authority (DPA), the monitoring of DG Stack shall be carried out at two locations, one at Kandla and one at Vadinar. The details of the DG Sets at Kandla and Vadinar have been mentioned in **Table 22** as follows:

**Table 22: Details of DG Set monitoring locations**

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

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


**Figure 10: Location Map for DG Set monitoring at Kandla**


**Figure 11: Location Map for DG Set monitoring at Vadinar**

**Frequency of DG Monitoring**

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

## 7.2 Method of sampling and analysis:

Under the study, the list of parameters to be monitored under the projects for the Soil Quality Monitoring been mentioned in **Table 23** as follows:

**Table 23: Parameters to be monitored under the study**

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

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

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

As per CPCB or Indian standards for Industrial Stack Monitoring the flue gas emission from DG set emissions should not exceed the limit as mentioned in **Table 24.**

**Table 24: Standards for stack emission**

| Sr. No. | Stack Monitoring Parameters for DG Sets | Stack Monitoring Limits / Standards As per CPCB ($mg/Nm^3$) |
|---|---|---|
| 1. | Particulate Matter | 150 |
| 2. | Sulphur Dioxide (SO2) | 40 |
| 3. | Oxides of Nitrogen (NOx) | 25 |
| 4. | Carbon Monoxide | 1% |

During the monitoring period, the DG sets were not utilized, and hence monitoring was not conducted.

This page is intentionally left blank

# CHAPTER 8: SOIL QUALITY MONITORING

## 8.1 Soil Quality Monitoring:

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

As defined in scope by Deendayal Port Authority (DPA), Soil Quality Monitoring shall be carried out at Six locations, four at Kandla and two at Vadinar. The details of the soil monitoring locations within the Port area of DPA are mentioned in **Table 25:**

**Table 25: Details of the Soil quality monitoring locations**

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

The map depicting the locations of Soil Quality Monitoring to be monitored in Kandla and Vadinar have been mentioned in **Map 12 and 13** as follows:


**Figure 12: Location Map for Soil Quality Monitoring at Kandla**


**Figure 13: Location Map for Soil Quality Monitoring at Vadinar**

## 8.2 Methodology of Monitoring:

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

The samples of soil collected from the locations of Kandla and Vadinar and analyzed for the various physico-chemical parameter. Collection and analysis of these samples was carried out as per established standard methods and procedures. The samples were analyzed for selected parameters to get the present soil quality status and its and environmental risks associated with various practices prevalent at the location. GEMI has framed its own guidelines for collection of soil samples titled as ***'Soil Sampling Manual'***. Soil samples were collected from up to 30 cm depth below the surface using scrapper, filled in polythene bags, labelled on-site with specific location code and name and sent to GEMI's laboratory for further detailed analysis. The samples collected from all locations are homogeneous representative of each location. The list of parameters to be monitored under the projects for the Soil Quality Monitoring been mentioned in **Table 26** as follows:

**Table 26: List of parameters to be monitored for Soil Quality**

| Sr. No. | Parameters | Units | Reference method | Instruments |
|---|---|---|---|---|
| 1. | TOC | % | Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934) | Titration Apparatus |
| 2. | Organic Carbon | % | | |
| 3. | Inorganic Phosphate | mg/Kg | Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017 Determination of Available Phosphorus in Soil | UV-Visible Spectrophotometer |
| 4. | Texture | - | Methods Manual Soil Testing in India January 2011,01 | Hydrometer |
| 5. | pH | - | IS 2720 (Part 26): 1987 | pH Meter |
| 6. | Conductivity | µS/cm | IS 14767: 2000 | Conductivity Meter |
| 7. | Particle size distribution & Silt content | - | Methods Manual Soil Testing in India January 2011 | Sieves Apparatus |
| 8. | SAR | meq/L | Procedures for Soil Analysis, International Soil Reference and Information Centre, 6th Edition 2002 13-5.5.3 Sodium Absorption Ratio (SAR), Soluble cations | Flame Photometer |

| Sr. No. | Parameters | Units | Reference method | Instruments |
|---|---|---|---|---|
| 9 | Water Holding Capacity | % | NCERT, Chapter 9, 2022-23 and Water Resources Department Laboratory Testing Procedure for Soil & Water Sample Analysis | Muffle Furnace |
| 10 | Aluminium | mg/Kg | EPA Method 3051A | ICP-OES |
| 11 | Chromium | mg/Kg | | |
| 12 | Nickel | mg/Kg | | |
| 13 | Copper | mg/Kg | Methods Manual Soil Testing in India January, 2011, 17a | |
| 14 | Zinc | mg/Kg | Methods Manual Soil Testing in India January, 2011, 17a | |
| 15 | Cadmium | mg/Kg | EPA Method 3051A | |
| 16 | Lead | mg/Kg | | |
| 17 | Arsenic | mg/Kg | | |
| 18 | Mercury | mg/Kg | | |

## 8.3 Result and Discussion

The analysis results of physical analysis of the soil samples collected during environmental monitoring mentioned in **Table 27** are shown below:

**Table 27: Results of Soil Quality**

| Sr. No | Location / Parameters | Unit | Kandla | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|
| | | | **S-1** (Oil Jetty 7) | **S-2** (IFFCO Plant) | **S-3** (Khori Creek) | **S-4** (Nakti Creek) | **S-5** (Near SPM) | **S-6** (Near Vadinar Jetty) |
| 1 | pH | - | 7.69 | 8.27 | 7.27 | 8.04 | 7.92 | 8.5 |
| 2 | Conductivity | µS/cm | 8840 | 6040 | 39600 | 11700 | 111 | 625 |
| 3 | Inorganic Phosphate | mg/Kg | 11.01 | 27.6 | 20.31 | 11.46 | 5.64 | 5.1 |
| 4 | Organic Carbon | % | 0.03 | 0.38 | 1.88 | 0.46 | 0.85 | 0.3 |
| 5 | Organic Matter | % | 0.06 | 0.66 | 3.23 | 0.79 | 1.47 | 0.52 |
| 6 | SAR | meq/L | 1.05 | 0.67 | 1.10 | 1.65 | 0.10 | 0.25 |
| 7 | Aluminium | mg/Kg | 1392.53 | 1368.22 | 1569.23 | 1388.41 | 1480.53 | 1425.50 |
| 8 | Chromium | mg/Kg | 69.98 | 69.92 | 79.56 | 70.18 | 106.00 | 91.88 |
| 9 | Nickel | mg/Kg | 33.32 | 27.54 | 27.16 | 31.51 | 40.89 | 42.68 |
| 10 | Copper | mg/Kg | 25.33 | 51.65 | 148.05 | 50.49 | 123.18 | 98.20 |
| 11 | Zinc | mg/Kg | 52.29 | 155.24 | 100.20 | 61.30 | 83.05 | 52.89 |
| 12 | Cadmium | mg/Kg | BQL | 1.07 | BQL | BQL | BQL | BQL |
| 13 | Lead | mg/Kg | 9.30 | 17.33 | 3.45 | 7.24 | BQL | 0.91 |
| 14 | Arsenic | mg/Kg | 4.87 | 8.4 | BQL | 4.03 | BQL | BQL |
| 15 | Mercury | mg/Kg | BQL | BQL | BQL | BQL | BQL | BQL |
| 16 | Water Holding Capacity | % | 45.54 | 45.29 | 25.98 | 45.84 | 39.85 | 54.23 |
| 17 | Sand | % | 70.7 | 72.28 | 60.08 | 76.33 | 51.84 | 53.62 |
| 18 | Silt | % | 9.77 | 13.86 | 29.74 | 11.84 | 12.24 | 36.08 |
| 19 | Clay | % | 19.53 | 13.86 | 10.18 | 11.84 | 35.92 | 10.3 |
| 20 | Texture | | Sandy loam | Loamy Sand | Sandy loam | Sandy loam | Sandy loam | Sandy loam |

Under the project, in order to classify the soil quality of Kandla and Vadinar, the "Standard Soil Classification" has been adopted from Hand Book of Agriculture, ICAR, New Delhi. The classification is mentioned in the **Table 28** as follows for the parameters pH, Electrical Conductivity, Organic Carbon.

**Table 28: Classification of soil parameters as mentioned in Hand Book of Agriculture**

| Sr. No. | Soil Parameters | Classification |
|---|---|---|
| 1. | pH | **<4.5** Extremely acidic<br>**4.51-5.50** Very strongly acidic<br>**5.51-6.00** moderately acidic<br>**6.01-6.50** slightly acidic<br>**6.51-7.30** Neutral<br>**7.31-7.80** slightly alkaline<br>**7.81-8.50** moderately alkaline<br>**8.51-9.0** strongly alkaline<br>**>9.00** very strongly alkaline |
| 2. | EC (ppm)<br>(1ppm = 640 µmhos) | **Up to 1.00** Average<br>**1.01-2.00** harmful to germination<br>**2.01-3.00** harmful to crops (sensitive to salts) |
| 3. | Organic Carbon | **Up to 0.2**: very less<br>**0.21-0.4**: less<br>**0.41-0.5** medium,<br>**0.51-0.8**: on an average sufficient<br>**0.81-1.00**: sufficient<br>**>1.0** more than sufficient |

## 8.4 Data Interpretation:

- **pH**

  For the month of April 2023, the value of pH ranges from 7.27-8.27, highest at location S-2 IFFCO Plant; while the average value was 7.81. Whereas, at Vadinar highest pH was observed at S-6 i.e., near Jetty Area (8.5) with the average soil pH as 8.21. As per the classification mentioned in the Handbook of Agriculture, the pH in Kandla varies from the Neutral to moderately alkaline. Whereas, pH of Soil at Vadinar was found to be moderately alkaline.

- **Electrical Conductivity (EC)**

  During the study period, at Kandla the value of EC ranges from 6040-39600 µs/cm, highest at location S-3 Khori creek (11700 µs/cm) and lowest at S-2 IFFCO Plant (6040 µs/cm); while the average value was 16545 µs/cm. Whereas, at Vadinar highest EC was observed at S-6 i.e., near Jetty Area (6.25 µs/cm) and lowest was observed at S-5 i.e., Near SPM (111 µs/cm), while the average value was 368 µs/cm.

  As per the classification mentioned in the Handbook of Agriculture, the Electrical Conductivity at Kandla the status of soil quality was found to be harmful to crops. Whereas, at Vadinar EC was observed to be below the average value of 640 µs/cm.

- **Inorganic Phosphate**

  During the monitoring period at Kandla the value of Inorganic Phosphate ranges from 11.01-27.6 mg/Kg, highest at location S-2 IFFCO Plant (27.6 mg/Kg) and lowest at S-1 Oil Jetty-7 (11.01 mg/Kg); while the average value was 17.595 mg/Kg. Whereas, at

Vadinar highest Inorganic Phosphate was observed at S-6 i.e., near Jetty Area (5.1 mg/Kg) and lowest was observed at S-5 i.e., Near SPM (5.64 mg/Kg), while the average value was 5.37 mg/Kg.

- **Total organic Carbon (TOC)**

  At Kandla the value of TOC ranges from 0.03 to 1.88 % highest at location S-3 Khori creek (1.18%) and lowest at S-1 Oil Jetty-7 (0.03%); while the average value was 0.68%. Whereas, at Vadinar highest TOC was observed at S-5 i.e., Near SPM (0.85%) and lowest was observed at S-6 i.e., near Jetty Area (0.3%). As per the classification mentioned in the Handbook of Agriculture, the Organic Carbon at Kandla and Vadinar was on an average in sufficient concentration.

- **Heavy Metals**

  For the sampling period, the concentration of **Aluminium** in the soil samples at varies from 1368.22 to 1569.23 mg/kg at Kandla and 1425.5 to 1480.53 mg/kg at Vadinar with mean value reported as 1429.59 and 1453.01 mg/kg at Kandla and Vadinar monitoring station respectively

  The concentration of **Chromium** in the soil samples varies from 69.92 to 79.5623 mg/kg at Kandla and 91.88 to 106mg/kg at Vadinar with mean value 72.41 and 98.94 mg/kg at Kandla and Vadinar monitoring station respectively.

  The concentration of **Nickel** in the soil samples of DPA Kandla varies from 27.16 to 33.32 mg/kg at Kandla and 40.89 to 42.68 mg/kg at Vadinar with mean value 29.88 and 41.78 mg/kg at Kandla and Vadinar monitoring station respectively.

  The concentration of **Copper** in the soil samples of DPA Kandla varies from 25.33 to 148.05 mg/kg and 98.2 to 123.18 mg/kg at Vadinar with mean value 68.88 and 110.69 mg/kg at Kandla and Vadinar monitoring station respectively.

  The concentration of **Zinc** in the soil samples of DPA Kandla varies from 52.29 to 155.24 mg/kg and 52.89 to 83.05mg/kg at Vadinar with mean value 92.25 and 67.97 mg/kg at Kandla and Vadinar monitoring station, respectively.

  The concentration of **Lead** in the soil samples of DPA Kandla varies from 3.45 to 17.33 mg/kg and BQL to 0.91 mg/kg at Vadinar with mean value 9.33 and 0.91 mg/kg at Kandla and Vadinar monitoring station, respectively.

  The concentration of **Arsenic** in the soil samples of DPA Kandla varies from BQL to 8.4 mg/kg with mean value 5.76 mg/Kg and observed below the detection Limit for Vadinar.

  The concentration of **Water Holding Capacity** in the soil samples of DPA Kandla varies from 25.98 to 45.84% and 39.85 to 54.23% at Vadinar and mean value 40.66% and 47.04 % for Kandla and Vadinar respectively.

  Heavy Metals like **Mercury and Cadmium** in the Soil was found to "Below the detection limit" for majority the soil samples collected at Kandla and Vadinar.

The soil texture observed at all the locations of Kandla and Vadinar for the sampling period was "Sandy Loam".

## 8.5 Conclusion:

The soil quality of Kandla and Vadinar was assessed based on the Handbook of Agriculture. As per the said comparison, the pH in Kandla varies from the Slightly acidic to moderately alkaline. Whereas, pH of Soil at Vadinar was found to be moderately alkaline, the Organic Carbon at Kandla and Vadinar was on an average in sufficient concentration, whereas, the Electrical Conductivity at Kandla for both the months of April and May was found to be harmful to crops. There are several reasons that can contribute to soil quality degradation at port areas, such as:

- **Contamination:** Port areas are prone to various types of contamination due to the handling, storage, and transportation of goods and materials. Spills of hazardous substances, leakage from storage tanks, and improper disposal of waste can result in soil contamination. Chemicals such as heavy metals, petroleum products, and industrial pollutants can accumulate in the soil, making it less suitable for plant growth and potentially harmful to human health.
- **Erosion:** Ports are often located near coastlines or rivers, where erosion can be a significant issue. The construction of port infrastructure, such as breakwaters, jetties, and embankments, can alter natural sediment flow and wave patterns, leading to increased erosion of nearby soils. Erosion can cause loss of topsoil, which is rich in organic matter and essential nutrients for plant growth.
- **Increased salinity:** Ports situated in coastal areas may experience saltwater intrusion into the soil. Dredging activities, land reclamation, and alteration of natural water flow can disrupt the balance between freshwater and saltwater, resulting in increased salinity in the soil. High salt concentrations can hinder plant growth, reduce crop productivity, and adversely affect soil structure.
- **Compaction:** Heavy machinery, trucks, and containers moving in port areas can exert significant pressure on the soil, leading to compaction. Compacted soils have reduced pore spaces, limiting air and water movement and impeding root penetration. This can result in poor drainage, decreased nutrient availability, and restricted plant growth.
- **Loss of organic matter**: Port areas often undergo significant land transformation, including the removal of vegetation and topsoil during construction. The removal of organic matter-rich topsoil reduces the soil's fertility and capacity to retain moisture, making it less suitable for supporting plant life.

## 8.6 Measures against adverse effects

Addressing soil quality degradation at port areas requires implementing measures such as proper soil management practices, regular monitoring and testing for contaminants, erosion control measures, and the use of sustainable construction techniques. Additionally, promoting the restoration of vegetation and implementing strategies to minimize the introduction and spread of invasive species can help mitigate soil degradation in port areas.

# CHAPTER 9: SEWAGE TREATMENT PLANT MONITORING

## 9.1 Sewage Treatment Plant (STP) Monitoring:

The principal objective of Sewage Treatment Plant is to remove contaminants from sewage to produce an effluent that is suitable to discharge to the surrounding environment or an intended reuse application, thereby preventing water pollution from raw sewage discharges. As defined in the scope by Deendayal Port Authority (DPA), Kandla, the Sewage Water Treatment Plant Monitoring as to be carried out at three locations, one at Kandla, one at Gopalpuri and one STP at Vadinar. The samples each from the treated wastewater of the STP have to be collected weekly. The details of the locations of Sewage Treatment Plants to be monitored for Kandla and Vadinar are as mentioned in **Table 29** as follows:

**Table 29: Details of the monitoring locations of Sewage Water Treatment Plants**

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

The Consolidated Consent and Authorization (CC&A) issued by the Gujarat Pollution Control Board (GPCB) were referred for the details of the Sewage Treatment Plant (STP) for Kandla and Gopalpuri. The said CC&A of Kandla and Gopalpuri suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 30.** The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

**Table 30: Norms of treated effluent as per CC&A for Kandla**

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

The detailed process flow diagram of the Kandla and Gopalpuri STP have been mentioned in **Figure 14 and 15** as follows:

**Process Flow Diagram of Kandla Sewage Treatment Plant (STP)**

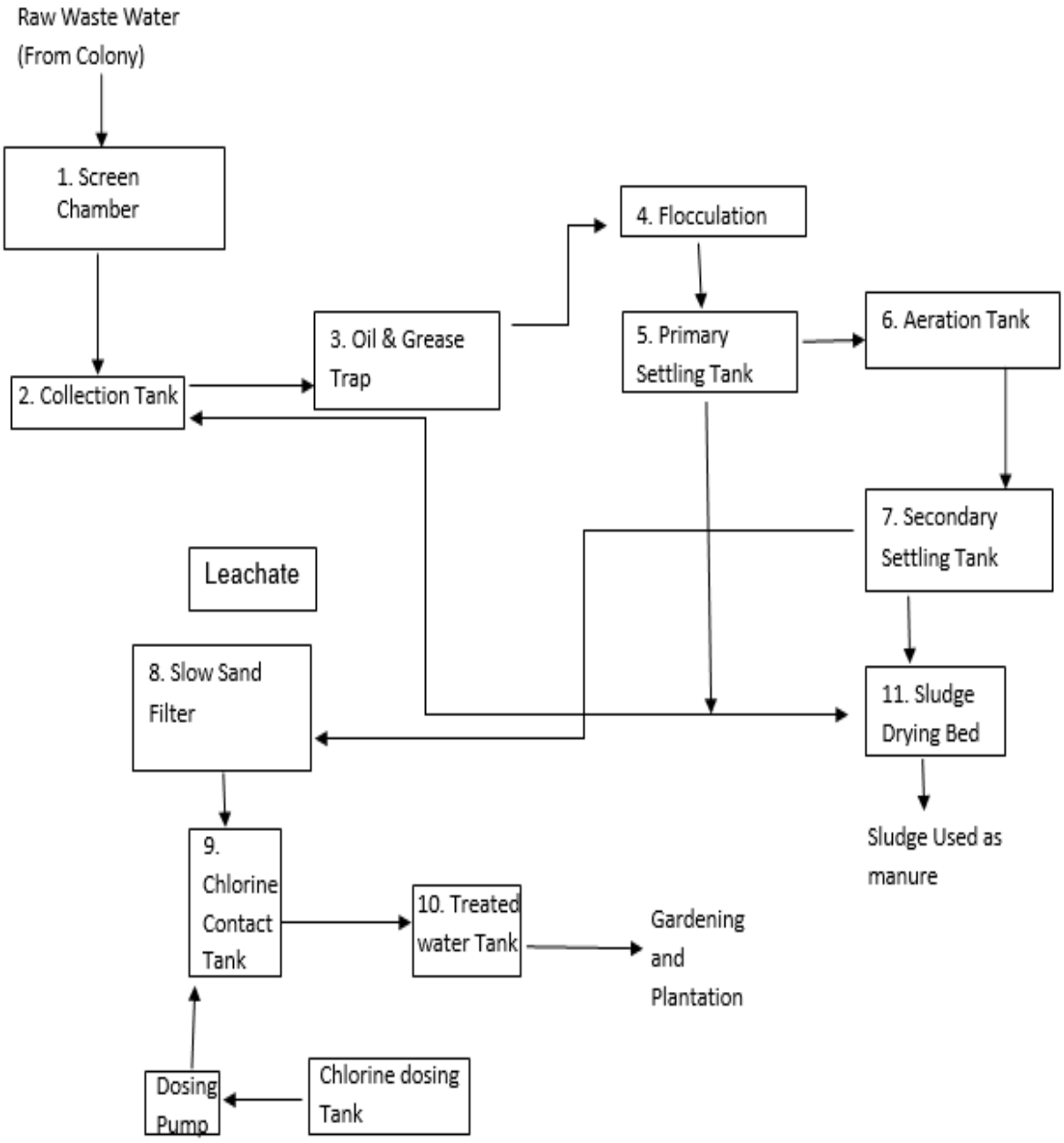



**Figure 14: Process flow diagram of Kandla STP**

**Process Flow Diagram of Gopalpuri Sewage Treatment Plant (STP)**

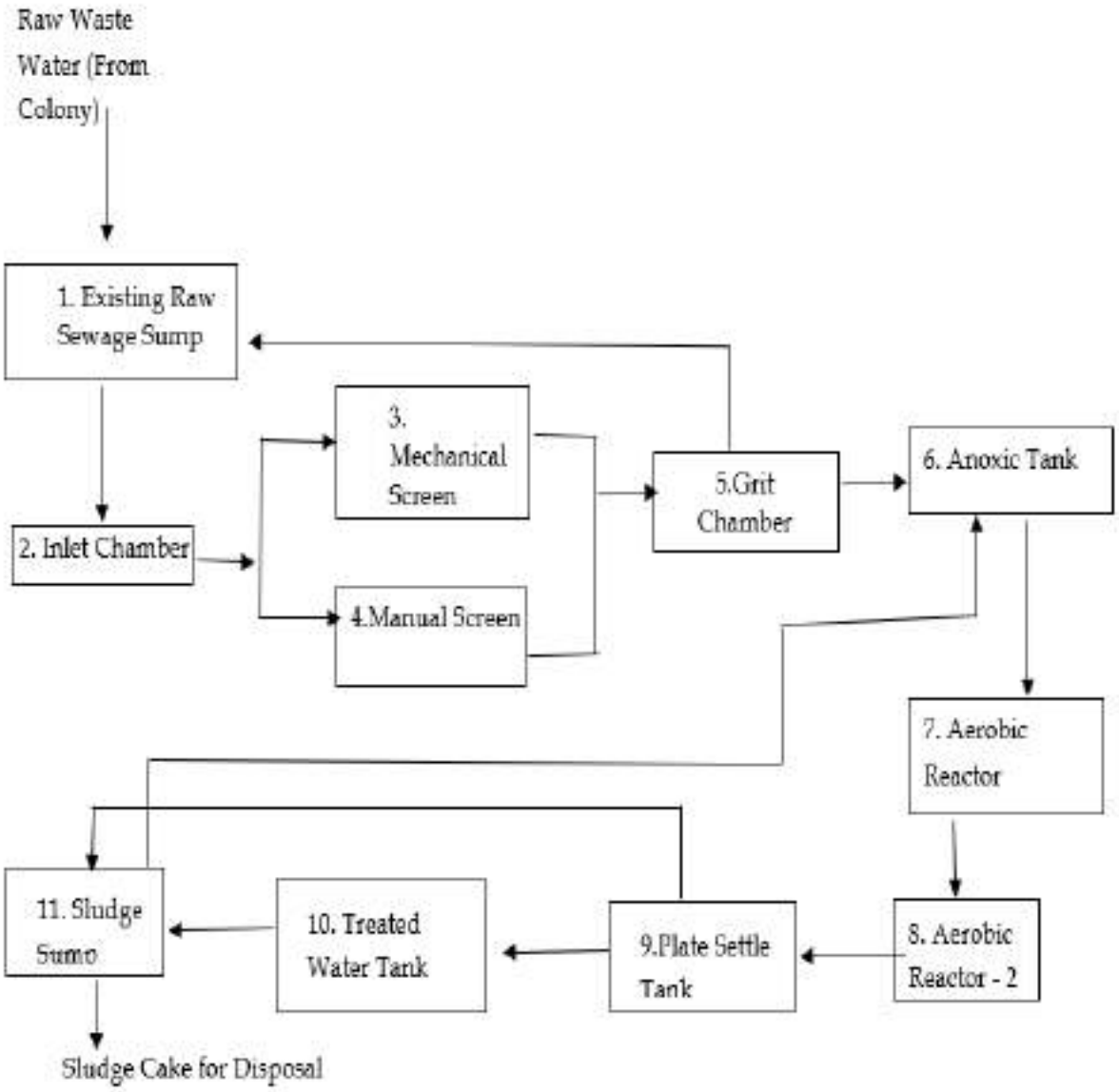



**Figure 15: Process flow diagram of Gopalpuri STP**

The STP at Vadinar has been built with a treatment capacity of 450 KLD/day. The Consolidated Consent and Authorization (CC&A) issued by the Gujarat Pollution Control Board (GPCB) were referred for the details of the Sewage Treatment Plant (STP) for Kandla and Gopalpuri. The said CC&A of the Vadinar STP suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 31**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

**Table 31: Norms of treated effluent as per CC&A for Vadinar**

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

The detailed process flow diagram of the Vadinar STP have been mentioned in **Figure 16** as follows:

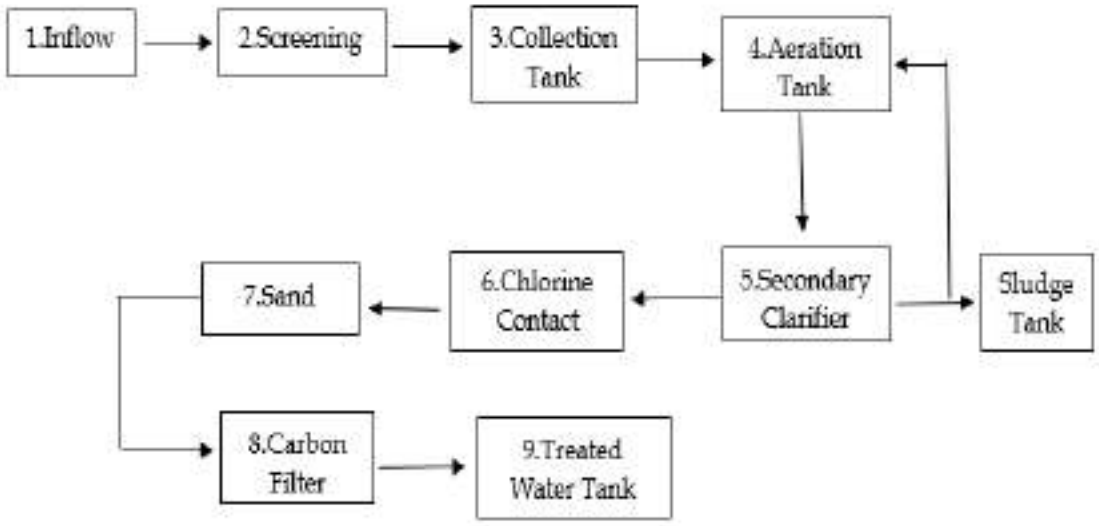



**Figure 16: Process flowchart for the Vadinar STP**

The map depicting the locations of Sewage Water Treatment Plant Monitoring to be monitored in Kandla and Vadinar have been shown in **Figure 17 and 18** as follows:


**Figure 17: Location Map for STP Monitoring at Kandla**


**Figure 18: Location Map for STP Monitoring at Vadinar**

## 9.2 Methodology of Monitoring:

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

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

Under the project, the list of parameters to be monitored for the STP have been mentioned in **Table 32** as follows:

**Table 32: List of parameters monitored for STP's at Kandla and Vadinar**

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

## 9.3 Result and Discussion

The quality of the water samples collected from the inlet and the outlet of the STP's of Kandla and Vadinar has been summarized in **Table 33 and 34** for the monitoring period. The said water quality has been represented in comparison with the standard values specified in the Consolidated Consent and Authorization (CC&A) of the STPs.

**Table 33: Water Quality of inlet and outlet of STPs for Kandla**

| Sr No. | Parameter | Units | GPCB Norms (Kandla) | Kandla | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Week 3 (April) | | | | Week 4 (April) | | | | Week 1 (May) | | | | Week 2 (May) | | | |
| | | | | STP-1 (I) | STP-1 (O) | STP-2 (I) | STP-2 (O) | STP-1 (I) | STP-1 (O) | STP-2 (I) | STP-2 (O) | STP-1 (I) | STP-1 (O) | STP-2 (I) | STP-2 (O) | STP-1 (I) | STP-1 (O) | STP-2 (I) | STP-2 (O) |
| **1.** | pH | - | **6.5-8.5** | 7.04 | 7.15 | 6.97 | 8.88 | 7.22 | 7.4 | 7.14 | 7.18 | 6.96 | 7.1 | 7.06 | 7.09 | 7.13 | 7.21 | 6.85 | 7.37 |
| **2.** | TDS | mg/L | - | 2522 | 3586 | 484 | 820 | 2688 | 4616 | 512 | 546 | 2564 | 3776 | 588 | 556 | 2280 | 3612 | 528 | 512 |
| **3.** | TSS | mg/L | **100** | 148 | 66 | 146 | 10 | 918 | 88 | 52 | 6 | 1648 | 32 | 138 | 12 | 102 | 28 | 150 | 4 |
| **4.** | DO | mg/L | - | BQL | 2 | 6.6 | BQL | BQL | 3.21 | BQL | 6.6 | BQL | 1 | BQL | 7.6 | BQL | 3.4 | BQL | 4.8 |
| **5.** | COD | mg/L | - | 255.06 | 117.41 | 275.3 | 76.92 | 307.5 | 202.2 | 200.8 | 60.24 | 135.46 | 277.09 | 388.65 | 67.73 | 156.63 | 96.39 | 333.33 | 68.27 |
| **6.** | BOD | mg/L | **30** | 65.77 | 25.1 | 56 | 18.45 | 80.78 | 27.89 | 40.16 | 11.12 | 32 | 52.4 | 76.1 | 13 | 36.45 | 22 | 71 | 15.1 |
| **7.** | SAR | meq/L | - | 11.36 | 12.58 | 2.71 | 2.89 | 12.65 | 14.98 | 2.67 | 2.85 | 9.69 | 12 | 3.63 | 3.31 | 12.81 | 16.02 | 3.48 | 3.22 |
| **8.** | Total Coliforms | MPN/ 100ml | **<1000** | 1600 | 1600 | 1600 | BQL | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 |

**Table 34: Water Quality of inlet and outlet of STP for Vadinar**

| Sr No. | Parameter | Units | GPCB Norms (Vadinar) | Vadinar (April) | | | | Vadinar (May) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Week 3 | | Week 4 | | Week 1 | | Week 2 | |
| | | | | STP-3 (Inlet) | STP-3 (Outlet) | STP-3 (Inlet) | STP-3 (Outlet) | STP-3 (Inlet) | STP-3 (Outlet) | STP-3 (Inlet) | STP-3 (Outlet) |
| **1.** | pH | - | **5.5-9** | 7.1 | 7.08 | 7.32 | 7.38 | 7.1 | 7.18 | 7.15 | 7.42 |
| **2.** | TDS | mg/L | - | 496 | 468 | 515 | 446 | 538 | 458 | 536 | 450 |
| **3.** | TSS | mg/L | **20** | 64 | 36 | 61 | 21 | 40 | 10 | 26 | 12 |
| **4.** | DO | mg/L | - | BQL | 4.6 | BQL | 4.24 | BQL | 1.7 | 0.5 | 7.4 |
| **5.** | COD | mg/L | **50** | 197.58 | 52.42 | 184.54 | 54.5 | 149.19 | 40.32 | 165.99 | 48.58 |
| **6.** | BOD | mg/L | **10** | 45 | 11 | 36.24 | 10.88 | 31 | 8 | 37.1 | 10 |
| **7.** | SAR | meq/L | - | 2.96 | 3.06 | 3.44 | 3.20 | 3.13 | 3.03 | 3.3 | 2.98 |
| **8.** | Total Coliforms | MPN/100ml | **100-230** | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 |

BQL: Below Quantification limit; Total Suspended Solids (QL=2), Dissolved Oxygen (QL=0.5)

## 9.4 Data Interpretation:

- **pH**: As per the norms, pH of the treated domestic effluent should conform to the standard of 6.5-8.5. the pH for the STP-1 and STP-2 of Kandla. Whereas for STP-3 at Vadinar falls within the 5.5-9 and hence conforms to the stipulated norms.
- **Total Suspended Solids**: The TSS for the STP-1 and STP-2 of Kandla and STP-3 of Vadinar falls within the stipulated norms of 100 mg/L and hence conforms to the norms specified.
- As per the norms, the **Chemical Oxygen Demand** (COD) for the outlet for Vadinar STP shall be 50 mg/L. COD exceeds slightly for month of April 2023 for Vadinar STP. Whereas, the COD was observed to comply with the stipulated norms for the month of May 2023.
- The main focus of wastewater treatment plants is supposed to reduce the **BOD** in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The final treated outlet was observed to have BOD values within the stipulated norms at STP-1, STP-2 and STP-3 for the sampling conducted during the month of April and May 2023. Exceeding value of BOD were observed at STP-1, during the sampling conducted in the first week of May 2023.
- The **Total Coliforms** were observed to exceed the norms at all the locations of the STP outlets of Kandla and Vadinar. This indicates that the method of disinfection applied is not adequate.

## 9.5 Conclusions:

During the monitoring period, only Total Coliforms and COD at STP Kandla, are found exceeding the limit while rest of the sewage parameters for STP outlet were within norms of CCA at both the monitoring sites. The treated sewage water of Kandla STP, Deendayal Port Colony (Gopalpuri) STP and Vadinar STP were in line with the standards set by the Central Pollution Control Board. Regular monitoring of the STP performance should be conducted on regular basis to ensure adequate treatment as per the norms.

## 9.6 Remedial Measures:

- The quantum of raw sewage (influent) entering the STP should be monitored flow meter. If the quantity of the sewage exceeds the treatment capacity of the treatment plant, then provision of additional capacity of collection sump should be provided.
- The adequacy and efficacy of the stages of Sewage treatment units shall be conducted.
- The treatment parameters such as retention time, Mixed Liquor Suspended Solids (MLSS), Mixed liquor volatile suspended solids (MLVSS), Recirculation rate, sludge generation, etc should be monitored timely.
- During the treatment, the required retention time and rate of aeration should be maintained, so that the efficiency of the treatment plant is maintained.
- The dosage of chemicals administered during the treatment should be reviewed and alterations in the dosage should be done.
- The results show the presence of total coliforms; hence the method of disinfection (Chlorination) sodium or calcium Hypochlorite can be used.
- Effectiveness of any technology depends on factors such as the specific pollutants in the wastewater, plant size, local regulations, and available resources. There are several processes that may be implemented such as - Advanced oxidation process involve using strong oxidants to break down complex organic compounds. Methods like Fenton's reagent (hydrogen peroxide and iron catalyst) and UV/H2O2 treatment can help in reducing COD through oxidation.
- Electrochemical processes like Electrocoagulation (EC) and Electrooxidation (EO) that involve the application of an electric current to facilitate the removal of pollutants through coagulation, flocculation, and oxidation. These methods can be useful for treating sewage containing various pollutants.
- Enhanced biological treatment processes, such as Moving Bed Biofilm Reactors (MBBR), Integrated Fixed-film Activated Sludge (IFAS) systems, and Membrane Bio-Reactors (MBRs) are utilised to improve the efficiency of organic matter and nutrient removal from wastewater.

This page is intentionally left blank

# CHAPTER 10: MARINE WATER QUALITY MONITORING

## 10.1 Marine Water:

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

Major water quality concerns at ports include wastewater and leakage of toxic substances from ships, stormwater runoff, etc. This discharge of wastewater, combined with other ship wastes which includes sewage and wastewater from other on-board uses, is a serious threat to the water quality as well as to the marine life. As defined in the scope by Deendayal Port Authority (DPA), the Marine Water sampling and analysis has to be carried out at a total of eight locations, six at Kandla and two at Vadinar. The marine water sampling was be carried out with the help of Niskin Sampler with a capacity of 5L. The Niskin Sampler is a device used to take water samples at a desired depth without the danger of mixing with water from other depths. The details of the locations to be monitored is as mentioned in **Table 35:**

**Table 35: Details of the sampling locations for Marine water**

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

The map depicting the locations of Marine Water to be sampled and analysed in Kandla and Vadinar have been mentioned in **Map 19 and 20** as follows:


**Figure 19: Location Map for Marine Water Monitoring at Kandla**

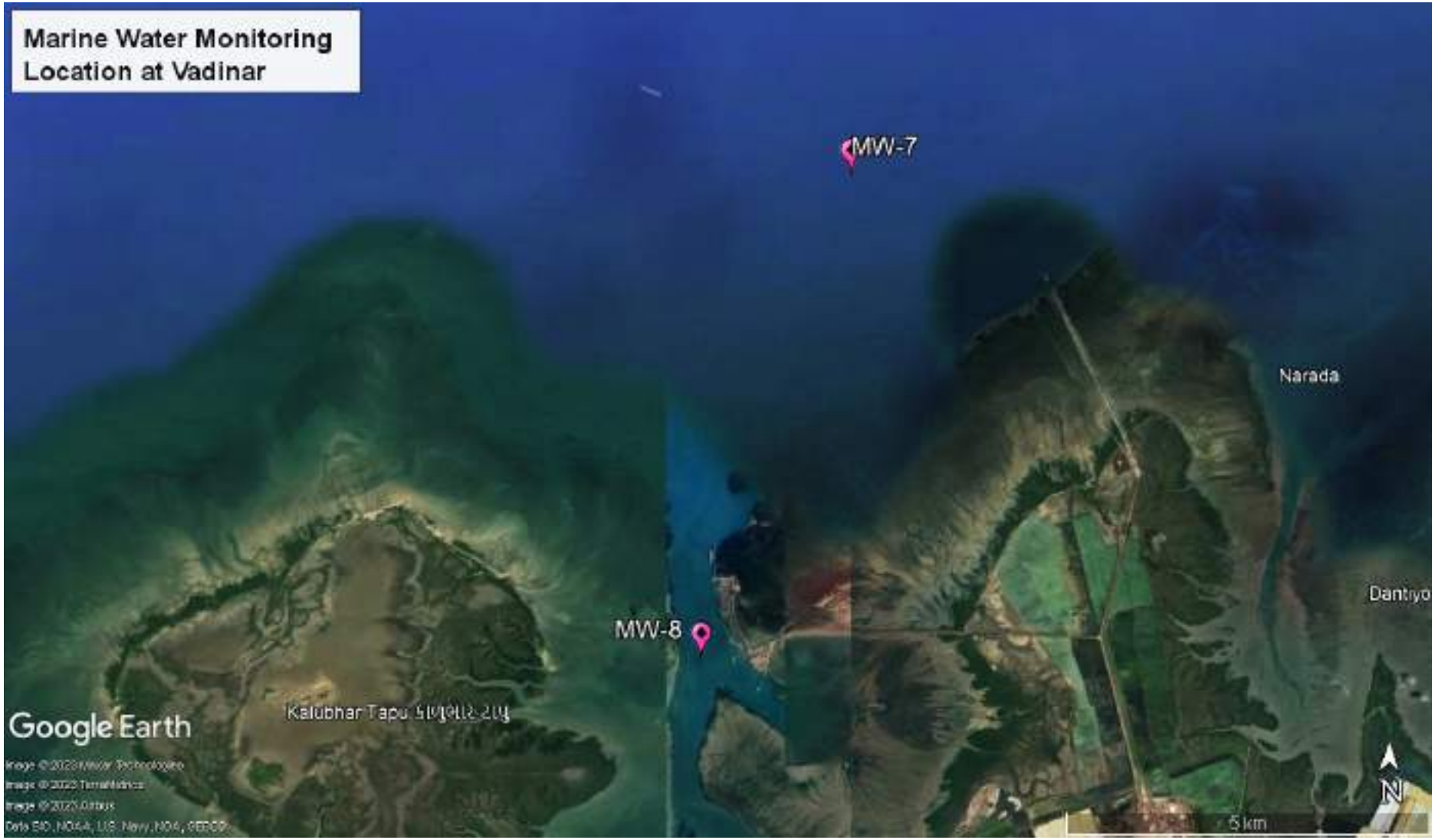



**Figure 20: Location Map for Marine Water Monitoring at Vadinar**

**Frequency**

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

## 10.2 Methodology

Similar to the methodology adopted for the sampling and monitoring of Drinking water under the study, the sampling of Marine Water was carried out as per the '**Sampling Protocol for Water & Wastewater'** developed by GEMI as well as the CPCB guidelines. The water samples collected through the Niskin Sampler are collected in a clean bucket to reduce the heterogeneity. From the collected water sample 1 liter of water sample is separated in an opaque plastic bottle for the estimation of chlorophyll. The list of parameters to be monitored under the project for the Marine Water quality have been mentioned in **Table 36** along with the analysis method and instrument.

**Table 36: List of parameters monitored for Marine Water**

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

| Sr. No | Parameters | Units | Reference method | Instrument |
|---|---|---|---|---|
| 14. | Sulphate | mg/L | APHA, 23rd Edition, 4500 SO4-2 E: 2017 | |
| 15. | Nitrate | mg/L | APHA, 23rd Edition, 4500 NO3-B: 2017 | |
| 16. | Nitrite | mg/L | APHA, 23rd Edition, 4500 NO2- B: 2017 | |
| 17. | Sodium | mg/L | APHA,23rd Edition, 3500 Na-B: 2017 | Flame photometer |
| 18. | Potassium | mg/L | APHA,23rd Edition, 3500 K-B: 2017 | |
| 19. | Manganese | mg/L | APHA,23rd Edition, ICP Method 3120 B: 2017 | ICP-OES |
| 20. | Iron | mg/L | APHA,23rd Edition, ICP Method 3120 B: 2017 | |
| 21. | Total Chromium | mg/L | APHA, 23rd Edition, 3500 Cr B: 2017 | |
| 22. | Hexavalent Chromium | mg/L | | UV- Visible Spectrophotometer |
| 23. | Copper | mg/L | APHA, 23rd Edition, ICP Method 3120 B: 2017 | ICP-OES |
| 24. | Cadmium | mg/L | | |
| 25. | Arsenic | mg/L | | |
| 26. | Lead | mg/L | | |
| 27. | Zinc | mg/L | | |
| 28. | Mercury | mg/L | EPA 200.7 | |
| 29. | Floating Material (Oil grease scum, petroleum products) | mg/L | APHA, 23rd Edition, 5520 C: 2017 | Soxhlet Assembly |
| 30. | Total Coliforms (MPN) | MPN/ 100ml | IS 1622: 2019 | LAF/ Incubator |

## 10.3 Result and Discussion

The quality of the Marine water samples collected from the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 37**. The said water quality has been represented in comparison with the standard values as stipulated by CPCB.

**Table 37: Results of Analysis of Marine Water Sample**

| Sr. No. | Parameters | Unit | Primary Water Quality Criteria for Class SW-IV Waters | Kandla | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MW-1 | MW-2 | MW-3 | MW-4 | MW-5 | MW-6 | MW-7 | MW-8 |
| 1. | Density | kg/m³ | - | 1.021 | 1.021 | 1.022 | 1.021 | 1.022 | 1.022 | 1.022 | 1.022 |
| 2. | pH | - | 6.5-9.0 | 7.76 | 7.74 | 7.83 | 7.81 | 7.84 | 8.04 | 8.07 | 8.11 |
| 3. | Color | Hazen | No Noticeable | 9 | 12 | 15 | 10 | 9 | 11.6 | 4 | 5 |
| 4. | EC | µS/cm | - | 60,391 | 58,491 | 57,913 | 54,179 | 55,587 | 61,528 | 55,871 | 52.119 |
| 5. | Turbidity | NTU | - | >50 | >50 | >50 | >50 | >50 | >50 | 3.2 | 4.5 |
| 6. | TDS | mg/L | - | 41,930 | 39,386 | 38,688 | 38,072 | 39,434 | 38,587 | 34,950 | 34,892 |
| 7. | TSS | mg/L | - | 184 | 334 | 124 | 740 | 642 | 852 | 220 | 151 |
| 8. | COD | mg/L | - | 72 | 76 | 81 | 81 | 71 | 78 | 75 | 75 |
| 9. | DO | mg/L | 3.0 mg/L | 5.6 | 5.5 | 5.4 | 5.6 | 5.7 | 5.7 | 7.3 | 7.4 |
| 10. | BOD | mg/L | 5.0 mg/L | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 11. | Oil & Grease | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 12. | Sulphate | mg/L | - | 2747.55 | 2665.78 | 2433.35 | 2684.05 | 2771.15 | 3156.54 | 2212.35 | 2441.56 |
| 13. | Nitrate | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 14. | Nitrite | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 15. | Phosphate | mg/L | | 0.46 | 0.09 | 1.46 | 0.75 | 0.57 | 0.54 | 0.64 | 1.43 |
| 16. | Silica | mg/L | - | 0.32 | 1.51 | 0.65 | 2.79 | 1.74 | 0.33 | BQL | BQL |
| 17. | Sodium | mg/L | - | >10,000 | >10,000 | >10,000 | >10,000 | >10,000 | >10,000 | >10,000 | >10,000 |
| 18. | Potassium | mg/L | - | 385.03 | 397.63 | 347.34 | 424.53 | 423.34 | 442.63 | 321.10 | 351.13 |
| 19. | Hexavalent Chromium | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 20. | Odour | - | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 21. | Arsenic | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 22. | Cadmium | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 23. | Copper | mg/L | - | 5.10 | 6.07 | BQL | 12.01 | 7.60 | 10.2 | BQL | BQL |
| 24. | Iron | mg/L | - | 1.03 | 1.05 | 2.2 | 5.4 | 3.9 | 5.3 | BQL | BQL |
| 25. | Lead | mg/L | - | BQL | 1.7 | 1.32 | 6.2 | 2.21 | 3.41 | BQL | BQL |
| 26. | Manganese | mg/L | - | 73.11 | 75.21 | 85.71 | 121.79 | 86.75 | 86.24 | BQL | BQL |
| 27. | Total Chromium | mg/L | - | BQL | 5.62 | BQL | 15.71 | 8.25 | BQL | BQL | BQL |
| 28. | Zinc | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 29. | Mercury | mg/L | - | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 30. | Total Coliform | MPN /100 ml | 500/100 ml | 900 | 35 | 10 | 55 | 30 | 44 | BQL | BQL |
| 31. | Particulate Organic Carbon | mg/L | - | 0.32 | 0.16 | 0.56 | 0.25 | 0.35 | 0.29 | 0.36 | 0.39 |

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

BQL- Below Quantification Limit; Turbidity (DL=50), Biochemical Oxygen Demand (QL=3), Oil & Grease (QL=1), Nitrate as NO3 (QL=1), Nitrite as No2 (QL=0.1), Phosphorous (QL=0.5), Silica (QL=0.05), Sodium as Na (QL=10,000), Hexavalent Chromium (QL=0.01), Arsenic (QL=5), Cadmium (QL=2), Copper (QL=5), Iron (QL=0.1), Lead (QL=2), Manganese (QL=40), Total Chromium (QL=5), Zinc (QL=0.5), Mercury (QL=0.5)

## 10.4 Data Interpretation:

The Marine water quality of Deendayal Port Harbor waters at Kandla and Vadinar has been monitored for various physico-chemical and biological parameters during the high tide at sampling time.

- The parameter **pH** was observed in the range of 7.74-8.04, with the average pH as 7.83 for the locations of Kandla, whereas for the locations of Vadinar, pH was observed in the range of 8.07-8.11, with the average pH as 8.09.
- The **Color** was observed in the range of 9-15 Hazen, with the average color as 11.1 Hazen for the locations of Kandla, whereas for the locations of Vadinar, color was observed in the range of 4-5 Hazen, with the average color as 4.5 Hazen.
- The **Density** of marine water for the locations of Kandla and Vadinar was observed to vary from 1.021-1.022 Kg/$m^3$.
- **Turbidity** for all locations of Kandla was observed >50 NTU for all the locations. Whereas for the locations of Vadinar, lower values of turbidity were observed. Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble color organic compounds, plankton and microscopic organisms. Turbidity affects the amount of light penetrating to the plants for photosynthesis.
- The parameter **Electrical conductivity (EC)** was observed in the range of 54179-61528 µS/cm, with the average EC as 58014.83 µS/cm for the locations of Kandla, whereas for the locations of Vadinar, EC was observed in the range of 52119-55871 µS/cm, with the average EC as 53995 µS/cm.

- **Total Dissolved Solids (TDS**) values in the studied area during high Tide varied between 38072-41930 mg/L at DPA Kandla and 34892-34950 mg/L at Vadinar with the average value as 39349.5 mg/L and 34921 mg/L respectively for Kandla and Vadinar.
- **Total Suspended Solids (TSS**) values in the studied area during high Tide varied between 124-852 mg/L at DPA Kandla and 151-220 mg/L at Vadinar, with the average value as 479.33 mg/L and 185.5 mg/L respectively for Kandla and Vadinar.
- **Chemical Oxygen Demand (COD)** values in the studied area varied between 71-81 mg/L at DPA Kandla and 74-75 mg/L at Vadinar, with the average value as 76.5 mg/L and 74.5 mg/L respectively for Kandla and Vadinar.
- **Dissolved Oxygen (DO)** level in the studied area during high Tide varied between 5.4-5.7 mg/L at DPA Kandla and 7.3-7.4 mg/L at Vadinar. The value of DO was found to exceed the minimum concentration of 3.0 mg/L for majority of the locations, which represents that the marine water quality is good and hence suitable for the aquatic species.
- The parameters BOD, Oil & Grease, Nitrate, Nitrite, Hexavalent Chromium, Arsenic, Cadmium, Zinc and Mercury were observed to have concentrations "Below the Quantification Limits (BQL)" for all the locations of Kandla and Vadinar.
- **Sulphate** concentration in the studied area during high Tide varied between 2433.35-3415.54 mg/L at DPA Kandla and 2212.35-2441.56 mg/L at Vadinar.
- The concentration of **Phosphate** in the studied area during high Tide varied between 0.09-1.46 mg/L at DPA Kandla, while at Vadinar, the concentration of Phosphate was observed to range from 0.64-1.43 mg/L at Vadinar.
- The concentration of **Potassium** in the studied area during high Tide varied between 347.34-442.63 mg/L at DPA Kandla and 321.10-351.13 mg/L at Vadinar, with the average value as 403.41 mg/L and 336.11 mg/L respectively for Kandla and Vadinar.
- The concentration of **Sodium** was detected to be >10,000 mg/L for the locations of Kandla and Vadinar.
- Under the study, the parameters BOD, Oil and Grease, Hexavalent and Total Chromium, Nitrate, Nitrite, Arsenic, Lead, Manganese, Cadmium, Zinc and Mercury were found to have concentrations "Below the detection limit" for both the locations of Kandla and Vadinar.
- **Total Coliforms (TC)** at Kandla were observed to be within the range of 10-900 MPN/100 ml. On the contrary, the TC were observed "Below the detection limit" for the months at Vadinar.
- **Floating Material (Oil grease scum, petroleum products)** was observed to be "Below the quantification limit" all the locations of Kandla and Vadinar.

## 10.5 Conclusion

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

## 10.6 Measures against adverse effects

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

# CHAPTER 11: MARINE SEDIMENT QUALITY MONITORING

## 11.1 Marine Sediment Monitoring:

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

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

As defined in the scope by Deendayal Port Authority (DPA), the Marine Sediment sampling is required to be carried out once in a month at total eight locations, i.e., six at Kandla and two at Vadinar. The sampling of the Marine Sediment is carried out using the Van Veen Grab Sampler of the make Holy Scientific Instruments Pvt. Ltd. The Van Veen Grab sampler is an instrument to sample (disturbed) sediment up to a depth of 20-30 cm into the sea bed. While letting the instrument down on the seafloor, sediment can be extracted. The details of the locations of Marine Sediment to be monitored under the study are mentioned in **Table 38** as follows:

**Table 38: Details of the sampling locations for Marine water**

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

The map depicting the locations of Marine Sediment sampling in Kandla and Vadinar have been mentioned in **Map 21 and 22** as follows:


**Figure 21: Location Map of Marine Sediment Monitoring at Kandla**


**Figure 22: Locations Map of Marine Sediment Monitoring at Vadinar**

The list of parameters to be monitored under the projects for the Marine Sediment sampling been mentioned in **Table 39** as follows:

**Table 39: List of parameters to be monitored for Sediments at Kandla and Vadinar**

| Sr. No. | Parameters | Units | Reference method | Instruments |
|---|---|---|---|---|
| 1. | Texture | | Methods Manual Soil Testing in India January 2011,01 | Hydrometer |
| 2. | Organic Matter | % | Methods Manual Soil Testing in India January, 2011, 09. Volumetric method (Walkley and Black, 1934) | Titration apparatus |
| 3. | Inorganic Phosphates | mg/Kg | Practical Manual Chemical Analysis of Soil and Plant Samples, ICAR-Indian Institute of Pulses Research 2017 | UV- Visible Spectrophotometer |
| 4. | Silica | mg/Kg | EPA METHOD 6010 C & IS: 3025 (Part 35) – 1888, part B | |
| 5. | Phosphate | mg/Kg | EPA Method 365.1 | |
| 6. | Sulphate as SO4- (Available) | mg/Kg | IS: 2720 (Part 27) - 1977 | |
| 7. | Nitrite | mg/Kg | ISO 14256:2005 | |
| 8. | Nitrate | mg/Kg | Methods Manual Soil Testing in India January, 2011, 12 | |
| 9. | Calcium as Ca | mg/Kg | Methods Manual Soil Testing in India January 2011, 16. | Titration Apparatus |
| 10. | Magnesium as Mg | mg/Kg | Method Manual Soil Testing in India January 2011 | |
| 11. | Sodium | mg/Kg | EPA Method 3051A | Flame Photometer |
| 12. | Potassium | mg/Kg | Methods Manual Soil Testing in India January, 2011 | |
| 13. | Aluminium | mg/Kg | EPA Method 3051A | ICP-OES |
| 14. | Chromium | mg/Kg | | |
| 15. | Nickel | mg/Kg | | |
| 16. | Zinc | mg/Kg | | |
| 17. | Cadmium | mg/Kg | | |
| 18. | Lead | mg/Kg | | |
| 19. | Arsenic | mg/Kg | | |
| 20. | Mercury | mg/Kg | | |

## 11.2 Result and Discussion

The quality of Marine Sediment samples collected from the locations of Kandla and Vadinar has been summarized in the **Table 40.**

**Table 40: Summarized Results of Marine Sediment Quality**

| Sr. No. | Parameters | Unit | Kandla | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MS-1 | MS-2 | MS-3 | MS-4 | MS-5 | MS-6 | MS-7 | MS-8 |
| 1. | Inorganic Phosphate | kg/ Hectare | 16.85 | 14.37 | 11.55 | 18.94 | 14.25 | 17.34 | 14.55 | 18.51 |
| 2. | Phosphate | mg/Kg | 3247.85 | 1497.25 | 2571.43 | 2671.98 | 3741.91 | 3541.28 | 2357.68 | 3217.54 |
| 3. | Organic Matter | mg/Kg | 0.32 | 1.60 | 0.50 | 1.21 | 0.94 | 1.14 | 0.26 | 0.38 |
| 4. | Sulphate as $SO^{4-}$ | mg/Kg | 759 | 849 | 555 | 496 | 768 | 732 | 296 | 179.43 |
| 5. | Calcium as Ca | mg/Kg | 2657 | 1259 | 962 | 1102 | 1089 | 1162 | 2585 | 2463 |
| 6. | Magnesium as Mg | mg/Kg | 1259 | 924 | 764 | 987 | 1032 | 953 | 1348 | 1167 |
| 7. | Silica | g/Kg | 498.5 | 465.12 | 571.51 | 549.6 | 531.88 | 487.2 | 379.45 | 492.5 |
| 8. | Nitrite | mg/Kg | 0.75 | 0.18 | 0.15 | 0.19 | 0.16 | 0.13 | 0.11 | 0.12 |
| 9. | Nitrate | mg/Kg | 19.75 | 20.98 | 10.22 | 21.64 | 9.67 | 15.34 | 25.33 | 24.82 |
| 10. | Sodium | mg/Kg | 3410 | 3670 | 4432 | 3940 | 3725 | 2394 | 9082 | 8854 |
| 11. | Potassium | mg/Kg | 241 | 276 | 264 | 294 | 322 | 394 | 1082 | 1028 |
| 12. | Aluminium | mg/Kg | 3517.25 | 4834.50 | 4317.46 | 4552.39 | 3751.85 | 4579.21 | 4138.27 | 4528.35 |
| 13. | Chromium | mg/Kg | 56.17 | 32.74 | 42.38 | 53.30 | 51.33 | 36.71 | 45.20 | 41.85 |
| 14. | Nickel | mg/Kg | 16.80 | 11.54 | 18.94 | 25.60 | 24.00 | 12.80 | 14.70 | 20.50 |
| 15. | Zinc | mg/Kg | 38.22 | 32.11 | 48.20 | 34.98 | 19.54 | 32.00 | 42.80 | 40.30 |
| 16. | Cadmium | mg/Kg | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 17. | Lead | mg/Kg | 6.1 | 5.84 | 4.25 | 5.85 | 5.71 | 4.24 | 6.88 | 7.41 |
| 18. | Arsenic | mg/Kg | BQL | BQL | BQL | BQL | BQL | BQL | 2.74 | 5.17 |
| 19. | Mercury | mg/Kg | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |
| 20. | Texture | | Sandy loam | Sandy loam | Sandy loam | Sandy loam | Sandy loam | Sandy loam | Sandy loam | Sandy loam |

## 11.3 Data Interpretation

- **Inorganic Phosphate** was observed in the range of 11.55 to 18.94 Kg/Ha for Kandla and 11.85 to 15.84 Kg/Ha for Vadinar.
- **Phosphate** was observed in the range of 1497.25 to 3741.91 mg/Kg for Kandla and 2357.68 to 3217.54 mg/Kg for Vadinar.
- **Organic Matter** was observed in the range of 0.32 to 1.6 % for Kandla and 0.26 to 0.38 % for Vadinar.
- **Sulphate** was observed in the range of 496 to 849 mg/Kg for Kandla and 179.43 to 296 mg/Kg for Vadinar.
- **Calcium** was observed in the range of 962 to 2657 mg/Kg for Kandla and 2463 to 2585 mg/Kg for Vadinar.
- **Magnesium** was observed in the range of 764 to 1259 mg/Kg for Kandla and 1167 to 1348 mg/Kg for Vadinar.
- **Nitrate** was observed in the range of 9.67 to 21.64 mg/Kg for Kandla and 24.82 to 25.33 mg/Kg for Vadinar.
- **Nitrite** was observed in the range of 0.13 to 0.75 mg/Kg for Kandla and 0.11 to 0.12 for Vadinar.

- **Sodium** was observed in the range of 2394 to 4432 for Kandla and 8854 to 9082 mg/Kg for Vadinar.
- **Silica** was observed in the range of 465.12 to 571.51 mg/Kg for Kandla and 379.45 to 492.5 mg/Kg.
- **Potassium** was observed in the range of 241 to 394 mg/Kg for Kandla and 1028 to 1082 mg/Kg for Vadinar.
- **Aluminium** was observed in the range of 3517.25 to 4834.5 mg/Kg for Kandla and 4138.27 to 4528.35 mg/Kg for Vadinar.
- **Mercury** was observed below the detection limit was limit for Kandla and Vadinar.
- Texture was observed to be "**Sandy Loamy**" in both Kandla and Vadinar.

**Heavy Metals**

The sediment quality of Kandla and Vadinar has been compared with respect to the Average Standard guideline applicable for heavy metals in marine sediment specified by EPA have been mentioned in **Table 41**.

**Table 41: Standard Guidelines applicable for heavy metals in sediments**

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

*(Source: G Perin et al. 1997)*

The details of the said comparison have been mentioned in the **Table 42** as follows:

**Table 42: Comparison of Heavy metals with Standard value in marine sediment**

| Sr. No. | Parameters | Kandla | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|
| | | **MS-1** | **MS-2** | **MS-3** | **MS-4** | **MS-5** | **MS-6** | **MS-7** | **MS-8** |
| 1. | Arsenic | BQL | BQL | BQL | BQL | BQL | BQL | 2.74 | 5.17 |
| 2. | Copper | 5.6 | 11.4 | 4.2 | 6.8 | 12 | 8.9 | 5.5 | 8.2 |
| 3. | Chromium | 56.17 | 32.74 | 42.38 | 53.30 | 51.33 | 36.71 | 45.20 | 41.85 |
| 4. | Nickel | 16.80 | 11.54 | 18.94 | 25.60 | 24.00 | 12.80 | 14.70 | 20.50 |
| 5. | Lead | 6.1 | 5.84 | 4.25 | 5.85 | 5.71 | 4.24 | 6.88 | 7.41 |
| 6. | Zinc | 38.22 | 32.11 | 48.20 | 34.98 | 19.54 | 32.00 | 42.80 | 40.30 |
| 7. | Cadmium | BQL | BQL | BQL | BQL | BQL | BQL | BQL | BQL |

- **Arsenic** was observed below the detection limit for Kandla in both the monitoring period of April and May. While for Vadinar 2.74 to 5.17 mg/Kg range in the month of

April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Arsenic in range of 3-8 mg/Kg which indicate the moderately polluted status of Sediment for both the April and May, 2023.

- **Copper** was observed in the range of 4.2 to 12 mg/Kg for Kandla and 5.5 to 8.2 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Copper <25 mg/Kg which indicate the non-polluted status of Sediment for both the April and May, 2023.
- **Chromium** was observed in range of 32.74 to 56.17 mg/Kg for Kandla and 41.85 to 45.2 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Chromium in range of 25-75 mg/Kg which indicates that the sediment is moderately polluted for both April and May, 2023.
- **Nickel** was observed in the range of 11.54 to 25.60 mg/Kg for Kandla and 14.17-20.50 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Nickel in range of 20-50 mg/Kg which indicate the moderately polluted Sediment for both the April and May, 2023.
- **Lead** was observed in the range of 4.24 to 6.10 mg/Kg for Kandla and 6.88 to 7.41 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Lead <40 mg/Kg which indicate the non-polluted status of Sediment for both the April and May, 2023.
- **Zinc** was observed in the range of 19.54 to 48.20 mg/Kg for Kandla and 40.30 to 42.8 mg/Kg for Vadinar for the month of April. The Sediment quality in both the monitoring period at Kandla and Vadinar show the concentration of Zinc <90 mg/Kg which indicate the non-polluted status of Sediment for both the April and May, 2023.
- **Cadmium** was observed below the detection limit was limit for Kandla and Vadinar in both April and May month, which indicates that the sediment is non polluted.

## 11.4 Conclusion:

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

# CHAPTER 12: MARINE ECOLOGY MONITORING

## 2.4 Marine Ecological Monitoring

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

As defined in the scope by Deendayal Port Authority (DPA), the Marine Ecological Monitoring is required to be carried out once a month specifically at eight locations, six at Kandla and two at Vadinar. The sampling of the Benthic Invertebrates has been carried out with the help of D-frame nets, whereas the sampling of zooplankton and phytoplankton has been carried out with the help of Plankton Nets (60 micron and 20 micron). The details of the locations of Marine Ecological Monitoring have been mentioned in **Table 43** as follows:

**Table 43: Details of the sampling locations for Marine Ecological**

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

The map depicting the locations of Marine Ecological monitoring in Kandla and Vadinar have been mentioned in **Map 23 and 24** as follows:


**Figure 23: Locations Map of Marine Ecological Monitoring at Kandla**

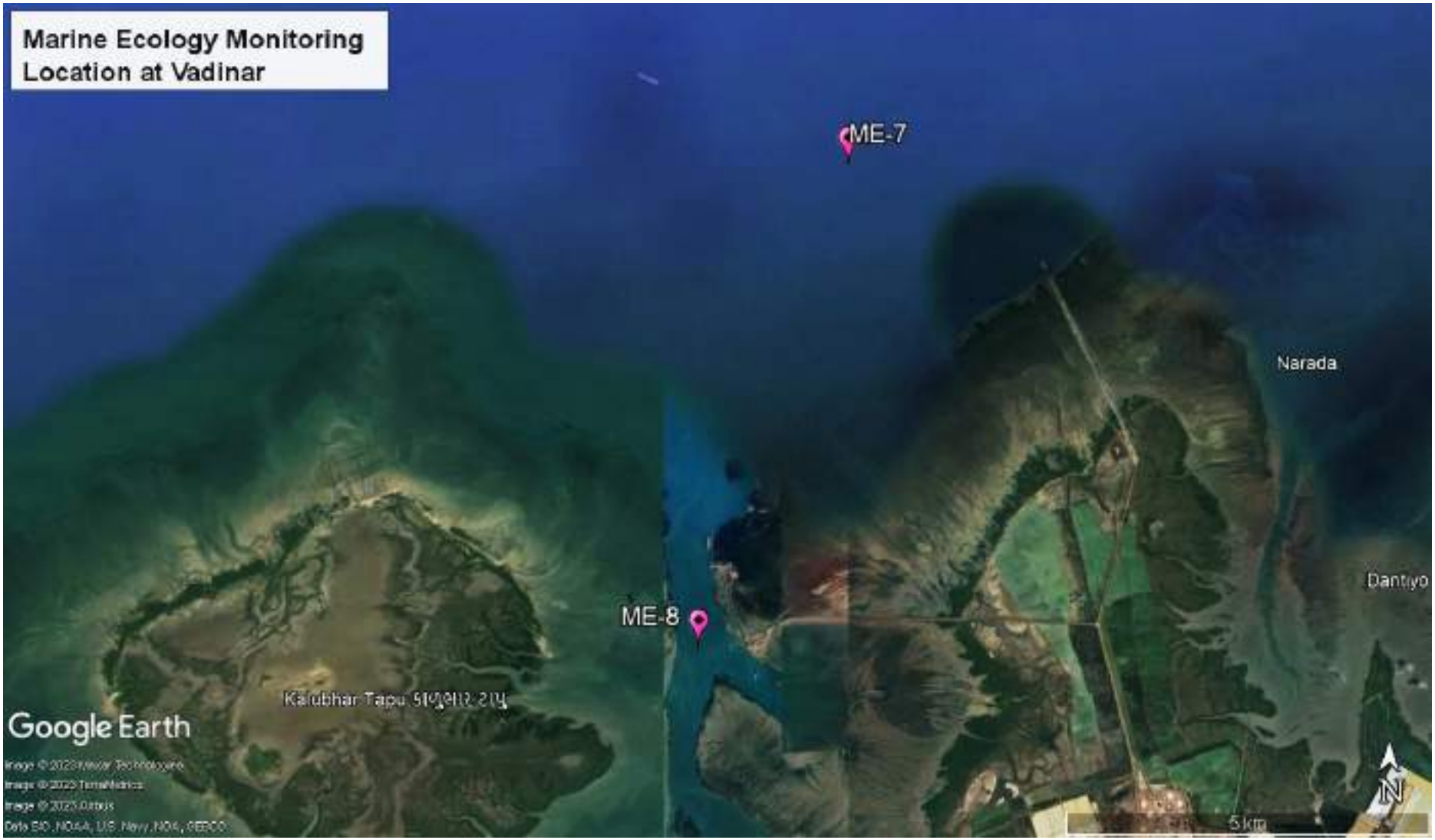



**Figure 24: Locations Map of Marine Ecological Monitoring at Vadinar**

The various parameters to be monitored under the study for Marine Ecological Monitoring are mentioned in **Table 44** as follows:

**Table 44: List of parameters to be monitored for Marine Ecological Monitoring**

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

## 2.5 Sampling Methodology

**Processing for chlorophyll estimation:**

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

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

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

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

**Diversity Index**

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

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

1. **Simpson's index:**

A reasonably high level of dominance by one or a small number of species is indicated by the range of **0.89 to 0.91**. The general health and stability of the ecosystem may be impacted by this dominance. Community disturbances or modifications that affect the dominant species may be more likely to have an impact. The dominating species determined by the Simpson's index can have big consequences on how the community is organised and how ecological interactions take place.

The formula for calculating D is presented as:

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

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

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

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

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

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

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

3. **Margalef's diversity index:**

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

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

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

Where N = total number of individuals collected
S = No. of taxa or species or genera

4. **Berger-Parker index:**

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

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

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

Where,

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

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

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

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

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

6. **Evenness index–**

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

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

Where,

H= Shannon value

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

## 2.6 Result and Discussion and Conclusion

The details of Marine Ecological Monitoring conducted for the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 45.**

**Table 45: Summarized Results of Biomass, Net Primary Productivity (NPP), Gross Primary Productivity (GPP), Pheophytin and Chlorophyll**

| Sr. No. | Parameters | Units | Kandla | | | | | | Vadinar | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
| 1. | Biomass | mg/l | 78 | 81 | 111 | 88 | 85 | 91 | 26 | 32 |
| 2. | Net Primary Productivity | mg/L/hr | 7.21 | 8.25 | 7.33 | 8.87 | 8.32 | 7.12 | 6.52 | 7.64 |
| 3. | Gross Primary Productivity | mg/L/hr | 8.55 | 7.12 | 8.32 | 8.71 | 6.45 | 7.13 | 6.94 | 5.74 |
| 4. | Pheophytin | mg/m$^3$ | NIL | 3 | NIL | NIL | NIL | 6 | 7.21 | 6.74 |
| 5. | Chlorophyll-a | mg/m$^3$ | 3.16 | BQL | 1.82 | BQL | 4.23 | BQL | 1.34 | BQL |
| 6. | Particulate Oxidizable Organic Carbon | mg/L | 0.32 | 0.16 | 0.56 | 0.25 | 0.35 | 0.29 | 0.36 | 0.39 |
| 7. | Secchi Depth | ft | 0.89 | 0.84 | 0.76 | 0.91 | 0.72 | 0.81 | 5.30 | 4.26 |

- **Biomass:**

  The value of **Biomass** reported from location ME-1 to ME-6 in range between 78-111 g/m$^2$ where highest biomass present in ME-3 (Near Coal Berth) and lowest biomass present in ME-1 (Near passenger Jetty 1) during sampling period. In Vadinar, the value of biomass was observed 26 g/m$^2$ at ME-7 (Near SPM), monitoring station and 32 g/m$^2$ in ME-8 (Near Vadinar Jetty).

- **Chlorophyll-a**

  In the sub surface water, the monitoring station reported the maximum **Chlorophyll-a** value at ME-5 (Nakti creek) i.e., 4.23 mg/m$^3$ and the value observed to be "Below the detection limit" at three locations (ME-2, ME-4 and ME-6) during the sampling. In the Vadinar, the value of chlorophyll-a was observed 1.34 mg/m$^3$ at ME-7 (Near SPM), monitoring station and ME-8 (Near Vadinar Jetty) recorded below the detection limit.

- **Pheophytin**
  The level of **Pheophytin** was detected or found nil in majority of the monitoring location in Kandla except for location ME-2 and 6 (Kandla and Nakti Creek) where it was recorded 3 and 6, respectively. While it was observed 7.21 and 6.74 in ME-7 (Near SPM) and ME-8 (Near Vadinar Jetty) respectively, in Vadinar.
- **Secchi Depth**
  In monitoring station of Kandla from ME-1 to ME-6 the level of **Secchi Depth** was observed between 0.72 to 0.91 ft whereas the value recorded in Near SPM (ME-7) is 5.30ft and in Near Vadinar Jetty is 4.26 ft.
- **Productivity (Net and Gross)**
  **Gross primary productivity (GPP)** is the rate at which organic matter is synthesised by producers per unit area and time (GPP). The amount of carbon fixed during photosynthesis by all producers in an ecosystem is referred to as gross primary productivity. The monitoring station reported **GPP** value in range between 6.45-8.71 mg/L/hr where the highest value recorded in Khori creek and lowest recorded at Nakti creek (near Tuna port) during sampling period. In the Vadinar, the value of **GPP** was observed 6.94 mg/L/hr at ME-7 (Near SPM) monitoring station and ME-8 (Near Vadinar Jetty) recoded 5.74 mg/L/hr.
  **Net primary productivity**, is the amount of fixed carbon that is not consumed by plants, and it is this remaining fixed carbon that is made available to various consumers in the ecosystem. The Net primary productivity of the monitoring location at Kandla from (ME-1 to ME-6) has been estimated to be between 7.12 to 8.87 mg/L/hr, while for Vadinar the value of NPP recorded 6.52 mg/L/hr and 7.64 mg/L/hr in ME-7 and ME-8 during the monitoring month.
- **Particulate Oxidisable Organic Carbon**
  For the month of April, the concentration of the Particulate oxidisable organic Carbon was observed to fall within the range of 0.16-0.35 mg/L at Kandla and 0.36-0.39 mg/L for Vadinar.
- **Ecological Diversity**
  **Phytoplankton:** For the evaluation of the Phytoplankton population in DPA Kandla and Vadinar within the immediate surroundings of the port, sampling was conducted between **mid-April to May**, 2023. Total 8 sampling locations were studied i.es. sampling locations (6 from Kandla and two from Vadinar). The details of variation in abundance and diversity in phytoplankton communities is mentioned in **Table 46**.

**Table 46: Phytoplankton variations in abundance and diversity in sub surface sampling stations**

| Genera | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
|---|---|---|---|---|---|---|---|---|
| *Bacillaria sp.* | 460 | 700 | 680 | 750 | 660 | 850 | 650 | 700 |
| *Biddulphia sp.* | 650 | 510 | - | 650 | - | - | 755 | 350 |
| *Chaetoceros sp.* | 350 | 765 | 680 | 530 | 755 | 550 | 800 | 480 |
| *Chlamydomonas sp.* | 150 | 560 | - | - | 380 | 860 | 420 | 545 |
| *Cyclotella sp.* | - | - | 800 | 540 | 650 | 880 | - | 390 |
| *Ditylum sp* | 900 | 780 | 390 | 685 | - | 350 | 450 | 600 |

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

The phytoplankton community of the sub surface water in the Kandla and Vadinar was represented by, Diatoms, blue green algae and Cynobacteria. Diatoms were represented by 14 genera, Blue green algae were represented by 1 genera and Cynobacteria were represented by 2 genera during the sampling period.

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from 6800-7220 units/L, while for Vadinar its density of phytoplankton observed 6535 units/L at ME-7 and 8360 units/L at ME-8. During the sampling, phytoplankton communities were dominated by *Cyclotella sp. and Navicula sp.* in Kandla, while *Nitzschia sp.* in Vadinar.

**Table 47: Species richness Index and Diversity Index in Phytoplankton**

| Indices | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
|---|---|---|---|---|---|---|---|---|
| Taxa S | 12 | 12 | 14 | 13 | 16 | 13 | 12 | 14 |
| Individuals | 7450 | 8745 | 9155 | 9100 | 10310 | 7990 | 8025 | 9650 |
| Shannon diversity | 2.49 | 2.68 | 2.46 | 2.53 | 2.29 | 2.68 | 2.61 | 2.52 |
| Simpson 1-D | 0.91 | 0.93 | 0.91 | 0.92 | 0.90 | 0.93 | 0.92 | 0.98 |
| Species Evenness | 0.97 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 |
| Margalef richness | 1.34 | 1.53 | 1.23 | 1.34 | 1.02 | 1.52 | 1.43 | 1.34 |
| Berger-Parker | 0.12 | 0.09 | 0.13 | 0.12 | 0.13 | 0.09 | 0.10 | 0.11 |
| Relative abundance | 0.16 | 0.16 | 0.16 | 0.17 | 0.15 | 0.15 | 0.16 | 0.17 |

- **Shannon-Wiener's Index (H)** of phytoplankton communities at the sampling stations was in the range of 2.29-2.68 between selected sampling stations from ME-1 to ME-6 with an average value of 2.52 at Kandla creek and nearby creeks which indicate the higher and stable diversity. Shannon-Wiener's Index (H) of phytoplankton communities in the sampling stations was in the range of 2.52–2.61 between selected sampling stations with an average value of 2.56 at Vadinar. The apportionment of the numbers of individuals

among the species observed higher in Nakti Creek in Kandla and Near Vadinar Jetty (Vadinar).

- In the month of **April, Margalef's diversity index** (Species Richness) of phytoplankton communities in the Kandla and nearby creeks sampling stations was varying from 1.02-1.53 with an average of 1.33 during the sampling. While for Vadinar Margalef's diversity index (Species Richness) of phytoplankton communities observed 1.43 at ME-7 and 1.34 at ME-8 with an average value of 1.38.
- **Simpson diversity index (1-D)** of phytoplankton communities was ranged between 0.90-0.93 at Kandla creek and nearby creeks, with an average of 0.91 in studied location. Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was 0.92 at ME-7 and 0.98 at ME-8 with an average of 0.92. Both the Monitoring station of Kandla and Vadinar shows a good diversity of phytoplankton communities.
- **Berger-Parker Index (d)** of phytoplankton communities in the sampling stations was in the range of 0.09-0.13 between selected sampling stations from ME-1 to ME-6 with an average value of 0.11 at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of 0.10–0.11 with an average value of 0.11 All the monitoring station signifies a low diversity with an even distribution among the different species.
- **Relative Abundance** of phytoplankton communities in the sampling stations was in the range of 0.15-0.17 between selected sampling stations from ME-1 to ME-6 with an average value of 0.15 at Kandla creek and nearby creeks. Relative Abundance of phytoplankton communities in the sampling stations was in the range of 0.16–0.17 with an average value of 0.17 at Vadinar. The average relative abundance is found in range of 0.15, thus the studied species can be stated as neither highly dominant nor rare.
- The **Species Evenness** is observed in the range of 0.99 to 1 for all the eight-monitoring station of Kandla and Vadinar, indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species. The details of variation in abundance and diversity in zooplankton communities is mentioned in **Table 48**.

**Table 48: Zooplankton variations in abundance and diversity in sub surface sampling stations**

| Genera | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
|---|---|---|---|---|---|---|---|---|
| *Acartia sp.* | - | 3 | 1 | 4 | 3 | 1 | 2 | |
| *Acrocalanus* | 1 | 2 | 7 | 4 | 1 | 1 | 3 | 5 |
| *Amoeba* | 6 | 1 | | 3 | 6 | 2 | 4 | 1 |
| *Brachionus sp.* | 2 | 4 | 2 | 1 | | 8 | 5 | - |
| *Calanus sp.* | 1 | 1 | - | 3 | - | 2 | 2 | 2 |
| *Cladocera sp.* | 1 | - | - | 2 | 1 | 1 | 2 | 3 |
| *Copepod larvae* | 3 | 8 | 5 | 6 | 5 | 3 | 10 | 3 |
| *Cyclopoida* | 2 | 4 | 1 | 3 | 2 | - | 1 | 1 |
| *Diaptomus sp.* | 4 | 1 | 3 | 1 | 10 | 1 | 1 | 3 |
| *Eucalanus sp.* | 5 | - | 1 | 4 | 4 | 8 | 7 | 9 |
| *Mysis sp.* | - | 11 | 8 | 4 | - | 2 | 7 | - |
| *Oithona sp.* | 1 | 2 | 5 | 2 | 1 | 2 | 3 | 9 |

| Genera | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
|---|---|---|---|---|---|---|---|---|
| *Paracalanus sp.* | 12 | 10 | 13 | 18 | 15 | 15 | 20 | 17 |
| **Density Unit/L** | **38** | **47** | **46** | **55** | **48** | **46** | **66** | **53** |
| **No. of genera** | **11** | **11** | **10** | **13** | **10** | **12** | **12** | **10** |

A total of 13 groups/taxa of zooplankton were recorded in Kandla and Vadinar during the study period which mainly constituted by copepods, branchiopoda, monogononata, fish and shrimp larval forms. Copepods had the largest representation at all stations from (ME-1 to ME-8). The density of Zooplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from 67-187 units/L, while for Vadinar its density of phytoplankton observed 198 units/L at ME-7 and 133 units/L at ME-8. During the sampling, zooplankton communities were dominated by *Mysis sp.* in Kandla, while *Paracalanus sp.* in both the monitoring location of Kandla and Vadinar.

**Table 49: Species richness Index and Diversity Index in Zooplankton**

| Indices | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
|---|---|---|---|---|---|---|---|---|
| Taxa S | 11 | 11 | 10 | 13 | 10 | 12 | 12 | 10 |
| Individuals | 38 | 47 | 46 | 55 | 48 | 46 | 66 | 53 |
| Shannon diversity | 2.05 | 2.08 | 1.99 | 2.23 | 1.94 | 2.03 | 2.15 | 1.95 |
| Simpson (1-D) | 0.85 | 0.87 | 0.85 | 0.86 | 0.84 | 0.84 | 0.86 | 0.83 |
| Species Evenness | 0.85 | 0.87 | 0.86 | 0.87 | 0.84 | 0.82 | 0.87 | 0.85 |
| Margalef | 2.75 | 2.6 | 2.35 | 2.99 | 2.32 | 2.87 | 2.63 | 2.27 |
| Berger-Parker | 0.32 | 0.23 | 0.28 | 0.33 | 0.31 | 0.33 | 0.3 | 0.32 |
| Relative abundance | 28.95 | 23.4 | 21.74 | 23.64 | 20.83 | 26.09 | 18.18 | 18.87 |

- **Shannon-Wiener's Index (H)** of Zooplankton communities, at sampling stations was in the range of 1.94-2.23 between selected sampling stations from ME-1 to ME-6 with an average value of 2.05 at Kandla creek and nearby creeks**.** Shannon-Wiener's Index (H) of zooplankton communities in the sampling stations was in the range of 1.95-2.15 between selected sampling stations with an average value of 2.05 at Vadinar. The diversity of zooplankton species was observed to be less in both the monitoring location of Kandla and Vadinar.
- **Margalef's diversity index** (Species Richness) of zooplankton communities in the Kandla and nearby creeks sampling stations was varying from 2.32-2.99 with an average of 2.64 during the sampling. While for Vadinar Margalef's diversity index (Species Richness) S of zooplankton communities observed 2.63 at ME-7 and 2.27 at ME-8 with an average of 2.45. The higher value was observed in Khori creek (ME-4), Kandla and in ME-7 (near SPM), Vadinar.
- **Simpson diversity index (1-D)** of zooplankton communities was ranged between 0.84-0.87 at all sampling stations in Kandla creek and nearby creeks, with an average of 0.85. While for Vadinar, Simpson diversity index (1-D) of zooplankton communities was 0.86 at ME-7 and 0.83 at ME-8 with an average of 0.84.

- **Berger-Parker Index (d)** of zooplankton communities in the sampling stations was in the range of 0.23-0.33 between selected sampling stations from ME-1 to ME-6 with an average value of 0.3 at Kandla creek and nearby creeks. Berger-Parker Index (d) of zooplankton communities in Vadinar sampling stations was found in range of 0.3–0.32 with an average value of 0.31. All the monitoring station signifies a low diversity with an even distribution among the different species.
- **Relative Abundance** of zooplankton communities at sampling stations was in the range of 20.83-28.95 between selected sampling stations from ME-1 to ME-6 with an average value of 24.10 at Kandla creek and nearby creeks. Relative Abundance of zooplankton communities in the sampling stations was in the range of 18.18–18.87 with an average value of 18.52 at Vadinar.
- The **Species Evenness** is observed in the range of 0.82 to 0.87 for all the eight-monitoring station of Kandla and Vadinar, the highest value recorded in ME-2,4&7 (Kandla & Khori Creek, near SPM), Kandla & Vadinar and the lowest value found in ME-6 (Nakti Creek).

**Table 50: Benthic Fauna variations in abundance and diversity in sub surface sampling stations at Kandla and Vadinar**

| Genera | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
|---|---|---|---|---|---|---|---|---|
| *Diapatra sp.* | 1 | 2 | 1 | 6 | 2 | 4 | 1 | 3 |
| *Mollusca sp.* | 3 | 1 | 4 | 3 | 1 | - | 1 | - |
| *Odonata sp.* | 4 | 1 | 1 | - | 1 | 3 | 4 | 5 |
| *Coleoptera sp.* | 1 | 2 | 2 | 3 | - | 1 | 3 | 1 |
| *Crustacea sp.* | - | 1 | 3 | 5 | 1 | 3 | 1 | - |
| *Hemiptera sp.* | 3 | 6 | - | 2 | 2 | 1 | - | 1 |
| *Tricoptera sp.* | 3 | 6 | 4 | - | 2 | 5 | 2 | 1 |
| **Density-Units/l** | **15** | **19** | **15** | **19** | **9** | **17** | **12** | **11** |
| **No of genera** | **6** | **7** | **6** | **5** | **6** | **6** | **6** | **5** |

Few Benthic organisms were observed in the collected sample by using the Van-Veen grabs during the sampling conducted in the month of April and May from DPA Kandla and Vadinar. Majority of the species were found under the Macro-benthic organisms during the sampling period were represented by Diapatra sp., Mollusca sp., Odonata sp., Crustacea sp. Etc. The density of benthic fauna was varying from 10-14- Unit/L. The dominating benthic communities at Kandla Creek and nearby creek (Nakti and Khori creek) were represented Diapatra sp. While lowest number of benthic species was represented by Hemiptera sp. Their population was found as 16 Unit /L at Near SPM and 5 Unit/L near Vadinar Jetty area during both the sampling period.

**Table 51: Species richness Index and Diversity Index in Benthic Organism**

| Indices | ME-1 | ME-2 | ME-3 | ME-4 | ME-5 | ME-6 | ME-7 | ME-8 |
|---|---|---|---|---|---|---|---|---|
| Taxa S | 6 | 7 | 6 | 5 | 6 | 6 | 6 | 5 |
| Individuals | 15 | 19 | 15 | 19 | 9 | 17 | 12 | 11 |
| Shannon diversity | 1.68 | 1.67 | 1.66 | 1.54 | 1.74 | 1.65 | 1.63 | 1.37 |
| Simpson 1-D | 0.86 | 0.81 | 0.85 | 0.81 | 0.92 | 0.84 | 0.85 | 0.76 |
| Species Evenness | 0.94 | 0.86 | 0.93 | 0.96 | 0.97 | 0.92 | 0.91 | 0.85 |
| Margalef | 1.85 | 2.04 | 1.85 | 1.36 | 2.28 | 1.76 | 2.01 | 1.67 |
| Berger-Parker | 0.27 | 0.32 | 0.27 | 0.32 | 0.22 | 0.29 | 0.33 | 0.45 |
| Relative abundance | 40 | 36.84 | 40 | 26.32 | 66.67 | 35.29 | 50 | 45.45 |

- **Shannon-Wiener's Index (H)** of Benthic organisms at sampling stations was in the range of 1.54-1.74 between selected sampling stations from ME-1 to ME-6 with an average value of 1.65 at Kandla creek and nearby creeks**.** Shannon-Wiener's Index (H) of Benthic organisms in the sampling stations was in the range of 1.37–1.63 between selected sampling stations with an average value of 1.5 at Vadinar. Diversity of zooplankton species was observed to be less in both the monitoring location of Kandla and Vadinar.
- **Margalef's diversity index** (Species Richness) of Benthic organisms in the Kandla and nearby creeks sampling stations was varying from 1.36-2.28 with an average of 1.85 during the sampling period. While for Vadinar Margalef's diversity index (Species Richness) of Benthic organisms observed 2.01 at ME-7 and 1.67 at ME-8 with an average of 1.84.
- **Simpson diversity index (1-D)** of Benthic organisms was ranged between 0.81-0.92 at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.84. The highest value was observed at ME-5. While for Vadinar Simpson diversity index (1-D) of benthic organism was 0.85 at ME-7 and 0.76 at ME-8 with an average of 0.80 during the sampling period.
- **Berger-Parker Index (d)** of Benthic organisms in the sampling stations was in the range of 0.22-0.32 between selected sampling stations from ME-1 to ME-6 with an average value of 0.28 at Kandla creek and nearby creeks. Berger-Parker Index (d) of Benthic organisms in Vadinar sampling stations was found in range of 0.33–0.45 with an average value of 0.39. Thus, all the eight-monitoring station of Kandla and Vadinar signifies a moderate diversity with an even distribution among the different species.
- **Relative Abundance** of benthic organism at sampling stations was in the range of 26.32-66.67 between selected sampling stations from ME-1 to ME-6 with an average value of 40.85 at Kandla creek and nearby creeks. Relative Abundance of phytoplankton communities in the sampling stations was in the range of 45.45–50 with an average value of 47.73 at Vadinar. The average relative abundance is found in range of 0.15, thus the studied species can be stated as neither highly dominant nor rare.
- The **Species Evenness** is observed in the range of 0.85 to 0.97 for all the eight-monitoring station, with an average value of 0.91 at Kandla and Vadinar indicate varying degrees of evenness or unevenness in the distribution of individuals among the studied species.

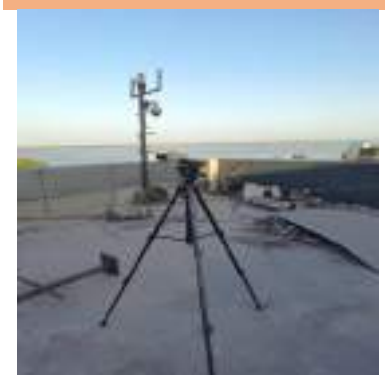
**Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla and Vadinar for April-May 2023**

## Ambient Air Monitoring at Kandla and Vadinar






## Noise Monitoring at Kandla and Vadinar




## Sewage Treatment Plant Monitoring at Kandla and Vadinar



## Drinking Water Monitoring at Kandla and Vadinar






## Soil Monitoring at Kandla and Vadinar



## Phytoplankton, Zooplankton and Bio-monitoring




## Marine Water and Sediment Monitoring

Source : GEMI

# Gujarat Environment Management Institute (GEMI)

**(An Autonomous Institute of Government of Gujarat)**

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


**Head Office**

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

Sector-25, Gandhinagar-382024

**Laboratory**

Plot No. B-64, G.I.D.C. Electronic Estate,

Opp. I.P.R., Sector-25, Gandhinagar-382025

Tel: (+91) 79-23240964 (O), T: (+91) 79-23287758 (Lab), F: (+91) 79-23240965

E-mail: info-gemi@gujarat.gov.in | Website: www.gemi.gujarat.gov.in


*"We Provide Environmental Solutions"*