DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

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EG/WK/4751/Part (Comp. 1)/ 08

Dated:21 /01/2025

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

Sub: "Development of 7 Integrated facilities (Stage I) within the existing Kandla Port Trust limit at District Kutch (Gujarat) by M/s Kandla Port Trust Limited" - Environmental & CRZ Clearance - **Pointwise Compliances of the conditions stipulated in the EC&CRZ Clearance and Monitoring Report in Datasheet reg.**

Ref.:
1) MoEF&CC, GoI letter F. No. 11-82/2011-IA.III dated 19/12/2016
2) Ministry's letter vide F.No. 6-1/2017 (ENV) dated 1/5/2017.
3) KPT letter no. EG/WK/4751/Part (Compliance)/77 dated 3/6/2017.
4) DPT letter no. EG/WK/4751/part(Compliance)/610 dated 13/12/2017-Submission of Six Monthly Compliance Report (June, 2017 to Nov., 2017).
5) DPT letter dated 14(21)/6/2018-Submission of Six Monthly Compliance Report (Dec, 2017 to May, 2018).
6) DPT letter dated 30(2)/3(4)/2019- Submission of Six Monthly Compliance Report (up to March, 2019).
7) DPT letter no. 14/11/2019- Submission of Compliance Report (up to October, 2019).
8) DPT letter dated 29/12/2020- Submission of Compliance Report (up to Nov., 2020).
9) DPT letter dated 07/10/2021- Submission of Compliance Report (up to May, 2021).
10) DPA letter dated 30/01/2023- Submission of Compliance Report (up to May, 2022).
11) DPA letter dated 20/04/2023- Submission of Compliance Report (up to Nov. 2022).
12) DPA letter dated 12/09/2023- Submission of Compliance Report (up to May, 2023).
13) DPA letter dated 20/2/2024- Submission of Compliance Report (up to Nov 2023).
14) DPA letter dated 25/7/2024- Submission of Compliance Report (up to May 2024).

Sir,

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

In this regard, it is to state that, Ministry of Environment, Forest and Climate Change (MoEF&CC), GoI vide F. No. 11-82/2011-IA.III dated 19/12/2016 has accorded Environmental and CRZ Clearance for the 7 project activities of Deendayal Port Authority.

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Subsequently, DPA vide above referred letter dated 3/6/2017 had submitted details/information (including point-wise compliance of stipulated conditions & duly filled in data sheet) asked by the Regional Office, MoEF&CC, GoI, Bhopal in connection with the EC & CRZ Clearance granted by the MoEF&CC, GoI dated 19/12/2016 for the subject mentioned above. Further, DPA vide above referred letters had submitted compliance report of stipulated conditions.

Now, as directed in above referred letter dated 1/5/2017 of the Regional Office, MoEF&CC, GoI, Bhopal, please find enclosed herewith compliance report of stipulated conditions mentioned in the EC & CRZ Clearance granted by the MoEF&CC, GoI dated 19/12/2016 **(Annexure 1)** & Monitoring Report in Data Sheet **(Annexure 2)** (for the period up June 2024 to September 2024) for kind information and record please.

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

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

Thanking You.

Yours faithfully,

Encl.: As above

21/1/25

Dy.CE & EMC(I/c)

Deendayal Port Authority

Copy along with point wise compliance of stipulated conditions, to:

1) Shri Amardeep Raju,
Scientist E, Ministry of Environment,
Forest and Climate Change,
& Member Secretary (EAC-Infra.1),
Indira Paryavaran Bhawan,
3rd Floor, Vayu Wing, Jor Bagh Road,
Aliganj,
New Delhi- 110 003;
E-mail:ad.raju@nic.in

2) Shri Prasoon Gargava,
Scientist E &Regional Director,
Central Pollution Control Board,
Parivesh Bhawan,
Opp. VMC Ward Office No.10,
Subhanpura,
Vadodara – 390 023.
Email Id.Prasoon.cpcb@nic.in

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

4) The Regional Officer,
Gujarat Pollution Control Board,
Regional Office (East Kutch)
Administrative Office Building,
Deendayal Port Authority,
Gandhidham 370201
Email Id. ro-gpcb-kute@gujarat.gov.in

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ANNEXURE 1
Point wise compliance Report

Annexure 1

CURRENT STATUS OF WORK (up to June - September, 2024)

Subject: Development of 7 integrated facilities (Stage I) within existing Deendayal Authority at Kandla.

Reference: Environmental and CRZ Clearance granted by MoEF&CC, GoI vide letter F. No. 11-82/2011-IA-III dated 19/12/2016.

Name of Project	Status
1. Development of oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode (jetty: 300m x 15m, approach 450 m X 10 m, back up area 5.5 HA, capacity – 3.39 MMTPA, capital dredging 1,73,660 m^3 maintenance dredging 1,56,294 m^3 (Estimated cost: 276.53 Cr.).	The Concession Agreement was executed between DPA and M/s KOTPL on 16/11/2013 to implement the project on Built, Transfer & Operate (BOT- PPP) Basis by M/s KOTPL. The award of concession was issued on 11/12/2020 to M/s KOTPL by DPA. **The Project is under construction phase.**
2. Multipurpose Cargo Terminal at Tekra off Tuna on BOT basis (T shape jetty 600m X 80 m Capacity 18MMTPA, back up area 101 Ha capital dredging 1,26,57,175 m3 maintenance dredging 18,98,576. 25 m^3 Estimated cost: 1686.66 Cr.	The Board of DPA approved the Feasibility Report in its meeting on 19.02.2021. The MoPSW, GoI vide communication dated 21/10/2022 has conveyed approval granted by the Cabinet Committee on Economic Affairs to the project. The project is under bidding stage. **No construction activity has started yet.**
3. Up gradation of Barge handling capacity at Bundar basis at Kandla capacity 3.33 MMTA back-up area 5 Ha, Estimated cost: 109.59 Cr.	The up-gradation work was completed.
4. Construction of Rail over Bridge at NH 8 A near Nakti Bridge (crossing of NH 8 A Estimated cost: 32.17 Cr.	**Construction activity has not yet started.**
5. Mechanization of Dry Cargo handling capacity at Kandla Port (Berth 7 and 8 capacity 7.35 MMTPA estimated cost 80.61 Cr.	Mechanization work already completed.
6. Strengthening of Oil jetty 1 (Estimated cost: 7.5 Cr.	The strengthening work completed.
7. Modification and strengthening of Cargo berth No. 6 at Kandla Port Estimated cost: 11.5 Cr.	The modification & strengthening work completed.

Out of a total of 7 project activities, construction activities of 4 projects (i.e. Sr. No. 3, 5, 6 & 7 mentioned in the EC & CRZ Clearance) have already been completed. Whereas construction activity of the project at Sr. No. 2 & 4 have not yet started.

For the current compliance period up to June – September , 2024, construction activity related to project No. 1 is ongoing. The compliance report submitted by the Concessionaire M/s KOTPL is attached herewith as Annexure A.

COMPLIANCE REPORT (for the period June to September, 2024)

Subject: Compliance of conditions stipulated by the Ministry of Environment, Forests & Climate Change (MoEF&CC), GoI in Environmental & CRZ Clearance granted for "**Development of 7 integrated facilities (Stage I) within existing Deendayal Authority at Kandla**".

Reference: Environmental and CRZ Clearance granted by MoEF&CC, GoI vide letter F. No. 11-82/2011-IA-III dated 19/12/2016.

Sr. No	EC Conditions	Compliance status
	A. Specific conditions	
I.	Construction activity shall be carried out strictly according to the provisions of CRZ Notification, 2011. No construction work other than those permitted in Costal Regulation Notification shall be carried out in coastal regulation zone area.	a) For Project at Sr. No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**. b) Further, w.r.t. project at Sr. No. 2 & 4 (construction not yet started), it is assured that no activity other than those permissible in Coastal Regulation Notification shall be carried out in the CRZ area.
II.	The Project Proponent shall ensure that there shall be no damage to the existing mangrove patches near site and also ensure the free flow of water to avoid damage to the mangroves.	a) For Project at Sr. No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) Further, w.r.t. project at sr.no. 2 & 4 (construction not yet started), it is assured that due care shall be taken to protect existing mangrove patches near the site and also the free flow of water to avoid damage to the mangroves.
III.	The Project Proponent shall ensure that no creeks or rivers are blocked due to any activities at the project site and free flow of water is maintained.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) Further, w.r.t. project at sr.no. 2 & 4 (construction not yet started), it is assured that no creeks or rivers shall be blocked due to any activities at the project site, and the free flow of water shall be maintained.
IV.	Shoreline should not be disturbed due to dumping. Periodical study on shore line changes shall be conducted and mitigation carried out, if necessary. The detail shall be submitted along with the six monthly monitoring report.	Deendayal Port Authority (Erstwhile, Deendayal Port Trust) vide Work order no. EG/WK/4751/Part (EC–Shoreline study)/98 dated 12/10/2021 had appointed NCSCM, Chennai for carrying out the work "**Shoreline Change Study for Deendayal Port Trust, Kandla, Kachchh District, Gujarat, to Study the Effect of Dumping, if any**". The study is completed and the final report submitted by NCSCM, Chennai has already been communicated to the MoEF&CC, GoI, Gandhinagar with six monthly compliance report submitted vide letter dated 30/1/2023.
V.	The foreshore facilities shall be set up in the stable / low or medium eroding site as demarcated in the shoreline change map by NCSCM. Further, NCSCM shall be authorized to monitor the project during construction and operation phases so as to ensure that the foreshore facilities cause minimum or no impact to the geomorphological systems.	Necessary CRZ recommendation from the Gujarat Coastal Zone Management Authority had already been obtained for establishment of 7 project facilities dated 1/7/2015 **(Copy submitted along with earlier compliance report submitted)** and accordingly, the MoEF&CC, GoI had accorded EC & CRZ Clearance dated 19/12/2016 for the proposed 7 project facilities.

VI.	The PP should take measures to ensure that construction materials / debris (Mortar, cementing materials etc.) do not fall into the water. Construction materials including labour camps should be located at adequate distance from CRZ areas.	a) For project no. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**. b) Further, w.r.t. project at sr.no. 2 & 4 (construction not yet started), it is assured that, the construction activities shall be carried out, with due care so that construction material /debris do not fall into the water. Further, it is also assured that, construction materials including labour camps will be located outside CRZ areas.
VII.	Dredged materials should be analyzed for presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted and the findings should be shared with the Gujarat SPCB and regional office of the ministry.	Dredged Material will be disposed of at designated location as identified by the CWPRS, Pune. DPA assigned work to M/s GUIDE, Bhuj for analysis of dredged material since the year 2017 and the reports are being submitted from time to time along with compliance reports submitted. In continuation of same, DPA had issued work order to GUIDE, Bhuj for "Study on dredged material for presence of Contaminants for year 2021-2024. The copy of 1st Season, 2nd season & 3rd reason report submitted by M/s GUIDE, Bhuj for the period 2023-2024 is attached herewith as **Annexure- B.**
VIII.	PP in consultation with GCZMA should prepare a regional strategic Impact Assessment Report with a special focus on region where the PP started construction without permission. The cost towards the study should be borne by the PP.	Based on the ToR finalized by the GCZMA vide letter dated 13/10/2022, M/s GUIDE, Bhuj had prepared and submitted final RSIA report dated 12/01/2024 Copy of same also submitted along with compliance report submitted on 25/07/2024 Further, a copy of final RSIA report has already been submitted to the GCZMA vide DPA letter dated 30/01/2024 and to the MoEF&CC, GOI vide DPA letter dated 30/01/2024 Copy of same also submitted along with compliance report submitted on 25/07/2024
IX.	A comprehensive and integrated conservation plan including detailed Bathymetry Study and protection of Creeks / Mangrove area including buffer zone, mapping of coordinates, running length, HTL, CRZ boundary should be put in place. The plan should take note of all the conditions of approvals granted to all the project Proponents in this area, and the reported cases of disappearance of Mangroves near project site. The preservation of entire area to maintain the fragile ecological conditions should be a part of the plan in relation to the creek and Mangrove conservation.	The final report submitted by M/s GUIDE, Bhuj (vide letter dated 21/5/2018) had already been communicated to the MoEF&CC, GoI, Bhopal & copy to the MoEF&CC, GoI, New Delhi, along with six monthly compliance report submitted vide letter dated 21/06/2018.
X.	The commitments made during the Public Hearing and recorded in the minutes shall be complied with letter and spirit. A hard copy of the action taken shall be submitted to the ministry.	The commitments made during the Public Hearing has already been complied with letter & spirit. In this regard, the details of CSR Activities implemented as well as proposed are enclosed herewith as **Annexure C.**
XI.	All the conditions stipulated in the earlier clearance including the recommendations of Environment Management Plan, Disaster Management Plan shall be strictly complied with.	a) DPA has already taken necessary steps for compliance with all the conditions stipulated in the earlier clearance, including the recommendations of the Environment Management Plan, Disaster Management Plan.

		DPA already has an updated Disaster Management Plan. Further, for monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest monitoring report submitted by GEMI, Gandhinagar is attached herewith as **Annexure D.** b) Further, w.r.t. Project at Sr.No.1, kindly refer to the Monitoring reports submitted by M/s KOTPL along with compliance report placed at **Annexure A**.
XII.	Disposal sites for excavated materials should be so designed that the revised land use after dumping and changes in the land use pattern do not interfere with the natural drainage.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**. b) For the remaining projects Sr.No 2 & 4 (construction not yet started), it is assured that the land use pattern will not interfere with the natural drainage.
XIII.	PP shall install a continuous automatic ambient air quality monitoring system (24 x 7) for all relevant parameters at two locations to monitor the ambient air quality status of the project area. Data should be transferred online to CPCB and SPCB websites.	a) For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the Latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as Annexure D. DPA has already initiated the action for inviting the tenders for carrying out online ambient air quality monitoring system (24 X 7). However, no response received. Hence, now, DPA is exploring other possibilities for appointing agency for installation of CAAQMS system. b) Further, w.r.t. Project at Sr.No.1, kindly refer to the Monitoring reports submitted by M/s KOTPL along with compliance report placed at Annexure A.
XIV.	The ground water shall not be tapped within the CRZ areas by the PP to meet with the water requirement in any case.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by

		M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) Further, w.r.t. Project at Sr. no.2 & 4 (construction not yet started), Water requirement will be met through procurement from GWSSB or private tankers. No ground water will be tapped. In addition, for completed projects, the Water requirement is being met through GWSSB (Narmada Pipeline) & through private tankers.
XV.	Necessary arrangements for the treatment of the effluents and solid wastes must be made and it must be ensured that they confirm to the standards laid down by competent authorities including the state or Central Pollution Control Board and under the Environmental (Protection) Act, 1986.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) Further, it is also relevant to submit here that, w.r.t. completed projects (modification/ strengthening/ up-gradation of existing facilities), Sewage is being treated in the STP of Kandla (1.5 MLD). The treated sewages from STP of DPA are utilized for plantation / Gardening. DPA has entered into 'Selling Agency' agreement with M/s. MSTC (Govt. of India Entreprise), Vadodara since 04/01/2022 for collection, transporting and disposal of scrap, surplus items, unserviceable equipment etc. Further, DPA has appointed GEMI, Gandhinagar for the work of "Preparation of Plan for Management of Plastic Wastes, Solid Waste, including C&D waste, E-waste, Hazardous waste, including Biomedical and Non-Hazardous Waste in the Deendayal Port Authority" vide Work Order dated 24/01/2023. The work is completed. Final report submitted herewith is attached herewith as **Annexure E**
XVI.	All the operational areas will be connected with the network of liquid waste collection corridor comprising of storm water, oily waste and sewage collection pipelines.	The 4 projects completed are of modification/strengthening/up-gradation of existing facilities, having already developed network of storm water drainage & other facilities. Further, oil wastes are being disposed of by selling to the authorized vendor of GPCB/CPCB, as per norms. However, for the operational phase of the ongoing as well as the remaining projects, DPA/BOT operator will provide the necessary facilities.
XVII.	Automatic/Online monitoring system (24 x 7 monitoring devices) for water pollution in respect of flow measurement and relevant pollutants in the treatment system to be installed. The data to be made available to the respective SPCB and in the company's website.	For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as **Annexure D.**

VIII.	Marine ecology shall also be monitored regularly in terms of sea weeds, grasses, mudflats, sand dunes, fisheries, echinoderms, shrimps, turtles, corals, coastal vegetation, mangroves and other marine bio diversity components as part of the management plan. Marine ecology shall be monitored regularly also in terms of all micro, macro and mega floral and faunal components of marine biodiversity.	DPA assigned work to M/s GUIDE, Bhuj, for regular monitoring of Marine Ecology since the year 2017 and final reports prepared by GUIDE,Bhuj have already been communicated to the Integrated Regional Office, MoEF&CC, GoI, Gandhinagar as well as to the MoEF&CC, GoI, New Delhi along with compliance reports submitted from time to time. (Period from 2017 to 2021). Further, it is again to submit that DPA issued a work order to M/s GUIDE vide its letter no. EG/ WK/ 4751/ Part (Marine Ecology Monitoring) /11 dated 03/05/2021 for Regular monitoring of Marine Ecology in and around Deendayal Port Authority (Erstwhile Deendayal Port Trust) and continuous Monitoring Program covering all seasons on various aspects of the Coastal Environs for the period 2021-24. Final Reports for the period 2021-22 , 2022-23 & 2023-24, have already been submitted along with compliance report submitted from time to time. In continuation of the same, DPA issued a work order to M/s GUIDE vide its letter no. EG/ WK/ 4751/ Part (Marine Ecology Monitoring) /72 dated 10/06/2024 for further period of 2024 – 27. A copy of same has already been submitted along with compliance report submitted on 25/07/2024.
XIX.	Measure should be taken to contain, control and recover the accidental spills of fuel and cargo handle.	DPA already having Oil Spill Contingency Plan. An adequate control measure has already been taken to control and recover accidental fuel and cargo handle spills.
XX.	All the mitigation measures submitted in the EIA report shall be prepared in a matrix format and the compliance for each mitigation plan shall be submitted to RO, MoEF&CC along with half yearly compliance report.	Compliance of mitigation measures suggested in the EIA report in the matrix format is attached herewith as **Annexure F.**
XXI.	Ship/barges shall not be allowed to release any oily bilge waste or ballast water in the sea. Any effluent from the jetty which have leachable characteristics shall be segregated and recycled/disposed as per SPCB guideline.	It is assured that Ships/barges shall not be allowed to release any oily bilge waste or ballast water in the sea. It is assured that any effluent from the jetty which has leachable characteristics shall be segregated, treated and recycled/disposed of as per SPCB guidelines. DPA issued a Grant of License/Permission to collect and dispose of "Hazardous Waste/Sludge/ Waste Oil" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars regarding the reception facilities at Swachch Sagar portal.
XXII. X	Location of DG sets and other emission generating equipment shall be decided keeping in view the predominant wind direction so that emission do not effect nearby resident areas. Installation and operation of DG Sets shall comply with the guideline of CPCB	a) DG sets will be installed keeping in view the predominant wind direction; as per prescribed guidelines, DG sets shall be used in case of power failure only. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by

		M/s KOTPL (concessionaire of the project) placed at **Annexure A**.
XXIII.	All the mechanized handling systems and other associated equipments such as hoppers, belt conveyors, stacker cum reclaimers shall have integrated dust suppression system. Dust suppression system shall be provided at all transfer point.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) DPA being an old establishment and the area is quite big, possibilities of mechanization is being explored. The work of mechanization at Cargo berth 8 and 9 were attended in 2023. However, both the tenders were discharged as none of the bidders were meeting the eligibility criteria. Based on stipulations requirement the project will be restructured accordingly. Further, w.r.t. Project at Sr.No.2 (construction not yet started), BOT operator will take the necessary step to provide all the mechanised handling systems and other associated equipment, such as hoppers, belt conveyors, and stacker cum reclaimers with integrated dust suppression systems. DPA/BOT operator will provide a Dust suppression system at all transfer points. DPA has already installed a water sprinkling system in the Port area for coal handling areas.
XXIV.	No products other than permitted under the CRZ Notification, 2011 shall be stored in the CRZ area.	It is hereby assured that only products permitted under the CRZ Notification, 2011 shall be stored in the CRZ area.
XXV.	It shall be ensured by the Project Proponent that the activities does not cause disturbance to the fishing activity, movement of fishing boats and destruction to mangroves during the construction and operation phase.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) Further, it is assured that, due care is being taken so that the activities do not cause disturbance to the fishing activity, movement of fishing boats and destruction to mangroves.
XXVI.	As proposed, green belt over an area of 36.8 ha shall be developed with at least 10 meter wide green belt on all sides along the periphery of the project area, in downward direction and along road side etc. Selection of plant species shall be as per the CPCB guidelines in consultation with the DFO.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) As already informed, DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares). The work is completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The final report submitted by GUIDE, already submitted along with compliance report submitted on 12/04/2023.

		Further DPA has accorded the work of "Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The work is completed final report is attached herewith as **Annexure G**
XXVII.	Mangrove plantation in an area of 100ha shall be carried out by KPT within 2 years in a time bound manner. Action taken report shall be submitted to the Regional Office of MoEF&CC.	Mangrove Plantation carried out during (2018-2020) through the Gujarat Ecology Commission. Totally DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005, through various agencies viz. GUIDE, GEC, State Forest Department etc., which includes 100 Ha.. The details have already been communicated with the earlier compliance reports submitted.
XXVIII.	Municipal Solid Waste and Hazardous wastes shall be managed as per Municipal Solid Waste Rule, 2016 and Hazardous Waste Management Rules 2016	Municipal solid waste and hazardous waste management by DPA are undertaken by appointing GPCB authorized vendor per the Municipal solid waste Rule, 2016 and Hazardous waste management Rules, 2016, for further treatment. Further, DPA has appointed GEMI, Gandhinagar for the work of "Preparation of Plan for Management of Plastic Wastes, Solid Waste, including C&D waste, E-waste, Hazardous waste, including Biomedical and Non-Hazardous Waste in the Deendayal Port Authority" vide Work Order dated 24/01/2023. The work is completed and final report submitted is attached herewith as **Annexure E**
XIX.	The project Proponent shall take up and earmark adequate fund for socio-economic development and welfare measure as proposed under the CSR programmed. This shall be taken up on priority.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**. b) The details of the fund earmarked under CSR activities and CSR activities undertaken by DPA to date & proposed activities are placed at **Annexure C.**
XXX.	The Project Proponent shall set up separate Environmental Management Cell for effective implementation of the stipulated environmental safeguards under the supervision of a senior executive	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**. b) DPA is already having Environment Management cell. Further, DPA has also appointed expert agency for providing Environmental Experts from time to time. Recently, DPA appointed M/s Precitech Laboratories, Vapi for providing Environmental Experts vide work order dated 05/02/2021 (for a period of 2 years & further extendable for 1 year). In addition, it is relevant to submit here that, DPA has appointed Manager (Environment) on contractual basis for the period of 3 years and further extendable to 2 years (Copy of the details has already been communicated with the earlier compliance report submitted).
XXXI.	The funds earmarked for environmental management plan shall be included in the budget and this shall not be diverted for any	a) The allocation made under the "Environmental Services & Clearance of other related Expenditure" scheme during BE 2023-24 is Rs. 657 Lakhs.

	other purpose.	The funds earmarked for EMP by the Concessionaire M/s KOTPL w.r.t. project at Sr.No. 1 are delineated in the compliance report submitted b) (**Annexure A**).
XXX II	The proponent shall abide by all the commitments and recommendations made in the EIA/EMP reports so also during their presentation to the EAC.	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**. b) DPA has installed Mist Canon at the Port area to minimize the dust. Further, DPA has already installed continuous sprinkling system in coal stack yard in DPA (40 ha. area) to prevent dust pollution. Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done. Regular sweeping of spilled cargo from roads is done by parties on regular basis. c) DPA has undertaken the project of dust supersession sprinkling system for the 34 hectare coal storage yard d) For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as **Annexure D.** e) For ship waste management, DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" and "Dry Solid Waste (Non- Hazardous)" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars regarding the reception facilities at Swachch Sagar portal. f) DPA assigned work to M/s GUIDE, Bhuj, for regular monitoring of Marine Ecology since the year 2017 (From 2017 – 2024), and the reports of the same submitted by GUIDE, Bhuj has already been communicated to the Regional Office, MoEF&CC, GoI, Gandhinagar as well as to the MoEF&CC, GoI, New Delhi along with compliance reports submitted. In continuation of the same, DPA issued a work order to M/s GUIDE vide its letter no. EG/ WK/ 4751/ Part (Marine Ecology Monitoring) /72 dated 10/06/2024. A copy of same already been submitted along with compliance report submitted on 25/07/2024 g) As already informed, DPA entrusted work of green belt development in and around the Port

		area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares). The work is completed. h) Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The work has been completed and the final report submitted by GUIDE, Bhuj has already been communicated with the last compliance report. i) Further DPA has accorded the work of "Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The work is completed and final report is attached herewith as **Annexure G.** j) DPA assigned work to M/s GUIDE, Bhuj for analysis of dredged material since the year 2017 and the reports are being submitted from time to time along with compliance reports submitted. k) In continuation of same, DPA had issued work order to GUIDE, Bhuj for "Study on dredged material for presence of Contaminants for year 2021-2024. The third season report submitted by M/s GUIDE, Bhuj for the period 2023-2024 is attached herewith as **Annexure- B.** l) Further, Dredged Material will be disposed of at designated location as identified by the CWPRS, Pune. m) For energy conservation measures, DPA is already generating 20 MW of Wind energy. In addition to it, DPA has commissioned a 45 kWP Solar Plant at Gandhidham. Further, it is relevant to mention that, two out of four Nos. of Harbour Mobile Crane (HMC) made electric operated. Balance 02 Nos. shall be made electric operated by 2023-2024. Four Nos. of Deisel operated RTGs converted to e-RTGs. Retrofitting of hydrogen fuel cell in Tug Kalinga and Pilot Boat Niharika to be done as a pilot project under the guidance of MoPSW. Also, 14 Nos. of EV cars to be hired in this year and 03 Nos. EV Bus to be procured by the year 2023-24. n) Further, for Oil Spill Management, DPA is already having Oil Spill Contingency Plan in place and Oil Response System as per the NOS-DCP guidelines.

XIII.	Company shall prepare operating manual in respect of all activities. It shall cover all safety & environment related issues and system. Measure to be taken for protection. One set of environmental manual shall be made available at the project site. Awareness shall be created at each level of the management. All the schedules and results of environmental monitoring shall be available at the project site office.	The operating manual plan in respect of all activities has already been communicated along with the compliance report submitted vide letter dated 2/4/2019.
XIV.	Corporate Social Responsibility a. The company shall have a well laid down Environmental Policy approved by the Board of Directors b. The Environmental policy shall prescribe for standard operating process/procedure to bring into focus any infringements / deviation/violation of the environmental or forest norms c. The system or Administrative order of the hierarchical company to deal with environmental issues and for ensuring compliance with the environmental clearance conditions shall be furnished. d. To have proper checks and balances, the company shall have a well laid down system of reporting of non compliances / violations of environmental norms to the board of directors of the company and/or share holders or stake holders at large.	The DPA has an Environmental Policy approved by the Board of Directors. The Environmental policy has already prescribed standard operating processes/procedures, bringing into focus any infringements/deviations/violations of the environmental or forest norms. DPA already has a well-established environmental Cell for ensuring proper checks on non-compliances/violations of Environmental norms. The organogram has already been communicated with the last compliance report submitted.
B. <u>General Condition</u>		
i.	The Project Authorities must strictly adhere to the stipulations made by the State Pollution Control Board (SPCB), State Govt. and any other statutory authority.	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**.
ii.	Full support shall be extended to the officers of this ministry/regional office at Bhopal by the project Proponent during inspection of the project for monitoring purposes by furnishing full details and action plan including action taken reports. In respect of mitigation measures and other environmental protection activities.	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**.
iii.	A six monthly monitoring report shall need to be submitted by the project proponents to the regional office of this ministry at Bhopal regarding the implementation of the stipulated conditions.	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**.

iv	Ministry of Environment Forest and Climate Change or any other competent authority may stipulate any other additional conditions or modify the existing one, if necessary in the interest of environment and the same shall be complied with.	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**.
v	The ministry reserves the right to revoke this clearance if any of the condition stipulated are not complied with the satisfaction of the ministry	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**.
vi	In the event of a change in project profile or change in the implementation agency, a fresh reference shall be made to the ministry of Environment, Forest and Climate Change.	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**.
vii	The Project Proponents shall inform the regional office as well as the ministry, the date of the financial closure and final approval of the project by the concerned authorities and the date of start of Land Development work.	DPA vide letter dated 14/12/2020 w.r.t. project No.1, i.e***. "Development of Oil Jetty to Handle Liquid Cargo and Ship Bunkering Terminal at Old Kandla under PPP Mode"***, has already informed the Regional Office, MoEF&CC, GoI, Bhopal & copy to MoEF&CC, GoI, New Delhi about the award of the concession granted to the Concessionaire M/s Kandla Oil Terminal Limited dated 11/12/2020, and the project implementation work has commenced .
viii	A copy of the clearance letter shall be marked to concerned panchayat / local NGO, if any, from whom any suggestion/representation has been made received while processing the proposal	DPA vide letter dated 29/12/2016 had already informed to Conservation Action Trust & Paryavaran Mitra (from whom DPA received the representation during the Public Hearing).
ix	A copy of the environmental clearance letter shall also be displayed on the website of the concerned State Pollution Control Board. The EC letter shall also be displayed at the Regional Office, District Industries Centre and Collector's Office / Tehsildar's office for30 days.	Point Noted.
11	The stipulations would be enforced among others under the provisions of water (Prevention and Control of Pollution) Act 1974, the Air (Prevention and control of Pollution) Act 1981, the environment (Protection) Act, 1986, the Public Liability (Insurance) Act, 1991 and EIA Notification 1994, including the amendments and rules made thereafter.	For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest environmental monitoring report submitted by GEMI, Gandhinagar is attached herewith as **Annexure D.** For Project at Sr.No. 1 which is under construction, kindly refer monitoring data submitted by M/s KOTPL along with compliance submitted placed at **Annexure A.**

12	All other statutory clearance such as the approvals for storage of diesel from Chief Controller of Explosives, Fire Department, Civil Aviation Department, Forest Conservation Act, 1980 and Wildlife (Protection) Act, 1972 etc. shall be obtained, as applicable by project proponents from the respective competent authorities.	DPA/BOT Operator will obtain all other statutory clearance applicable as per the condition stipulated.
13	The project proponent shall advertise in at least two local Newspapers widely circulated in the region, one of which shall be in the vernacular language informing that the project has been accorded Environmental and CRZ Clearance and copies of clearance letters are available with the state Pollution Control Board and may also be seen on the website of the Ministry of Environment and Forests at http://www.envfor.nic.in. the advertisement should be made within 10 days from the date if receipt of the clearance letter and a copy of the same should be forwarded to the Regional Office of this Ministry at Bhopal.	Deendayal Port had already given advertisement in two newspapers, i.e., in KUTCHMITRA (Gujarati) & in The Indian Express (Ahmedabad Edition) (English) dated 20/12/2016. Further, DPA forwarded the copies to the Regional Office, MoEF&CC, GoI, Gandhinagar vide letter dated 22/12/2016.
14	This Clearance is subject to final order of the Hon'ble Supreme Court of India in the matter of Goa Foundation Vs. Union of India in Writ Petition (Civil) No. 460 of 2004 as may be applicable to this project.	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.**
15	Status of compliance to the various stipulated Environmental conditions and environmental safeguards will be uploaded by the project proponent in its website.	Status of compliance with the various stipulated Environmental conditions being uploaded on the website of DPA. The present compliance report has already been uploaded to the website www.deendayalport.gov.in.
16	Any appeal against this clearance shall be lie with the National Green Tribunal, if preferred, within a period of 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.	a) Point Noted. b) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A**.
17	A copy of the clearance letter shall be sent by the proponent to concerned Panchayat, Zilla Parisad / Municipal Corporation, Urban Local Body and the Local NGO, if any, from whom suggestions / representations, if any, were received while processing the proposal. The clearance letter shall also be put on the website of the company by the proponent.	DPA vide letter dated 29/12/2016 had already informed to Conservation Action Trust & Paryavaran Mitra (from whom KPT received the representation during the Public Hearing).
18	The Proponent shall upload the status of compliance of the stipulated Clearance conditions, including results of monitored data on their website and shall update the same periodically. It shall simultaneously be sent to the Regional Office of MoEF, the respective Zonal Office of CPCB and the SPCB.	The status of compliance with the various stipulated Environmental conditions is being uploaded on the website of DPA. The present compliance report has already been uploaded to the website www.deenbdayalport.gov.in. Copy of the compliance report has also been marked to the Regional Office of MoEF&CC, GoI, the respective Zonal Office of CPCB and the SPCB.
19	The environmental statement for each financial year ending 31st March in Form – V as is mandated to be submitted by the project proponent to the concerned State Pollution Control Board as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall also be put on the website of the company along with the status of compliance of clearance conditions and shall also	a) For Project at Sr.No. 1 which is under construction, kindly refer compliance submitted by M/s KOTPL (concessionaire of the project) placed at **Annexure A.** b) As informed earlier, out of 7 projects, the projects mentioned at Sr. No. 3, 5, 6 & 7 in the EC Letter dated 19/12/2016 are not new projects (strengthening/ upgradation work). These projects

	be sent to the respective Regional Office of MoEF by e – Mail.	are already covered under consent to operate granted by the GPCB for the whole DPA area (GPCB ID 28494 –Renewed Consent Order no-AWH-110594 dated issue-8/12/2020- Valid up to 21/7/2025) and for which DPA regularly submitted the Environmental statement in Form V to the GPCB. A copy of the Environmental Statement submitted to the GPCB (the year 2023-24) for the entire DPA area is attached herewith as **Annexure H** .Further, DPA also uploaded the said Environmental statement in Form V in the website www.deendayalport.gov.in.

ANNEXURE A
COMPLAINCE REPORT OF M/S KOTPL

Kandla Oil Terminal Private Limited

Registered Office: "NEELADRI", 3rd Floor, No. 9, Cenotaph Road, Alwarpet, Chennai - 600 018.
Tel: +91-44-4590 2222, 4590 2299, Fax: + 91-44-4590 2200, URL : www.imc.net.in CIN: U60200TN2013PTC092551

KRO/KOTPL/03122024

14-12-2024

The Executive Engineer(Design)

Deendayal Port Authority

Administrative-Office

Gandhidham

Kutch-370201

Dear Sir,

Sub: Development of oil jetty to handle Liquid Bulk and Ship bunkering Terminal at Old Kandla (Project)-Half Yearly EC & CRZ Compliance report.

The half yearly compliance report for the KOTPL project for the period from June 2024 to Nov 2024 are enclosed herewith (EC, CRZ & CTE)

We would appreciate your acknowledgment of receipt of these documents.

Your sincerely,

For Kandla Oil Terminal (p) Limited.

(Authorized Signatory)

AXEN (D)

17/12/2024

Shri Varun Mani

17/12/2024

CC: independent Engineer, IITM

Encl:

1. EC Compliance report
2. CRZ Compliance report
3. CTE Compliance report
4. Monitoring data sheet
5. Ambient air (Six months).
6. Noise Monitoring (Six months)
7. Drinking water Report (Six Months).

462(D)
16/12/24

Kandla Oil Terminal Private Limited

Subject: Point-wise Compliance Status Report for CRZ clearance for Developing integrated facility within the existing Kandla Port at Kandla, Dist: Kutch by M/s. Kandla Port Trust Limited – Reg.

Ref No: - GCZMA CRZ recommendation vide Letter No – ENV-10-2014-25-E Cell dated 01.07.2015

S. No.	CRZ Conditions	Compliance Status
	SPECIFIC CONDITIONS	
1.	The provisions of the CRZ notification of 2011 shall be strictly adhered to by the KPT. No activity in contradiction to the provisions of the CRZ Notification shall be carried out by the KPT.	It is assured that no activity contradicting the Provisions of the CRZ Notification shall be carried out.
2.	The KPT shall have to ensure that there shall not be any damage to the existing mangrove area.	It is ensured that due care shall be taken to protect the existing mangrove area.
3.	The KPT shall prepare an emergency plan to protect existing mangroves in case of any eventuality/accident	Not Applicable
4.	The KPT shall have to make a provision that mangrove areas get proper flushing water and free flow of water shall not be obstructed.	It is assured that provisions are being made that mangrove areas get proper flushing water and free flow of water shall not be obstructed.
5.	The KPT shall have to abide by whatever decision taken by the GCZMA for violations of CRZ notification 2011	Decisions taken by the GCZMA for violations of CRZ Notification, 2011, will be abided by.
6.	There shall not be violations of the order dated 9-12-2013 passed by the National Green Tribunal, and accordingly, there shall be no mangrove destruction taking place in the KPT area.	It is assured that due care shall be taken to protect the existing mangrove area.
7.	No dredging, reclamation or any other project-related activities shall be carried out in the CRZ area categorized as CRZ I (i), and it shall have to be ensured that the mangrove habitats and other ecologically important and significant areas, if any, in the region are not affected due to any of the project activities.	Noted
8.	The KPT shall participate financially in installing and operating the Vessel Traffic Management System in the Gulf of Kachchh and shall also take the lead in preparing and operational sing the Regional Oil Spill Contingency plan in the Gulf of Kachchh.	Not Applicable
9.	The KPT shall strictly ensure that no creeks or	It is assured that no creeks or rivers shall be

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

S. No.	CRZ Conditions	Compliance Status
	rivers are blocked due to any activity at Kandla.	blocked due to any activity at Kandla.
10.	Mangrove plantation in an area of 100 ha. shall be carried out by the KPT within 2 years in a time-bound manner on the Gujarat coastline either within or outside the Kandla Port Trust area, and a six-monthly compliance report along with the satellite images shall be submitted to the Ministry of Environment and Forests as well as to this Department without fail.	Not Applicable
11.	No activities other than those permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.	It is assured that only activities permitted by the competent authority under the CRZ Notification shall be carried out in the CRZ area.
12.	No groundwater shall be tapped for any purpose during the proposed expansion/modernization activities.	Water requirements will be met through GWSSB or private tankers. No groundwater shall be tapped.
13.	All necessary permissions from different Government Departments/agencies shall be obtained by the KPT before commencing the expansion activities.	Noted
14.	No effluent or sewage shall be discharged into the sea/creek or in the CRZ area, and it shall be treated to conform to the norms prescribed by the Gujarat Pollution Control Board and would be reused/recycled within the plant premises.	No waste water generation during the construction phase
15.	All the recommendations and suggestions given by Mantec Consultants Pvt. Ltd. New Delhi in their Comprehensive Environment Impact Assessment report for conservation/protection and betterment of the environment shall be implemented strictly by the KPT.	Noted
16.	The construction and operational activities shall be carried out in such a way that there is no negative impact on mangroves and other coastal/marine habitats. The construction activities and dredging shall be carried out only under the constant supervision and guidelines of the Institute of National repute like NIOT.	It is assured that construction activities are being carried out under constant supervision.
17.	The KPT shall contribute financially to any common study or project that may be proposed by this Department for environmental management/conservation /improvement for the Gulf of Kutch.	Not applicable

KANDLA OIL TERMINAL PRIVATE LIMITED
KANDLA
370210

S. No.	CRZ Conditions	Compliance Status
18.	The construction debris and/or any other type of waste shall not be disposed of into the sea, creek, or in CRZ areas. The debris shall be removed from the construction site immediately after the construction is over.	It is assured that the construction activities are being carried out, with due care, and that the construction material /debris does not fall into the water. Further, it is also assured that construction waste will be collected at a designated location before being sent to the disposal site.
19.	The construction camps shall be located outside the CRZ area, and the construction labour shall be provided with the necessary amenities, including sanitation, water supply and fuel, and it shall be ensured that the environmental conditions are not deteriorated by the construction labours.	No construction camps on the site. Only Local laborers are involved.
20.	The KPT shall regularly update their Local Oil Spill Contingency and Disaster Management plan in consonance with the National Oil Spill and Disaster Contingency Plan and shall submit the same to this Department after having it vetted through the Indian Coast Guard.	Project is in construction phase.
21.	The KPT shall bear the cost of the external agency that may be appointed by this Department for supervision/ monitoring of proposed activities and the environmental impacts of the proposed activities.	Not applicable
22.	The KPT shall take up massive greenbelt development activities in and around Kandla and also within the KPT limits.	Not applicable
23.	The KPT shall have to contribute financially for taking up the socio-economic upliftment activities in this region in consultation with the Forests and Environment Department and the District Collector/ District Development officer.	Not applicable
24.	A separate budget shall be earmarked for environmental management and socio-economic activities, and details thereof shall be furnished to this Department as well as MoEF,GOI. The details with respect to the expenditure from this budget head shall also be furnished.	Noted
25.	A separate environmental management cell with qualified personnel shall be created for environmental monitoring and management during the construction and operational phases of the project.	An NABL-accredited laboratory with expert manpower has assigned the work of monitoring. The Environmental Monitoring Reports are enclosed herewith as **Annexure**.

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

S. No.	CRZ Conditions	Compliance Status
26.	An environmental report indicating the changes, if any, with respect to the baseline environmental quality in the coastal and marine environment shall be submitted every year by the KPT to this Department as well as to the MoEF&CC, GOI.	Noted. The Environmental Monitoring Reports are enclosed herewith as **Annexure.**
27.	The KPT shall have to contribute financially to support the National Green Corps Scheme being implemented in Gujarat by the GEER Foundation, Gandhinagar, in consultation with the Forests and Environment Department	Not applicable
28.	A six-monthly report on compliance with the conditions mentioned in this letter shall have to be furnished by the KPT on a regular basis to this Department/ MoEF&CC, GOI	Noted
29.	Any other conditions that may be stipulated by this Department/ MoEF&CC, GOI from time to time for environmental protection/management purposes shall also have to be complied with by the KPT.	Noted.

KANDLA OIL TERMINAL PRIVATE LIMITED
KANDLA
370210

Kandla Oil Terminal Private Limited

Subject: Point-wise Compliance Status Report for Environmental clearance for Developing Integrated Facility within the existing Kandla Port at Kandla, Dist: Kutch by M/s. Kandla Port Trust Limited – Reg.

Ref No: - Environmental Clearance vide Letter No- F. No. 11-82/2011-IA III dated 19.12.2016

Sr. No.	EC Conditions	Compliance Status
PART A – SPECIFIC CONDITIONS		
I	Construction activity shall be carried out strictly according to the provisions of CRZ Notification 2011 No. construction work other than those permitted in coastal Regulation Zone Notification Shall be carried out in Coastal Regulation Zone area	It is assured that no activity other than those permissible in the Coastal Regulation Notification shall be carried out in the CRZ area.
ii	The project proponent shall ensure that there shall be no damage to the existing mangrove patches near the site and also ensure the free flow of water to avoid damage to the mangroves.	It is assured that due care shall be taken to protect existing mangrove patches near the site and the free flow of water to avoid damage to the mangroves.
iii	The project proponent shall ensure that no creeks or rivers are blocked due to any activities at the project site, and free flow of water is maintained.	It is assured that no creeks or rivers shall be blocked due to any activities at the project site, and the free flow of water shall be maintained.
iv	The shoreline should not be disturbed due to dumping. Periodical study on shoreline changes shall be conducted, and mitigation carried out, if necessary. The details shall be submitted along with the six-monthly monitoring reports.	No shoreline is disturbed due to dumping.
v	The foreshore facilities shall be set up in the stable/low or medium eroding site as demarcated in the shoreline change map by NCSCM. Further, NCSCM shall be authorized to monitor the project during the construction and operation phases so as to ensure that the foreshore facilities cause minimum or no impact to the geomorphological systems.	Ongoing construction is in line with and strictly adhering to EC-CRZ conditions issued about this project.

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
vi	The PP should take measures to ensure that construction materials/debris (mortar, cementing material, etc.) do not fall into the water. Construction materials including labor camps should be located at an adequate distance from CRZ areas.	It is assured that the construction activities are being carried out, with due care, and that the construction material /debris does not fall into the water. Further, it is also assured that construction waste will be collected at a designated location before being sent to the disposal site.
vii	Dredged materials should be analyzed for the presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted, and the findings should be shared with the Gujarat SPCB and the Regional office of the Ministry.	The project is under construction stage, and no dredging activity has been carried out to date.
viii	PP in consultation with GCZMA should prepare a regional strategic impact assessment report with a special focus on the region where the PP started construction without permission. The cost towards this study should be borne by the PP	Not Applicable
ix	A comprehensive and integrated conservation plan including a detailed bathymetry study and protection of creeks/mangrove area including buffer zone, mapping of coordinates, running length, HTL, and CRZ boundary should be put in the palace. The plan should take note of all the conditions of approvals granted to all the project proponents in this area, and the reported cases of the disappearance of mangroves near the project site. The preservation of the entire area to maintain the fragile ecological conditions should be a part of the plan in relation to the creek and mangrove conservation.	DPA has appointed the Gujrat Institute of Desert Ecology, Bhuj, for the work.
x	The commitments made during the Public Hearing and recorded in the minutes shall comply with by letter and spirit. A hard copy of the action taken	Not Applicable

KANDLA 370210

KANDLA OIL TERMINAL PRIVATE LIMITED

Sr. No.	EC Conditions	Compliance Status
	shall be submitted to the ministry.	
xi	All the conditions stipulated in the earlier clearance including the recommendations of the Environment Management Plan, and Disaster Management Plan shall be strictly complied with.	Noted
xii	Disposal sites for excavated material should be so designed that the revised land use after dumping and changes in the land use pattern does not interfere with the natural drainage.	It is assured that; construction waste will be collected at a designated location before sending to the disposal site. Also, the land use pattern will not interfere with the natural drainage.
xiii	PP shall install a continuous automatic ambient air quality monitoring system (24x7) for all relevant parameters at two locations to monitor the ambient air quality status of the project area. Data should be transferred online to CPCB and SPCB websites.	The Environmental Monitoring Reports following CPCB guidelines and as submitted by NABL accredited laboratory is enclosed as **Annexure**.
xiv	The groundwater shall not be tapped within the CRZ areas by the PP to meet the water requirement in any case.	Water requirements will be met through GWSSB or private tankers. No groundwater shall be tapped.
xv	Necessary arrangements for the treatment of the effluents and solid wastes must be made and it must be ensured that they conform to the standards laid down by the competent authorities including the Central or State Pollution Control Board and under the Environment (Protection) Act, 1986.	Noted, the project is under the construction stage.
xvi	All the operational areas will be connected with the network of liquid waste collection corridors comprising of stormwater, oily waste and sewage collection pipelines.	Noted, the project is under the construction stage.

KANDLA TERMINAL PRIVATE LIMITED KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
xvii	Automatic /online monitoring system (24x7) monitoring devices) for water pollution in respect of flow measurement and relevant pollutants in the treatment system to be installed. The data to be made available to the respective SPCB and in the Company's website.	Noted
xviii	Marine ecology shall be monitored regularly also in terms of seaweeds, sea grasses, mudflats, sand dunes, fisheries, echinoderms, shrimps, turtles, corals, coastal vegetation, mangroves, and other marine biodiversity components as part of the management plan. Marine ecology shall be monitored regularly also in terms of all micro, macro, and mega floral and faunal components of marine biodiversity.	DPA appointed the Gujarat Institute of Desert Ecology, Bhuj for Regular Monitoring of Marine Ecology.
xix	Measures should be taken to contain, control, and recover the accidental spills of fuel and cargo handles.	Noted, the project is under the construction stage.
xx	All the mitigation measures submitted in the EIA report shall be prepared in a matrix format and the compliance for each mitigation plan shall be submitted to the RO, MoEF&CC along with half yearly compliance report.	Noted
xxi	Ships/barges shall not be allowed to release any oily bilge waste or ballast water in the sea. Any effluents from the Jetty which have leachable characteristics shall be segregated and recycled/disposed of as per SPCB guidelines.	Noted, the project is under the construction stage.
xxii	The location of DG sets and other emission-generating equipment shall be decided keeping in view the predominant wind direction so that emissions do not affect nearby	Not Applicable

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
	residential areas. Installation and operation of DG sets shall comply with the guidelines of CPCB.	
xxiii	All the mechanized handling systems and other associated equipment such as hoppers, belt conveyors, stackers cum reclaimers shall have integrated dust suppression systems. Dust suppression systems shall be provided at all transfer points.	Not applicable, as this project is for the handling of liquid cargo.
xxiv	No product other than permitted under the CRZ notification, 2011 shall be stored in the CRZ area.	It is hereby assured that only products permitted under the CRZ Notification, 2011 shall be stored in the CRZ area.
xxv	It shall be ensured by the Project Proponent that the activities do not cause disturbance to the fishing activity, movements of fishing boats and destruction of mangroves during the construction and operation phase.	It is assured that, due care will be taken so that the activities do not cause disturbance to the fishing activity, movement of fishing boats and destruction to mangroves.
xxvi	As proposed, a green belt over an area of 36.8 ha shall be developed with at least 10-meter-wide green belt on all sides along the periphery of the project area, in the downward direction, and along roadsides etc. Selection of plant species shall be as per the CPCB guidelines in consultation with the DFO.	Noted.
xxvii	Mangrove plantation in an area of 100 ha. shall be carried out by KPT within 2 years in a time bound manner. Action taken report shall be submitted to the Regional Office of MoEF &CC.	Not Applicable
xxviii	Municipal solid wastes and hazardous wastes shall be managed as per the Municipal Solid Waste Rule, 2016 and Hazardous Waste Management Rule, 2016.	Noted.
xxix	The Project Proponent shall take up and earmark adequate funds for socio-economic development and welfare measures as proposed under the CSR program. This shall be taken up on	Noted, the project is under the construction stage.

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
	priority.	
xxx	The project proponent shall set up a separate environmental management cell for the effective implementation of the stipulated environmental safeguards under the supervision of a Senior Executive.	An NABL-accredited laboratory with expert manpower has assigned the work of monitoring. The Environmental Monitoring Reports are enclosed herewith as **Annexure**.
xxxi	The funds earmarked for the environment management plan shall be included in the budget, and this shall not be diverted for any other purposes.	Noted
xxxii	The proponent shall abide by all the commitments and recommendations made in the EIA/EMP report and also during their presentation to the EAC.	Noted, the project is under the construction stage.
xxxiii	The company shall prepare an operating manual in respect of all activities. It shall cover all safety & environmental related issues and systems. Measures to be taken for protection. One set of the environmental manual shall be made available at the project site. Awareness shall be created at each level of management. All the schedules and results of environmental monitoring shall be available at the project site office.	Noted, the project is under the construction stage.
xxxiv	Corporate Social Responsibility.	
	a. The Company shall have a well-laid-down Environment Policy approved by the Board of Directors. b. The Environment Policy shall prescribe standard operating processes/procedures to bring into focus any infringements/deviations/ violations of the environmental or forest norms/ conditions. c. The hierarchical system or Administrative Order of the	Noted. Noted. Noted.

KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
	company to deal with environmental issues and for ensuring compliance with the environmental clearance conditions shall be furnished. d. To have proper checks and balances, the company shall have a well-laid-down system of reporting non-compliances/ violations of environmental norms to the board of Directors of the company and/or shareholders or stakeholders at large.	Noted
B. GENERAL CONDITIONS:		
(i)	The project authorities must strictly adhere to the stipulations made by the State Pollution Control Board (SPCB), State Government, and any other statutory authority.	The project authorities assure to strictly adhere to the stipulations
(ii)	Full support shall be extended to the officers of this Ministry/ Regional Office at Bhopal by the project proponent during the inspection of the project for monitoring purposes by furnishing full details and an action plan including action is taken reports in respect of mitigation measures and other environmental protection activities.	Full support shall be extended to the regulatory officers during the inspection and furnishing required project details.
(iii)	A six-Monthly monitoring report shall need to be submitted by the project proponents to the Regional Office of this Ministry at Bhopal regarding the implementation of the stipulated conditions.	Noted.
(iv)	Ministry of Environment, Forest and Climate Change or any other competent authority may stipulate any additional conditions or modify the existing ones, if necessary, in the interest of the environment and the same shall be complied with.	Noted.
(v)	The Ministry reserves the right to	Noted.

OIL TERMINAL PRIVATE LIMITED KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
	revoke this clearance if any of the conditions stipulated have not complied with the satisfaction of the Ministry.	
(vi)	In the event of a change in the project profile or change in the implementation agency, a fresh reference shall be made to the Ministry of Environment, Forest and Climate Change.	Noted.
(vii)	The project proponents shall inform the Regional Office as well as the Ministry, of the date of financial closure and final approval of the project by the concerned authorities and the date of start of land development work.	Noted.
(viii)	A copy of the clearance letter shall be marked to the concerned Panchayat/local NGO, if any, from whom any suggestion/ representation has been made or received while processing the proposal.	Complied.
(ix)	A copy of the environmental clearance letter shall also be displayed on the website of the concerned State Pollution Control Board. The EC letter shall also be displayed at the Regional Office, District Industries centre and Collector's Office/Tehsildar's office for 30 days.	Complied.
11	These stipulations would be enforced among others under the provisions of the Water (Prevention and Control of Pollution) Act 1974, the Air (Prevention and Control of Pollution) Act 1981, the Environment (Protection) Act 1986, the Public Liability (Insurance) Act, 1991 and EIA Notification 1994, including the amendments and rules made thereafter.	Noted. The Environmental Monitoring Reports are enclosed herewith as **Annexure**.
12	All other statutory clearances such as the approvals for storage of diesel from	Noted, the project is under the construction stage. Due statutory

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
	Chief Controller of Explosives, Fire Department, Civil Aviation Department, Forest Conservation Act, 1980 and Wildlife (Protection) Act, 1972 etc. shall be obtained, as applicable by project proponents from the respective competent authorities.	clearances applicable, will be taken during the course of respective project stages as per the condition stipulated.
13	The project proponent shall advertise in at least two local Newspapers widely circulated in the region, one of which shall be in the vernacular language informing that the project has been accorded Environmental and CRZ Clearance and copies of clearance letters are available with the State Pollution Control Board and may also be seen on the website of the Ministry of Environment, Forest and Climate Change at http://www.envfor.nic.in. The advertisement should be made within Seven days from the date of receipt of the Clearance letter and a copy of the same should be forwarded to the Regional office of this Ministry at Bhopal.	Complied
14	This Clearance is subject to a final order of the Hon'ble Supreme Court of India in the matter of Goa Foundation Vs Union of India in Writ Petition (Civil) No. 460 of 2004 as may be applicable to this product.	Noted.
15	The status of compliance with the various stipulated environmental conditions and environmental safeguards will be uploaded by the project proponent on its website.	Noted.
16	Any appeal against this Clearance shall lie with the National Green Tribunal, if preferred, within a period of 30 days as prescribed under Section 16 of the National Green Tribunal Act, 2010.	Noted.
17	A copy of the clearance letter shall be sent by the proponent to the	Complied.

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

Sr. No.	EC Conditions	Compliance Status
	concerned Panchayat, Zilla Parishad/Municipal Corporation, Urban Local Body and the Local NGO, if any, from whom suggestions/ representations, if any, were received while processing the proposal. The clearance letter shall also be put on the website of the company by the proponent.	
18	The proponent shall upload the status of compliance with the stipulated EC conditions, including results of monitored data on their website and shall update the same periodically. It shall simultaneously be sent to the Regional Office of MoEFCC, the respective Zonal Office of CPCB and the SPCB.	Noted.
19	The environmental statement for each financial year ending 31st March in Form-V as is mandated to be submitted by the project proponent to the concerned State Pollution Control Board as prescribed under the Environment (Protection) Rules, 1986, as amended subsequently, shall also be put on the website of the company along with the status of compliance of EC conditions and shall also be sent to the respective Regional Offices of MoEFCC by e-mail.	Noted.

KANDLA TERMINAL PRIVATE LIMITED
KANDLA
370210

Kandla Oil Terminal Private Limited

Subject: Point-wise Compliance Status Report for Consent to Establish for Developing Integrated Facility within the existing Kandla Port at Kandla, Dist: Kutch by M/s. Kandla Port Trust Limited – Reg.

Ref No: - PC/CCA-KUTCH-1231/GPCB ID 44000 dated 22.12.2015 and Amendment of Consent to Establish dated 04.12.2017

Sr. No.	Condition	Compliance Status
2.	**SPECIFIC CONDITIONS:**	
	1. Kandla Port Trust shall strictly adhere to all conditions of CRZ Clearance issued by the Forest & Environment Department vide order no. ENV-10-2014-25-E dated 01/07/2015.	All conditions of CRZ Clearance issued vide order no. ENV-10-2014-25-E dated 01/07/2015 will be strictly adhered to. The CRZ compliance report is attached.
	2. CTE is granted conditionally that Kandla Port Trust shall not install & commission, including the construction activity of seven activities mentioned above, without obtaining environmental clearance from MoEF&CC, New Delhi.	The construction activity was commissioned after due agreement and as per Environment Clearance was issued in the year 2016 by MoEF&CC, New Delhi.
	3. Kandla Port Trust shall strictly adhere to all conditions of the Terms of Reference (ToR) (vide letter no. F. No. 11-82/2011-IA.III) by MoEF&CC, New Delhi.	Noted
3.	**CONDITION UNDER THE WATER ACT 1974:**	
	3.1 There shall be no industrial effluent generation from the loading and unloading activities at the port and other ancillary operations.	Not applicable
	3.2 The quantity of Domestic wastewater (Sewage) shall not exceed 6.4 KL/Day.	The project is under the construction stage
	3.3 The quality of the sewage shall conform to the following standards:	The project is under the construction stage

PARAMETERS	GPCB NORMS
BOD (5 days at 20 °C)	20 mg/L
Suspended solids	30 mg/L
Residual Chlorine	Minimum 0.5 mg/L

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

<table>
<tr><td></td><td>3.4 Sewage shall be disposed of through a septic tank/soak pit system.

3.5 The unit shall install meters at utilities for measuring category-wise (Category as given in Schedule II of "Water (Prevention & Control of Pollution) Cess Act-1977") consumption of water.</td><td>Noted

Noted</td></tr>
<tr><td>4.</td><td>CONDITION UNDER THE AIR ACT 1981:
4.1 There shall be no use of fuel hence there shall be no flue and process gas emission from storage handling activity and other ancillary operations.

4.2 The applicant shall provide portholes, ladder, platform, etc at chimney(s) for monitoring the air emissions and the same shall be open for inspection. The chimney(s) vents attached to various sources of emission shall be designed by numbers such as S-1, S-2, etc. and these shall be painted/ displayed to facilitate identification.

4.3 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 Standards issued by MoEF&CC dated 16th November-2009.

<table>
<tr><th>Sr. No.</th><th>Pollutant</th><th>Time Weighted Average</th><th>Concentration in Ambient air in µg/m³</th></tr>
<tr><td>1.</td><td>Sulphur Dioxide (SO_2)</td><td>Annual
24Hours</td><td>50
80</td></tr>
<tr><td>2.</td><td>Nitrogen Dioxide (NO_2)</td><td>Annual
24Hours</td><td>40
80</td></tr>
<tr><td>3.</td><td>Particulate Matter (Size <10 µm) OR PM10</td><td>Annual
24Hours</td><td>60
100</td></tr>
<tr><td>4.</td><td>Particulate</td><td>Annual</td><td>40</td></tr>
</table>
</td><td>Not Applicable

Not Applicable

The environment monitoring is being done through a NABL accredited laboratory, and the data is being submitted along with compliance reports. The latest environmental monitoring reports are enclosed as Annexure.</td></tr>
</table>

KANDLA 370210

	<table><tr><td></td><td>Matter (Size <2.5μm) OR PM2.5</td><td>24Hours</td><td>60</td></tr></table> 4.4 The level of Noise in ambient air within the premises of the industrial unit shall not exceed the following levels: Between 6 A.M. to 10 P.M.:75 dB(A) Between 10 P.M. to 6 A.M.:70 dB(A)	The latest environmental monitoring reports are enclosed as **Annexure**.
5.	**CONDITIONS UNDER HAZARDOUS WASTE:**	
	5.1 The applicant shall provide temporary storage facilities for each type of Hazardous Waste as per Hazardous Waste (Management, Handling & Transboundary Movement) Rules, 2008, as amended from time to time.	Noted, the Project is under construction stage.
	5.2 The applicant shall obtain membership of a common TSDF site for the disposal Hazardous. Waste as categorized in Hazardous Waste (Management, Handling & Transboundary Movement) Rules, 2008, as amended from time to time.	Noted, the Project is under construction stage.
6.	**GENERAL CONDITIONS**	
	6.1 Any change in personnel, equipment, or working conditions as mentioned in the consent form/order should immediately be intimated to this Board.	Noted
	6.2 The waste generator shall be totally responsible for (i.e. Collection, storage, transportation and ultimate disposal) the wastes generated.	Noted
	6.3 Records of waste generation, its management, and annual return shall be submitted to the Gujarat Pollution Control Board in Form- 4 by 31st January of every year.	Noted
	6.4 In case of any accident, details of the same shall be submitted in Form- 5 to the Gujarat Pollution Control Board.	Noted
	6.5 Applicant shall comply with the relevant provision of "Public Liability Insurance Act-91".	Noted

KANDLA OIL TERMINAL PRIVATE LIMITED
KANDLA 370210

	6.6 Unit shall take all concrete measures to show tangible results in waste generation reduction, avoidance, reuse, and recycling. Action taken in this regard shall be submitted within 03 months and also along with Form 4.	Noted, the project is under the construction stage
	6.7 Industry shall have to display online data outside the main factory gate with regard to the quantity and nature of hazardous chemicals being handled in the plant, including wastewater and air emissions and solid hazardous waste generated within the factory premises.	Noted, the project is under the construction stage
	6.8 Adequate plantation shall be carried out all along the periphery of the industrial premises in such a way that the density of plantation is at least 1000 trees per acre of land and a green belt of 10 meters width is developed.	Noted.
	6.9 The applicant shall have to submit the returns in the 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.	Noted, the project is under the construction stage

KANDLA OIL TERMINAL PVT LTD KANDLA

Kandla Oil Terminal Private Limited

Monitoring Report (for December 2024 submission)

DATA SHEET

Sr. No.	Particulars	Reply
1.	Project type: River valley/ Mining/Industry/ thermal/nuclear/Other (specify)	Development of Oil Jetty to handle Liquid Bulk and Ship bunkering Terminal at Old Kandla
2.	Name of the project	Development of Oil Jetty to handle Liquid Bulk and Ship bunkering Terminal at Old Kandla
3.	Clearance Letter (s). OM no and date	MoEF&CC File No. F.No.11-82/2011-IA-III Proposal No. IA/GJ/MIS/28772/2011 Dated 16th May 2016
4.	Location a) District (s) b) State (s)	Location: a) Kutch b) Gujarat
5.	Address for Correspondence a) address of Concerned Project Chief Engineer (with pin code & telephone/telex/fax numbers b) Address of Executive project Engineer/manager/ (with pin code fax numbers)	 Regional Head (IMCL) Near IOCL foreshore Terminal, Kandla Gandhidham, Kutch 370 201 Dy. General Manager Near IOCL foreshore Terminal, Kandla Gandhidham, Kutch 370 201
6.	Salient features a) Of the Project b) Of the Environmental Management Plan	 Jetty: 3.39 MMTPA Tank farm: About 1,37,000 KL & Allied Facilities
7.	Production Details during compliance period and (or) during the previous financial year	The project is under the construction stage.
8.	Breakup of the project area a) Submergence area: forest & non-forest b) Others	N/A
9.	Breakup of the project affected population with enumeration of those loing houses/dwelling units only agricultural land & landless laborer's/artisan	Not Applicable

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

	a) SC. ST/Adivasis b) Others (please indicate whether these figures are based on any scientific and systematic survey carried out of only provisional figures, if a survey is carried out give details and years of survey).	
10.	Financial details a) Project cost as originally planned and subsequent revised estimates and the year of prices reference b) Allocation made for environmental management plans with item wise and year wise break-up c) Benefit cost ratio/Internal rate of Return and the year of assessment Whether (c) includes the cost of environmental management plans so far. d) Actual expenditure incurred on the project e) Actual expenditure incurred on the environmental management plans so far.	Estimated Project cost: Rs. 233.50 Cr. Revised project cost: Rs. 343 Cr. (Estimated) Rs. 06 Lakhs Rs. 84.45 Cr. Rs. 04 Lakhs
11.	Forest land requirement a) The status of approval for diversion of forest land for non-forestry use b) The status of clear felling c) The status of compensatory a forestation, if any d) Comments on the viability & sustainability of compensatory a forestation programmed in the light of actual field experience so far	Nil N/A. N/A N/A N/A
12.	The status of clear felling in non-forest areas (such as the submergence area of the	N/A

KANDLA 370210

	reservoir, approach roads), if any, with quantitative information.	
13.	Status of construction a) Date of commencement (Actual and/or planned) b) Date of completion (Actual and/or planned)	The project is under the construction stage. Award of concession: December 2020 Planned date of Completion: December 2025
14.	Reasons for the delay if the Project is yet to start	The project is under construction stage, and delayed because of the Pandemic & Local hindrances.
15.	Date of site visited a) The dates on which the project was monitored by the regional office on pervious occasion. if any b) The date site visit for this monitoring report	No
16.	Details of the correspondence with project authorities for obtaining action plans/information on status of compliance to safeguard other than the routine letters for logistic support for site visit. (The first monitoring report may contain the details of all the letters issued so far but the later reports may cover only the letters issued subsequently.)	Noted.

KANDLA OIL TERMINAL PRIVATE LIMITED KANDLA 370210

GreenEnviro

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Environmental Consultancy & Laboratory
Approved by MoEF&CC

AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s. KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	30/06/2024		
Sample Drawn By	Vendor on 24/06/2024	Sample Received On	25/06/2024
Start of Analysis	27/06/2024	End Of Analysis	29/06/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 35.6^{0}C, Min- 25.4^{0}C	Relative Humidity	Max-78.2%, Min- 60.3%
Average Wind Speed	9.5 Km/Hr	Wind Direction	From EW
Flow (PM 10)	1.2 Cube Meter(1200LPM)	Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-1	Sample Qty & Pkng.	F.P(2Nos) & CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	µg/m^3	24 Hrs	76.53	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	µg/m^3	24 Hrs	42.20	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	µg/m^3	24 Hrs	17.79	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. FPS 26-F- 22, (Make: Enviro Earth Services), Model:EEC-115MFC), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024, Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

Note - 1.This Test Report refers only to the sample tested
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For **GREEN ENVIRO**

GREEN ENVIRO ENVIRONMENTAL CONSULTANCY & LABORATORY Approved by MoEF & CC Government of India

Authorized Signatory

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

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Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	30/06/2024		
Sample Drawn By	Vendor on 24/06/2024	Sample Received On	25/06/2024
Start of Analysis	27/06/2024	End Of Analysis	29/06/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 35.6^{0}C, Min- 25.4^{0}C	Relative Humidity	Max-78.2%, Min- 60.3%
Average Wind Speed	9.5 Km/Hr	Wind Direction	From EW
Sample/Report No.	GE/LAB/AAQ/KOTPL-01	Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	$\mu g/m^3$	24 Hrs	21.86	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405)
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s.KOTPL.				
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210				
Report Dated	30/06/2024				
Sample Drawn By	Vendor on 24/06/2024			Sample Received On	25/06/2024
Start of Analysis	27/06/2024			End Of Analysis	29/06/2024
Monitoring For	Ambient Air Monitoring			Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly			Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 35.5^{0}C, Min- 25.2^{0}C			Relative Humidity	Max-78.4%, Min- 60.6%
Average Wind Speed	9.4 Km/Hr			Wind Direction	From EW
Flow (PM 10)	1.2 Cube Meter(1200LPM)			Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-2			Sample Qty & Pkng.	F.P(2Nos)& CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009				
Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	µg/m^3	24 Hrs	70.57	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	µg/m^3	24 Hrs	38.04	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	µg/m^3	24 Hrs	15.63	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. GE-15-2018, (Make Natel india, Model - NPM2.5A), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024, Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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ISO 9001:2015, Reg. No. 18IQBL75
ISO 14001:2015, Reg. No. 18IEBL76
OHSAS 45001:2018, Reg. No. 18IOCF79

AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

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Report Dated	30/06/2024		
Sample Drawn By	Vendor on 24/06/2024	Sample Received On	25/06/2024
Start of Analysis	27/06/2024	End Of Analysis	29/06/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 35.5°C, Min- 25.2°C	Relative Humidity	Max-78.4%, Min- 60.6%
Average Wind Speed	9.4 Km/Hr	Wind Direction	From EW
Sample/Report No.	GE/LAB/AAQ/KOTPL-02	Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	$\mu g/m^3$	24 Hrs	19.70	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405)
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

Note - 1.This Test Report refers only to the sample tested
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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL1
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	30/06/2024
Date Of Sampling	Vendor on 24/06/2024
Date Of Analysis	26/06/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Tank Farm
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	66.2	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	51.3	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686

Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

For **GREEN ENVIRO**

GREEN ENVIRO ENVIRONMENTAL CONSULTANCY & LABORATORY

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL2
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	30/06/2024
Date Of Sampling	Vendor on 24/06/2024
Date Of Analysis	26/06/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Jeety Landfall Area
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	64.5	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	50.6	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686

Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

For **GREEN ENVIRO**

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL3
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	30/06/2024
Date Of Sampling	Vendor on 24/06/2024
Date Of Analysis	26/06/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Right Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	60.8	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	45.3	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL4
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	30/06/2024
Date Of Sampling	Vendor on 24/06/2024
Date Of Analysis	26/06/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Left Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	61.9	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	48.7	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

For **GREEN ENVIRO**

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL1	Lab Reference No: - GE/LAB/W/KOTPL01
Dated:- 30/06/2024	Date Of Sampling: - 24/06/2024
Date Of Analysis – 26/06/2024	End Of Analysis – 29/06/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard : (IS 10500:2012)	Methods of Analysis
pH @ 25 ^{0}C	Value	7.09	6.5 - 8.5	IS 3025 (Part II) 1983, Reaff: 2017
Total Dissolved Solids	mg/lit	75.13	500	IS 3025 (Part XVI) 1984, Reaff: 2017
Total Suspended Solids	mg/lit	04.01	Not Specified	IS 3025 (Part XVII)1984, Reaff- 2017
Total Hardness	mg/lit	41.35	200	IS 3025 (Part XXI) 2009, Reaff: 2019
Calcium	mg/lit	16.29	75	IS 3025 (Part 40) 1991, Reaff: 2019
Magnesium	mg/lit	08.31	30	IS 3025 (Part 46) 1994, Reaff: 2019
Chloride	mg/lit	21.62	200	IS 3025 (Part 32) 1998, Reaff: 2019

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL2	Lab Reference No: - GE/LAB/W/KOTPL02
Dated:- 30/06/2024	Date Of Sampling: - 24/06/2024
Date Of Analysis – 26/06/2024	End Of Analysis – 29/06/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard: (IS 10500:2012)	Methods of Analysis
Temperature	^0C	29	--	IS 3025 (Part 9) 1984
Electrical Conductivity 25 ^0C	µS/cm	347.5	Not Specified	IS 3025 (Part 14) – 2013
E. coli	/100ml	Absent	0-1/100ml	IS 5887 – 1 & IS15186:2002

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s. KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	29/07/2024		
Sample Drawn By	Vendor on 22/07/2024	Sample Received On	23/07/2024
Start of Analysis	25/07/2024	End Of Analysis	27/07/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 31.7⁰C, Min- 24.8⁰C	Relative Humidity	Max-80.6%, Min- 74.1%
Average Wind Speed	9.7 Km/Hr	Wind Direction	From SW
Flow (PM 10)	1.2 Cube Meter(1200LPM)	Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-1	Sample Qty & Pkng.	F.P(2Nos) & CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	$\mu g/m^3$	24 Hrs	72.64	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	$\mu g/m^3$	24 Hrs	38.91	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	$\mu g/m^3$	24 Hrs	14.67	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. FPS 26-F- 22, (Make: Enviro Earth Services), Model:EEC-115MFC), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024, Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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ISO 9001:2015, Reg. No. 18IQBL76
ISO 14001:2015, Reg. No. 18IEBL76
OHSAS 45001: 2018, Reg. No. 19IOCF79

AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s. KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	29/07/2024		
Sample Drawn By	Vendor on 22/07/2024	Sample Received On	23/07/2024
Start of Analysis	25/07/2024	End Of Analysis	27/07/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 31.7°C, Min- 24.8°C	Relative Humidity	Max-80.6%, Min- 74.1%
Average Wind Speed	9.7 Km/Hr	Wind Direction	From SW
Sample/Report No.	GE/LAB/AAQ/KOTPL-01	Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	$\mu g/m^3$	24 Hrs	18.30	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405)
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s.KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210		
Report Dated	29/07/2024		
Sample Drawn By	Vendor on 22/07/2024	Sample Received On	23/07/2024
Start of Analysis	25/07/2024	End Of Analysis	27/07/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 31.5⁰C, Min- 24.7⁰C	Relative Humidity	Max-80.9%, Min- 74.3%
Average Wind Speed	9.8 Km/Hr	Wind Direction	From SW
Flow (PM 10)	1.2 Cube Meter(1200LPM)	Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-2	Sample Qty & Pkng.	F.P(2Nos)& CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	$\mu g/m^3$	24 Hrs	68.04	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	$\mu g/m^3$	24 Hrs	35.57	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	$\mu g/m^3$	24 Hrs	12.90	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. GE-15-2018, (Make Natel india, Model - NPM2.5A), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024,
Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405)
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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OHSAS 45001: 2018, Reg. No. 19IOCF79

AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s.KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	29/07/2024		
Sample Drawn By	Vendor on 22/07/2024	Sample Received On	23/07/2024
Start of Analysis	25/07/2024	End Of Analysis	27/07/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 31.5°C, Min- 24.7°C	Relative Humidity	Max-80.9%, Min- 74.3%
Average Wind Speed	9.8 Km/Hr	Wind Direction	From SW
Sample/Report No.	GE/LAB/AAQ/KOTPL-02	Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	µg/m³	24 Hrs	15.78	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405)
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL1
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	29/07/2024
Date Of Sampling	Vendor on 22/07/2024
Date Of Analysis	24/07/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Tank Farm
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	64.9	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	49.6	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

For **GREEN ENVIRO**

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL2
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	29/07/2024
Date Of Sampling	Vendor on 22/07/2024
Date Of Analysis	24/07/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Jeety Landfall Area
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	62.8	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	48.4	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

For **GREEN ENVIRO**

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TC-8081

AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL3
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing. Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	29/07/2024
Date Of Sampling	Vendor on 22/07/2024
Date Of Analysis	24/07/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Right Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	58.3	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	46.7	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686

Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL4
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	29/07/2024
Date Of Sampling	Vendor on 22/07/2024
Date Of Analysis	24/07/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Left Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	60.1	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	47.2	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

For **GREEN ENVIRO**

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL1	Lab Reference No: - GE/LAB/W/KOTPL01
Dated:- 29/07/2024	Date Of Sampling: - 22/07/2024
Date Of Analysis – 24/07/2024	End Of Analysis – 27/07/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard : (IS 10500:2012)	Methods of Analysis
pH @ 25 ^{0}C	Value	7.29	6.5 - 8.5	IS 3025 (Part II) 1983, Reaff: 2017
Total Dissolved Solids	mg/lit	84.75	500	IS 3025 (Part XVI) 1984, Reaff: 2017
Total Suspended Solids	mg/lit	05.10	Not Specified	IS 3025 (Part XVII)1984, Reaff- 2017
Total Hardness	mg/lit	49.33	200	IS 3025 (Part XXI) 2009, Reaff: 2019
Calcium	mg/lit	21.38	75	IS 3025 (Part 40) 1991, Reaff: 2019
Magnesium	mg/lit	11.59	30	IS 3025 (Part 46) 1994, Reaff: 2019
Chloride	mg/lit	27.80	200	IS 3025 (Part 32) 1998, Reaff: 2019

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL2	Lab Reference No: - GE/LAB/W/KOTPL02
Dated:- 29/07/2024	Date Of Sampling: - 22/07/2024
Date Of Analysis – 24/07/2024	End Of Analysis – 27/07/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard: (IS 10500:2012)	Methods of Analysis
Temperature	^0C	26	--	IS 3025 (Part 9) 1984
Electrical Conductivity 25 ^0C	µS/cm	428.9	Not Specified	IS 3025 (Part 14) – 2013
E. coli	/100ml	Absent	0-1/100ml	IS 5887 – 1 & IS15186:2002

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s. KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	02/09/2024		
Sample Drawn By	Vendor on 27/08/2024	Sample Received On	28/08/2024
Start of Analysis	29/08/2024	End Of Analysis	31/08/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 29.5⁰C, Min- 22.4⁰C	Relative Humidity	Max-87.3%, Min- 81.1%
Average Wind Speed	9.3 Km/Hr	Wind Direction	From EW
Flow (PM 10)	1.2 Cube Meter(1200LPM)	Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-1	Sample Qty & Pkng.	F.P(2Nos) & CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	µg/m³	24 Hrs	78.56	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	µg/m³	24 Hrs	44.23	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	µg/m³	24 Hrs	19.91	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. FPS 26-F- 22, (Make: Enviro Earth Services), Model:EEC-115MFC), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024, Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

Note - 1.This Test Report refers only to the sample tested
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ISO 9001:2015, Reg. No. 18IQBL75
ISO 14001:2015, Reg. No. 18IEBL76
OHSAS 45001: 2018, Reg. No. 18IOCF79

AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s. KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	02/09/2024		
Sample Drawn By	Vendor on 27/08/2024	Sample Received On	28/08/2024
Start of Analysis	29/08/2024	End Of Analysis	31/08/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 29.5°C, Min- 22.4°C	Relative Humidity	Max-87.3%, Min- 81.1%
Average Wind Speed	9.2 Km/Hr	Wind Direction	From EW
Sample/Report No.	GE/LAB/AAQ/KOTPL-01	Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	$\mu g/m^3$	24 Hrs	23.65	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s.KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210		
Report Dated	02/09/2024		
Sample Drawn By	Vendor on 27/08/2024	Sample Received On	28/08/2024
Start of Analysis	29/08/2024	End Of Analysis	31/08/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 29.2°C, Min- 22.3°C	Relative Humidity	Max-87.5%, Min- 81.4%
Average Wind Speed	9.2 Km/Hr	Wind Direction	From EW
Flow (PM 10)	1.2 Cube Meter(1200LPM)	Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-2	Sample Qty & Pkng.	F.P(2Nos)& CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	µg/m³	24 Hrs	73.58	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	µg/m³	24 Hrs	41.86	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	µg/m³	24 Hrs	17.39	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. GE-15-2018, (Make Natel india, Model - NPM2.5A), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024, Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s.KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	02/09/2024		
Sample Drawn By	Vendor on 27/08/2024	Sample Received On	28/08/2024
Start of Analysis	29/08/2024	End Of Analysis	31/08/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 29.3^{0}C, Min- 22.3^{0}C	Relative Humidity	Max-87.5%, Min- 81.4%
Average Wind Speed	9.3 Km/Hr	Wind Direction	From EW
Sample/Report No.	GE/LAB/AAQ/KOTPL-02	Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	µg/m^3	24 Hrs	21.86	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405)
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL1
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	02/09/2024
Date Of Sampling	Vendor on 27/08/2024
Date Of Analysis	28/08/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Tank Farm
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	68.3	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	53.4	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686

Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL2
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	02/09/2024
Date Of Sampling	Vendor on 27/08/2024
Date Of Analysis	28/08/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Jeety Landfall Area
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	66.7	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	52.1	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL3
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	02/09/2024
Date Of Sampling	Vendor on 27/08/2024
Date Of Analysis	28/08/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Right Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	62.7	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	48.5	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL4
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	02/09/2024
Date Of Sampling	Vendor on 27/08/2024
Date Of Analysis	28/08/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Left Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	63.8	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	50.4	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL1	Lab Reference No: - GE/LAB/W/KOTPL01
Dated:- 02/09/2024	Date Of Sampling: - 27/08/2024
Date Of Analysis – 28/08/2024	End Of Analysis – 31/08/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard : (IS 10500:2012)	Methods of Analysis
pH @ 25 ^{0}C	Value	7.13	6.5 - 8.5	IS 3025 (Part II) 1983, Reaff: 2017
Total Dissolved Solids	mg/lit	78.56	500	IS 3025 (Part XVI) 1984, Reaff: 2017
Total Suspended Solids	mg/lit	04.29	Not Specified	IS 3025 (Part XVII)1984, Reaff- 2017
Total Hardness	mg/lit	43.63	200	IS 3025 (Part XXI) 2009, Reaff: 2019
Calcium	mg/lit	17.94	75	IS 3025 (Part 40) 1991, Reaff: 2019
Magnesium	mg/lit	08.75	30	IS 3025 (Part 46) 1994, Reaff: 2019
Chloride	mg/lit	23.82	200	IS 3025 (Part 32) 1998, Reaff: 2019

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL2	Lab Reference No: - GE/LAB/W/KOTPL02
Dated:- 02/09/2024	Date Of Sampling: - 27/08/2024
Date Of Analysis – 28/08/2024	End Of Analysis – 31/08/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard: (IS 10500:2012)	Methods of Analysis
Temperature	^{0}C	25	--	IS 3025 (Part 9) 1984
Electrical Conductivity 25 ^{0}C	µS/cm	373.4	Not Specified	IS 3025 (Part 14) – 2013
E. coli	/100ml	Absent	0-1/100ml	IS 5887 – 1 & IS15186:2002

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s. KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	26/09/2024		
Sample Drawn By	Vendor on 19/09/2024	Sample Received On	20/09/2024
Start of Analysis	22/09/2024	End Of Analysis	24/09/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 28.9^{0}C, Min- 23.7^{0}C	Relative Humidity	Max-89.1%, Min- 83.4%
Average Wind Speed	9.1 Km/Hr	Wind Direction	From EW
Flow (PM 10)	1.2 Cube Meter(1200LPM)	Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-1	Sample Qty & Pkng.	F.P(2Nos) & CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	µg/m^3	24 Hrs	68.75	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	µg/m^3	24 Hrs	36.53	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	µg/m^3	24 Hrs	12.89	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. FPS 26-F- 22, (Make: Enviro Earth Services), Model:EEC-115MFC), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024, Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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ISO 14001:2015, Reg. No. 18IEBL76
OHSAS 45001:2018, Reg. No. 19IOCF79

AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s. KOTPL,		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	26/09/2024		
Sample Drawn By	Vendor on 19/09/2024	Sample Received On	20/09/2024
Start of Analysis	22/09/2024	End Of Analysis	24/09/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Near Jeety Landfall Point
Sampling Duration	24 Hrly		
Ambient Temperature	Max- 28.9^{0}C, Min- 23.7^{0}C	Receptor Height	2.00 meter from G.L.
Average Wind Speed	9.1 Km/Hr	Relative Humidity	Max-89.1%, Min- 83.4%
Sample/Report No.	GE/LAB/AAQ/KOTPL-01	Wind Direction	From EW
		Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	µg/m^3	24 Hrs	16.73	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 224-I-21,(Make: Enviro Instruments), Model: ECC-RDS- 405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s.KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210		
Report Dated	26/09/2024		
Sample Drawn By	Vendor on 19/09/2024	Sample Received On	20/09/2024
Start of Analysis	22/09/2024	End Of Analysis	24/09/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 28.7°C, Min- 23.5°C	Relative Humidity	Max-89.4%, Min- 83.6%
Average Wind Speed	9.0 Km/Hr	Wind Direction	From EW
Flow (PM 10)	1.2 Cube Meter(1200LPM)	Flow (PM 2.5)	16:67 LPM
Sample/Report No.	GE/LAB/AAQ/KOTPL-2	Sample Qty & Pkng.	F.P(2Nos)& CT Bladder & 50 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Particulate matter less than 10 micron	µg/m³	24 Hrs	66.25	100	EPA/625/R-96/010a(Compendium Method IO-2.1): 2017
Particulate matter less than 2.5 micron	µg/m³	24 Hrs	33.69	60	USEPA Method Aerosol Science Tech FRM 35(4)339-342: 2017
Sulphur Dioxide	µg/m³	24 Hrs	11.47	80	IS 5182 (part II) 2001,Reaff: 2017

Equipment Used: - Fine Dust Sample, Sr. No. GE-15-2018, (Make Natel india, Model - NPM2.5A), Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024, Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405) Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT AIR QUALITY MONITORING ANALYSIS REPORT

TEST REPORT

Name Of Customer	M/s.KOTPL.		
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla - 370210		
Report Dated	26/09/2024		
Sample Drawn By	Vendor on 19/09/2024	Sample Received On	20/09/2024
Start of Analysis	22/09/2024	End Of Analysis	24/09/2024
Monitoring For	Ambient Air Monitoring	Sampling Location	Tank Farm Area
Sampling Duration	24 Hrly	Receptor Height	2.00 meter from G.L.
Ambient Temperature	Max- 28.7^{0}C, Min- 23.5^{0}C	Relative Humidity	Max-89.4%, Min- 83.6%
Average Wind Speed	9.0 Km/Hr	Wind Direction	From EW
Sample/Report No.	GE/LAB/AAQ/KOTPL-02	Sample Qty & Pkng.	CT Bladder & 30 ml P.B.(3 Nos)
Limits	National Ambient Air Quality Standards Vide GSR 826(E)16.11.2009		

Parameters	Unit	Duration	Result	Limits	Methods of Analysis
General Parameters					
Oxides of Nitrogen	µg/m^3	24 Hrs	14.81	80	IS 5182 (part VI) 2006,Reaff:2017

Respirable Dust Sample, Sr. No. 225-I-21,(Make: Enviro Instruments), Model: ECC-RDS-405)
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL1
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	26/09/2024
Date Of Sampling	Vendor on 19/09/2024
Date Of Analysis	21/09/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Tank Farm
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	61.5	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	47.8	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686

Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL2
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	26/09/2024
Date Of Sampling	Vendor on 19/09/2024
Date Of Analysis	21/09/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Near Jeety Landfall Area
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	60.7	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	46.3	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL3
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	26/09/2024
Date Of Sampling	Vendor on 19/09/2024
Date Of Analysis	21/09/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Right Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	56.4	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	44.1	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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AMBIENT NOISE MONITORING ANALYSIS REPORT

TEST REPORT

Sample/Report No.	GE/LAB/ANM/KOTPL4
Name Of Customer	M/s. KOTPL.
Address Of Customer	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report Dated	26/09/2024
Date Of Sampling	Vendor on 19/09/2024
Date Of Analysis	21/09/2024
Monitoring For	Ambient Noise Monitoring
Sampling Location	Tank Farm Left Side
Limits*	Central Pollution Control Board has prescribed 75 dB(A) as an upper limit of Noise Level during day time & 70 dB(A) during Night time
Time Of Sampling	1) Day time shall mean from 06:00 A.M. to 10:00 P.M. 2) Night time shall mean from 10:00 P.M. to 06:00 A.M

RESULTS OF ANALYSIS (DAY TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	57.2	75	IS- 9989-1991

RESULTS OF ANALYSIS (NIGHT TIME)

UNIT	READINGS	CPCB LIMITS	REFERENCE METHOD
dB(A)	45.9	70	IS- 9989-1991

REMARK/OBSERVATIONS: Monitoring results are well within the limits prescribed by CPCB.

Equipment Used: Digital Noise level meter - Lutron Model No: SL-4035SD Sr. No: Q641686
Date of Calibration: - 18/11/2023, Next Calibration Due: - 17/11/2024

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL1	Lab Reference No: - GE/LAB/W/KOTPL01
Dated:- 26/09/2024	Date Of Sampling: - 19/09/2024
Date Of Analysis – 21/09/2024	End Of Analysis – 24/09/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard : (IS 10500:2012)	Methods of Analysis
pH @ 25 ^{0}C	Value	7.02	6.5 - 8.5	IS 3025 (Part II) 1983, Reaff: 2017
Total Dissolved Solids	mg/lit	73.57	500	IS 3025 (Part XVI) 1984, Reaff: 2017
Total Suspended Solids	mg/lit	03.54	Not Specified	IS 3025 (Part XVII)1984, Reaff- 2017
Total Hardness	mg/lit	36.18	200	IS 3025 (Part XXI) 2009, Reaff: 2019
Calcium	mg/lit	14.92	75	IS 3025 (Part 40) 1991, Reaff: 2019
Magnesium	mg/lit	06.48	30	IS 3025 (Part 46) 1994, Reaff: 2019
Chloride	mg/lit	19.27	200	IS 3025 (Part 32) 1998, Reaff: 2019

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DRINKING WATER SAMPLE ANALYSIS REPORT

CLIENT'S NAME	M/s. KOTPL.
CLIENT'S ADDRESS	Opp. Shirva Railway Crossing, Near Ioc Foreshore Terminals New Kandla – 370210
Report No: - GE/LAB/W/KOTPL2	Lab Reference No: - GE/LAB/W/KOTPL02
Dated:- 26/09/2024	Date Of Sampling: - 19/09/2024
Date Of Analysis – 21/09/2024	End Of Analysis – 24/09/2024
Details Of Sample- Drinking Water	Quantity of Sample Received – 2 Lit
Sample Collected By – Vendor	Sample Container – Sterilized Bottle
Sample Nature – Drinking	Location – Near Office Area

RESULTS OF ANALYSIS

Parameter	Unit	Result	Standard: (IS 10500:2012)	Methods of Analysis
Temperature	^0C	24	--	IS 3025 (Part 9) 1984
Electrical Conductivity 25 ^0C	μS/cm	321.9	Not Specified	IS 3025 (Part 14) – 2013
E. coli	/100ml	Absent	0-1/100ml	IS 5887 – 1 & IS15186:2002

For **GREEN ENVIRO**

GREEN ENVIRO ENVIRONMENTAL CONSULTANCY & LABORATORY

Authorized Signatory

Note – 1. Results relate only to the sample tested.
2. Test report shall not be reproduced except in full, without written approval of the laboratory
3. This report, in full or in part, shall not be used for advertising or legal action.

---End of the Report---

ANNEXURE B
S1, S2, S3 report of Contaminant in Dredged material

FIRST SEASON REPORT

(2023-24)

for the Project entitled

"Studies on Dredged Materials for the presence of Contaminants"

(As per EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016- specific condition no. vii)

DPT Work order No. EG/WK/4751/Part (EC&CRZ-1)/84. Dt.18.09.2021

Submitted by

Gujarat Institute of Desert Ecology

P.B. No. 83, Mundra Road

Opp. Changleshwar temple

Bhuj - Kachchh, Gujarat – 370001, India

Submitted to

Deendayal Port Authority

Administrative Office Building

Post Box No. 50

Gandhidham (Kachchh)

Gujarat - 370201

Project Team

Project Co-Ordinator **:** Dr. V. Vijay Kumar, Director

S. No	Name and Designation	Role	Background
1.	Dr. K. Karthikeyan Assistant Director	Principal Investigator	M.Sc., Ph.D. in Environmental Science; 15 years of experience in Marine Environmental Monitoring and Pollution Assessment studies.
2.	Dr. G. Jayanthi Scientist	Co- Investigator	MSc., MPhil., PhD in Botany; 13 years of Research and teaching experience inclusive of Post-Doctoral experience for 5 years.
3.	Dr. Krushnakant. D. Baxi Scientific Officer	Co- Investigator	Ph.D in Zoology (Marine Biology) with 5 years of experience
4.	Ds. Monika Sharma Sr. Scientific Asst.	Team member	M.Sc. in Environmental Sciences; 7 years of experience in Marine water and sediment analysis
5.	Ms. Dipti Parmar Scientific Assistant	Team member	M.Sc. in Environmental Sciences; 6 years of experience in sediment and water analysis.

Dr. V. Vijay Kumar
Director

Gujarat Institute of Desert Ecology

Certificate

This is to state that the **First Season Report** of the work entitled, **"Studies on Dredged Material for the presence of contaminants"** has been prepared in line with the Work order issued by DPT vide No. EG/WK/4751/Part (EC & CRZ-1)/84. Dt.18.09.2021 as per the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016, Specific Condition No. vii. This work order is for a period of Three years from 2021 –2024 for the above-mentioned study.

Authorized Signatory

Gujarat Institute of Desert Ecology Bhuj

Institute Seal

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CONTENTS

Among the twelve major ports across the nation, Deendayal Port Authority, formerly known as Deendayal Port Trust, erstwhile called as Kandla Port Trust, holds a prominent position as a significant maritime gateway in India, situated within Gujarat's Kutch district. This stands out as the largest Creek-based port, positioned at the southwestern tip of the Gulf of Kachchh, on India's north-western coastline within the state of Gujarat. Deendayal Port Authority (DPA) serves as a pivotal hub for maritime trade, facilitating the transportation needs of several hinterland states. It boasts excellent connectivity through an extensive rail and road network, functioning as a crucial gateway for the export and import activities of northern and western Indian states, including Jammu & Kashmir, Delhi, Punjab, Himachal Pradesh, Haryana, Rajasthan, Gujarat, as well as parts of Madhya Pradesh, Uttaranchal, and Uttar Pradesh. This port ranks among the largest and most essential ports in the country, playing a vital role in India's international trade and maritime infrastructure. The administration and operations of the port are overseen by the Deendayal Port Trust (DPT), an autonomous entity established under the Major Port Trusts Act of 1963.

The Deendayal Port Trust is entrusted with the comprehensive management, development, and administration of the port. The authority is comprised of a dedicated team of professionals and experts who work diligently to ensure the efficient operation of the port and all related activities. About 35% of the country’s total export takes place through the ports of Gujarat in which the contribution by Deendayal port is considerable. The port handled a total cargo of 105 MMTPA during 2016-17, 110 MMTPA during 2017-18, 115 MMTPA during 2018-19, 122.5 MMTPA during 2019-2020, 117.5 MMTPA during 2020-21 and 137 MMTPA during 2022-23. DPA is the only major Indian port to handle more than 127 MMT cargo throughput, and it has also registered the highest cargo throughput in its history. The port has handled a total of 3151 vessels during FY 2021-22. Over the years, the port has witnessed significant growth and development, becoming a crucial gateway for India's international trade. Deendayal Port has a strategic location on the west coast of India, offering direct access to the Arabian Sea. It serves as a vital link for India's trade with countries in the Middle East, Africa, Europe, and Asia. The port handles a wide range of cargoes, including petroleum products, chemicals, coal, iron ore, fertilizers, salt, and general cargo.

Further, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. With such capacity, the Port ranks No. 1 among all the major ports in India for 12th Consecutive year. Further, a regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. The port has high commercial importance in the Indian maritime trade as it handled 36.1 million tons (17%) of Cargo out of total Cargo of 213.1 million tons of the maritime Cargo of India during 2015. In addition, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements.

Deendayal Port Authority (DPA) has taken up Development of 7 Integrated facilities, and the Ministry of Environment, Forest and Climate Change (MoEF & CC), has put up some conditions while according Environmental and CRZ clearance. One of the conditions is to carry out the *"Study on Dredged Material for presence of contaminants"* as accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific condition no. vii)" which states that ***"Dredged materials should be analyzed for presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted and the findings should be shared with the Gujarat SPCB and Regional Office of the Ministry"***.

1.1 Need of the study

Considering the aforementioned condition, DPA has assigned the task of carrying out the study to Gujarat Institute of Desert Ecology (GUIDE), Bhuj. This study will be attempted three times in a year at two specified locations. Further, the study will envisage the evaluation of physico-chemical constituents in the dredged materials in the dumped locations in the study area. GUIDE has been entrusted with the project, which has duration of three years (01.11.2021 – 31.10.2024) as specified in the work order. Accordingly, the study was initiated to evaluate the dredged materials for potential contamination, employing a systematic investigation that encompasses the analysis of physical, chemical, and biological characteristics with special reference to pollutants including heavy metal, Petroleum hydrocarbon etc.

1.2. Scope of the study

a. To monitor the locations where dredged materials are dumped will be conducted.
b. Dredged materials in the area will be analyzed for the presence of contaminants in two different locations.
c. Detailed assessment of the dredged materials for physical, chemical and biological characteristics will be studied.
d. Suggesting suitable disposal options for the dredged material will be made.

1.3. Sampling locations for 2023-24

The study focused on investigating the presence of contaminants in the dredged materials during the year 2022-24. The specific locations for sampling can be found in Table 1 and Plate 1. The selection of these sampling sites was based on information supplied by the Hydraulic and Dredging Division to the Department of Port Administration (DPA), concerning the locations of dumping grounds. These location details were subsequently shared with the Gujarat Institute of Desert Ecology (GUIDE) via an email dated October 24, 2018. Three seasonal studies covering Location 1, Location 2 and Location 3 with the First season of the study was conducted during 22.01.2024 – 24.01.2024.

Table 1: GPS Co-ordinates of sampling locations

Station	Latitude (N)	Longitude (E)
Location 1 (Offshore)	22° 51' 00" N	70° 10’ 00" E
Location 2 (Cargo jetty)	22°56' 31" N	70 13' 00" E
Location 3 (Phang Creek)	23° 04' 28" N	70°13’ 28" E

1.4. Details of work done during 2nd Quarter (February 2024 – April 2024)

The First season sampling of the project was conducted in the 1st Quarter of the project period, i.e., 2023-24. The First season sampling was performed in the month of January 2024. During the sampling, the surface and bottom marine water samples and bottom marine sediment samples were collected from the three designated locations, *i.e.,* Offshore, Cargo Jetty and Creek systems which was pre-designated locations as earmarked by CPWRS was conducted.

After the collection, the samples were preserved using standard protocols and stored in an Ice box and brought to the laboratory within 2-3 hrs of collection Comprehensive analysis was performed on all the samples, both water (36 samples) and sediment (18 samples), to determine various physical, chemical, and biological characteristics. The analysis followed the standard methods prescribed by the Integrated Coastal and Marine Area Management (ICMAM) in 2012. All samples were analysed in triplicates, and the obtained data was compared against the marine water limits specified by the Central Pollution Control Board (CPCB) and other relevant standards.

Plate 1: Map showing locations of proposed sampling (2023-2024)

The sediment samples from the study area were collected for the purpose of characterization employing standard methodology and the analysis of the samples were also performed as per standard protocol and the data of sediment analysis is presented in this Chapter 1. The sediment samples were collected in pre-fixed stations using a Van-Veen type of grab sampler. After collection, the sediment samples were preserved with Rose Bengal and formalin to avoid decomposition of samples and processed for analysis and the samples after collection were brought to the laboratory on the same day of collection and air dried and used for further analysis for the test parameters (Table 2).

Table 2: Physico-chemical and biological characteristics of sediment samples

S. No.	Physico-chemical and biological parameters
1	pH (1: 10 suspension)
2	Salinity (ppt)
3	Sand (%)
4	Silt (%)
5	Clay (%)
6	Total organic carbon (%)
7	Phosphorus (mg/kg)
8	Sulphur (mg/kg)
9	Petroleum Hydrocarbon (µg/kg)
10	Cadmium (mg/kg)
11	Lead (mg/kg)
12	Chromium (mg/kg)
13	Copper (mg/kg)
14	Cobalt (mg/kg)
15	Nickel (mg/kg)
16	Zinc (mg/kg)
17	Magnesium (mg/kg)
18	Macrobenthos

2.1. pH and Salinity (1: 10 suspension)

The pH of the sediment suspension is a measure of the activity of H+ ions within the sediment-water system. It indicates whether the sediment is acidic, neutral or alkaline in nature. Since ions are the carrier of electricity, the electrical conductivity (EC) of the sediment-water system rises according to the content of soluble salts. The EC measurement directly corresponds to the concentration of soluble salts in the sediment at any particular temperature. To conduct the analysis, ten grams of the finely sieved sediment was dissolved in 100ml of distilled water to prepare leachate. This leachate was taken for shaking using a rotator shaker for one hour to ensure proper homogenization of the suspension. Following this, the suspension was allowed to settle for two hours, and the supernatant was collected after filtration for the subsequent analysis of pH and salinity using the pH and EC meter (Make: Systronics 361) and Refractometer (Make: Atago) respectively. Each sample was analyzed in triplicates to ensure accuracy, and the mean values were considered for further evaluation.

2.2. Textural analysis (Sand/Silt/Clay)

Sediment samples were collected using Van Veen grab whereas intertidal sediments will be collected using a handheld shovel. After collection, the scooped samples are transferred to polythene bags, labelled and stored under refrigerated conditions. The sediment samples are thawed, oven dried at 40ºC and ground to a fine powder before analyses.

For texture analysis, specified unit of sediment samples were sieved using sieves of different mesh size as per Unified Sediment Classification System (USCS). Cumulative weight retained in each sieve will be calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves. The percent retained will be calculated from the weight retained and the total weight of the sample. The cumulative percent will be calculated by sequentially subtracting percent retained from 100%.

2.3. Total organic carbon

Total organic carbon refers to the carbon content stored within sediment organic matter. It is derived from various sources such as the decomposition of plant and animal residues, root exudates, living and deceased microorganisms, sediment biota etc. To measure total organic carbon in sediment, a process of oxidation is employed using potassium dichromate in the presence of concentrated sulfuric acid. During the analysis, potassium dichromate generates nascent oxygen, which reacts with the carbon present in organic matter, resulting in the production of carbon dioxide (CO2). The excess volume of potassium dichromate is then titrated against a standardized solution of ferrous ammonium sulfate in the presence of phosphoric acid, using Ferroin indicator to detect the initial appearance of unoxidized ferrous iron. This titration allows the determination of the volume of potassium dichromate required to oxidize the organic carbon present in the sample.

Procedure

The determination of the percentage of total organic carbon in sediment involves oxidizing the organic matter within the sediment samples using chromic acid. The excess chromic acid is then estimated by titrating it against ferrous ammonium sulfate, with ferroin serving as an indicator. The step-by-step procedure is outlined as follows:

To begin, 1 gram of sediment sieved to a particle size of 0.5 mm is weighed and transferred into a 500 ml conical flask. Then, 10 ml of 1N $K_2Cr_2O_7$ is added to the flask with pipette followed by gentle swirling to ensure thorough mixing. Next, 20 ml of concentrated H2SO4 is added, and the sediment and reagents are mixed gently. This mixture is allowed to react for 30 minutes on a marble stone to avoid any damage caused by the release of intense heat from the sulfuric acid reaction. Afterward, 200 ml of distilled water is slowly added to the flask, along with 10 ml of concentrated orthophosphoric acid and approximately 0.2 grams of NaF. The sample and reagent mixture is left to stand for 1.5 hours, as the titration endpoint is better observed in a cooled solution. Just before the titration, 1 ml of ferroin indicator is added to the conical flask. The excess $K_2Cr_2O_7$ is then titrated with 0.5 N ferrous ammonium sulfate until the color changes from yellowish green to greenish, and finally to a brownish-red color indicating the endpoint. A blank test without the sediment sample is also performed simultaneously for reference. Through this procedure, the percentage of total organic carbon in the sediment can be accurately determined.

2.4. Total Phosphorus

The determination of total phosphorus in sediment is commonly conducted using Bray's extraction method. This method involves the formation of specific-colored compounds by adding appropriate reagents to the solution, with the intensity of the color being directly proportional to the concentration of phosphorus being estimated. The color intensity is measured spectrophotometrically. In the spectrophotometric analysis, a light source emitting light of a specific wavelength (usually within a band width of 0.1 to 1.0 nm) in the ultraviolet region of the spectrum is used. The photoelectric cells in spectrophotometer measure the light transmitted by the solution allowing for quantitative analysis.

Procedure

To perform the analysis, 50 ml of the Bray's extractant is added to a 100 ml conical flask containing 5 grams of sediment sample. The flask is shaken for 5 minutes and then filtered. Exactly 5 ml of the filtered sediment extract is transferred to a 25 ml measuring flask using a bulb pipette. Subsequently, 5 ml of the molybdate reagent is added using an automatic pipette, followed by dilution to 20 ml with distilled water and shaken well. Furthermore, 1 ml of dilute Stannous Chloride solution is added, and the volume is made up to the 25 ml mark. Thorough shaking is performed to ensure proper mixing. The mixture is then allowed to develop color, and after 10 minutes, readings are taken in the spectrophotometer at a wavelength of 660 nm. Prior to the readings, the instrument is zeroed using a blank prepared similarly but without the sediment.

2.5. Total Sulphur

Total sulphur in the sediment extract was determined using a turbidimetric method with a spectrophotometer. A series of standards containing sulphur at concentrations of 2, 4, 6, 8, and 10 ppm were prepared from a stock solution. Each flask in the series received 25 ml of the respective standard solution, and 2.5 ml of conditioning reagent solution was added. Additionally, 5 ml of extraction solution was added to the mixture. To facilitate the reaction, 0.2-0.3 grams of barium chloride were included and thoroughly mixed. The volume was adjusted to 25 ml with distilled water, and readings were taken at 340 nm using a spectrophotometer.

For the sample analysis, 5 grams of marine sediment were placed in a 100 ml conical flask. To this, 25 ml of a 0.15% $CaCl2$ solution was added and shaken for 30 minutes. The mixture was then filtered through Whatman No. 42 filter paper. Subsequently, 5 ml of the sample aliquot was transferred into a 25 ml volumetric flask. Conditioning reagent (2.5 ml) and 0.2 to 0.3 grams of barium chloride powder were added, followed by making up the volume to 25 ml with distilled water. The flask contents were shaken for 2 minutes, and the absorbance was measured using the same procedure as the standard solutions.

2.6. Petroleum Hydrocarbons

To analyze petroleum hydrocarbons in sediment, the following procedure will be conducted. First, the sediment will undergo reflux with a mixture of KOH and methanol, allowing for the extraction of petroleum hydrocarbons. This reflux process helps release the hydrocarbons from the sediment matrix. Next, the sediment will be subjected to extraction using hexane, which selectively dissolves the hydrocarbons present in the sediment. The excess hexane will be carefully removed, leaving behind a residue containing the concentrated hydrocarbons of interest. To further purify the sample and remove any impurities, a clean-up procedure will be performed using silica gel column chromatography. This column chromatography process helps separate the hydrocarbons from other compounds present in the residue, resulting in a cleaner sample for analysis. Finally, the hydrocarbon content in the sediment will be estimated by measuring fluorescence, following the standard method for petroleum hydrocarbon analysis. This fluorescence measurement allows for quantification and determination of the hydrocarbon levels present in the sediment sample. By following this procedure, accurate analysis of petroleum hydrocarbons in sediment can be achieved.

2.7. Heavy metals

Heavy metals, such as Cadmium (Cd), Lead (Pb), Chromium (Cr), Nickel (Ni), Cobalt (Co), Copper (Cu), Zinc (Zn), Manganese (Mn), and others, are of particular concern in relation to the environment. To release mineral elements from sediment samples, wet oxidation is commonly employed, utilizing oxidizing acids, such as tri/di-acid mixtures.

In the analysis procedure, a sediment sample weighing 1.0 gram is taken in a 100 ml beaker, which is covered with a watch glass. A mixture of Aqua regia (1:3 HNO_3:HCl) in the amount of 12 ml is added to the beaker. The beaker is then subjected to digestion for 3 hours at 100°C on a hot plate using a sand bath. Afterward, the samples are evaporated to near dryness, allowed to cool for 5 minutes, and then 20 ml of 2% nitric acid is added. The beaker is placed on a hot plate for digestion for 15 minutes, after which it is removed from the hot plate and allowed to cool. The mixture is then filtered using Whatman No. 42 mm filter paper. Finally, the volume is adjusted to 50 ml with 2% nitric acid to make up the final solution. The extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis. By following this procedure, the heavy metal content in the sediment can be accurately analyzed using wet oxidation, filtration, and AAS techniques.

2.8. Results

2.8.1. pH (Hydrogen Ion)

When any characteristics study of water or sediment is concerned, pH is considered to be one of the major variable especially in marine sediments as it influences various biogeochemical processes and ecosystem dynamics. These values are influenced by various factors, including the carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron, and manganese cycles. They are closely associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and the dissolution of calcium carbonate in marine water and sediments. In our investigation, we conducted measurements of average pH values at different locations. The offshore area exhibited an average pH of 8.18±0.13, the cargo jetty had an average pH of 8.15±0.05, and the Phang Creek showed an average pH of 8.26±0.07. The data on individual values at all the locations and stations are given in Table 3.

2.8.2. Salinity

Salinity of seawater is subject to fluctuations influenced by temperature changes, following diurnal and seasonal cycles that correspond to variations in atmospheric temperature. Salinity levels in marine water and sediment exhibit a wide range, typically spanning from 0 to 36 in most estuaries. Semi-enclosed bays can experience hyper-salinity conditions. In the present study, it was observed that a broader range of salinity concentrations at different stations. The highest salinity concentration of 51.00 ppt was recorded at station 1A in the Offshore area, while the lowest salinity concentration of 19.50 ppt was found at station 2 Cargo Jetty. The mean ± standard deviation (SD) salinity values were determined to be 41.10±7.92 ppt, 35.25±11.84 ppt, and 31.44±4.04 ppt in the offshore, cargo jetty, and Phang creek, respectively. These findings are summarized in Tables 3-5, where all the data is presented.

2.8.3. Sediment Texture

Understanding the sediment texture at different stations provides valuable insights into the habitat characteristics and ecological dynamics of the marine environment. The sediment texture plays a significant role in determining the physical and chemical properties of the marine sediment, influencing the distribution and abundance of benthic organisms at the offshore station, the average percentage composition of sand, silt, and clay was found to be 28.65 %, 9.53 % and 61.82 %, respectively. The cargo jetty station exhibited average percentages of 44.92% for sand, 25.28 % for silt, and 29.80 % for clay. Similarly, at the Phang creek station, the average percentages were 40.60% for sand, 26.23% for silt, and 33.17% for clay. These findings are summarized in Tables 3-5, which presents the data from all the stations.

2.8.4. Total organic Carbon

Total Organic carbon in sediments primarily originates from the decomposition of animals, plants, and anthropogenic sources such as chemical waste, fertilizers, and organic-rich waste. These sources contribute to the enrichment of the marine environment with organic material, which subsequently settles to the bottom sediments from the water column. This pathway leads to an increase in Total Organic Carbon (TOC) values and can have implications for the faunal communities inhabiting the sediments. In our study, during this first season, it was investigated the TOC concentrations at different stations. The mean ± standard deviation (SD) TOC percentages were determined to be 0.48±0.19% at the offshore station, 0.89±0.20% at the cargo jetty station, and 0.57±0.08% at the Phang creek station. The TOC concentrations at all stations are presented in Tables 3-5. Understanding the dynamics of organic carbon in marine sediments is vital for assessing the health and ecological integrity of marine environments. It helps in monitoring anthropogenic influences and their potential impacts on the marine ecosystem.

2.8.5. Organic matter

Organic matter serves as the primary reservoir of organic carbon in marine sediments, encompassing the chemical, physical, and biological degradation processes that contribute to the formation of organic material in the marine environment. It consists of a mixture of materials derived from various planktonic and benthic species, forming the ecological foundation for primary producers and consumers in the overlying surface sediment.

In our study conducted during the First season, we investigated the levels of organic matter in different locations. The organic matter percentages ranged from 0.62% to 1.49% in the offshore location, 1.18% to 1.96% at the cargo jetty, and 0.77% to 1.93% in the Phang creek area and the findings are summarized in the below tables (3-5), which illustrates the variation in organic matter content across the studied locations. Understanding the presence and dynamics of organic matter in marine sediments is crucial for assessing the overall health and ecological functioning of marine ecosystems. It provides insights into the cycling of carbon and nutrients, as well as the interactions between different species and trophic levels within the sediment community. Monitoring and studying organic matter in marine sediments helps to comprehend the intricate processes that shape marine environments and their associated biota.

2.8.6. Phosphorus and Sulphur

Sulphur (S) is involved in dissimilatory sulfate reduction by microbial activity, which is a primary pathway for organic matter mineralization in anoxic sea beds. This process leads to the production of sulfide. Subsequently, chemical or microbial oxidation of the produced sulfide forms a complex network of pathways in the sulfur cycle, resulting in intermediate sulfur species and partial conversion back to sulfate. On the other hand, Phosphorus (P) is an essential nutrient for life and plays a crucial role in regulating primary productivity within marine systems. It serves as a key element in various biological processes. In marine sediments, phosphorus availability influences primary productivity, affecting the growth and development of marine organisms.

In the present study, the highest concentration of sulphur was recorded as 48.33 mg/kg was recorded at Offshore station, while the lowest concentration of 26.52 mg/kg was observed at Phang creek. The concentrations of phosphorus and sulphur at all stations are presented in Tables 3,4 and 5. Similarly, the highest phosphorus concentration was found to be 50.00 mg/kg at Phang creek location, while the lowest concentration of 6.81 mg/kg was observed at Offshore station. Further, understanding the levels of phosphorus and sulphur in marine sediments is crucial for comprehending nutrient dynamics and biogeochemical processes in marine ecosystems. These elements influence the availability of essential nutrients and can have implications for primary productivity and the overall functioning of marine ecosystems.

2.8.7. Petroleum hydrocarbon

Petroleum hydrocarbons in general have low solubility in marine water and tend to adsorb onto particulate matter, leading to their long-term persistence in sediment bottoms. This persistence can have significant negative impacts on benthic aquatic communities within the marine ecosystem. PHCs are a major source of contamination in marine environments, primarily comprising compounds from three classes: alkanes, olefins, and aromatics. In the present study, the levels of PHCs in different locations were measure. The range of PHC concentrations was found to be 0.48 – 1.39 µg/kg in the offshore area, 06.4 – 1.10 µg/kg at the cargo jetty and 0.53 – 1.22 µg/kg in the

Phang Creek. The highest concentration of PHCs with 1.39 µg/kg was observed at station 1C (Offshore), while the lowest concentration with 0.48 µg/kg was also found at a different point at the same station 1D (Offshore Creek). The presence of petroleum hydrocarbons in marine environments is of great concern due to their potential harmful effects on marine organisms and ecosystems. These contaminants can bioaccumulate in organisms and disrupt their physiological processes, as well as cause long-lasting damage to the benthic communities. Continuous monitoring and mitigation efforts are necessary to prevent and minimize the negative impacts of petroleum hydrocarbon contamination in marine ecosystems.

2.8.8. Magnesium

Understanding the distribution and dynamics of magnesium in marine sediments provides valuable insights into the geochemical processes occurring within the sediment column and their impact on the marine ecosystem. Continuous monitoring of magnesium levels is crucial for assessing the health and ecological integrity of marine environments. Dissolved magnesium flux from the overlying ocean into marine sediments is primarily driven by molecular diffusion. This process occurs as pore water magnesium is depleted during the formation of authigenic minerals within the sediment column. Additionally, direct burial of seawater occurs as sediment accumulates on the seafloor, contributing to the input of magnesium into the sediment. Its concentration in sediments can have implications for nutrient availability, sediment mineralogy, and the diverse organisms inhabiting the sediment environment.

In our study conducted during the First season at Deendayal Port, we determined the concentrations of magnesium at different stations. The average ± standard deviation (SD) magnesium concentrations were found to be 1548.42±227.70 mg/kg at the offshore station, 1450.67±365.58 mg/kg at the cargo jetty, and 1573.58±256.28 mg/kg at the Phang Creek station. The highest concentration of magnesium 1919.50 mg/kg was observed at station 2D (Cargo Jetty Creek), while the lowest concentration with 1008.00 mg/kg was found at Control point in the same location.

2.8.9. Heavy metals

The heavy metal concentration in the sediment samples were examined for the presence of heavy metals from the samples collected from various stations at different locations at Deendayal Port. The concentrations of Lead was found to be Below Detection Limit in all the three location. The highest concentration of nickel was found to be 54.50 mg/kg at Offshore and Cargo Jetty location, while the lowest concentration of Nickel was observed at Cargo Jetty (36.40 mg/kg). Among the three stations, site 2B (Cargo Jetty) recorded the highest concentration of zinc, with 55.95 mg/kg at and the Control site at the Cargo jetty location recorded the Below Detection Limit of Zinc.

In case of Manganese, the 2E site at Cargo jetty had the highest concentration of 825.50 mg/kg, while Control 2 in Cargo jetty recorded the lowest mean concentration of 184.00 mg/kg. The highest concentration of cadmium of 19.90 mg/kg was observed in Cargo Jetty station, whereas the lowest concentration of 0.85 mg/kg was found at station Offshore location (Site 1C). The data is presented in Tables 3-5.

Table 3: Physico-chemical characteristics of sediment samples collected from Offshore location

S. No	Parameters	1A	1B	1C	1D	1E	Control 1
1	pH (1: 10 suspension)	8.14	8.19	8.20	8.00	8.40	8.14
2	Salinity	33.00	30.20	44.41	45.29	51.00	42.67
3	Petroleum Hydrocarbon	0.988	0.9874	1.3915	0.48	0.6531	0.6512
4	Magnesium	1723.5	1383	1806	1507	1667.5	1203.5
5	Sand (%)	25.1	14.8	27.5	43.4	29.6	31.5
	Silt (%)	4.8	5.0	7.8	22.3	5.9	11.4
	Clay (%)	70.1	80.2	64.7	34.3	64.5	57.1
6	Organic matter (%)	0.67	0.62	0.77	1.49	0.67	0.72
7	Total organic carbon	0.39	0.36	0.45	0.87	0.39	0.42
8	Phosphorus	6.81	8.63	10.68	11.59	12.50	13.63
9	Sulphur	34.91	32.02	31.94	45.16	48.33	33.30
10	Nickel	41.35	54.5	36.4	37.65	47.25	BDL
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	9.95	14.9	0.85	14.8	12.4	12.1
13	Chromium	77.2	31.7	37.1	54.4	37.95	44.45
14	Zinc	BDL	50.35	34.75	49.8	49.65	43.7
15	Copper	5.6	5.2	11.55	26.65	13.6	11.95
16	Manganese	664	645.5	750.5	824	795	732.5
17	Cobalt	BDL	BDL	4.35	7.85	7.05	4.3

Table 4: Physico-chemical characteristics of sediment samples collected from Cargo jetty

S. No	Parameters	2A	2B	2C	2D	2E	Control 2
1	pH (1: 10 suspension)	8.13	8.2	8.16	8.06	8.13	8.2
2	Salinity	47.00	40.93	45.29	36.92	21.86	19.50
3	Petroleum Hydrocarbon	0.8864	1.0957	0.8895	0.837	0.6447	0.6573
4	Magnesium	1074.5	1465	1783.5	1919.5	1453.5	1008
5	Sand (%)	43.1	36.7	34.9	29.9	47.3	77.6
	Silt (%)	28.5	34.7	20.0	18.5	32.8	17.2
	Clay (%)	28.4	28.6	45.1	51.6	19.9	5.2
6	Organic matter (%)	1.96	1.91	1.29	1.60	1.24	1.18
7	Total organic carbon	1.14	1.11	0.75	0.93	0.72	0.69
8	Phosphorus	17.72	18.40	14.77	43.86	47.27	31.13
9	Sulphur	36.36	34.61	35.05	38.94	34.50	26.72
10	Nickel	41.35	54.5	36.4	37.65	47.25	BDL
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	9.8	17.4	19.9	5.25	17.7	6.75
13	Chromium	72.2	171.25	50.5	46.7	47.15	7.25
14	Zinc	42.55	55.95	31.45	51.4	44.45	BDL
15	Copper	18	28.95	16.7	18.2	20.2	BDL
16	Manganese	810.5	825	816.5	775.5	825.5	184
17	Cobalt	7.95	8.2	3.95	6.1	9.25	BDL

Table 5: Physico-chemical characteristics of sediment samples collected from Phang creek

S. No	Parameters	3A	3B	3C	3D	3E	Control 3
1	pH (1: 10 suspension)	8.18	8.32	8.17	8.33	8.28	8.30
2	Salinity	35.62	31.87	29.09	28.91	36.66	26.47
3	Petroleum Hydrocarbon	1.2217	1.1875	0.8305	0.542	1.0876	0.5261
4	Magnesium	1061	1630.5	1728.5	1673	1610	1738.5
5	Sand (%)	28.1	42.6	35.5	42.5	55.1	39.8
	Silt (%)	11.5	38.8	14.5	34.4	35.0	23.2
	Clay (%)	60.4	18.6	50.0	23.1	9.9	37.0
6	Organic matter (%)	0.82	0.98	1.08	1.03	0.77	1.13
7	Total organic carbon	0.48	0.57	0.63	0.6	0.45	0.66
8	Phosphorus	35.90	45.22	40.22	8.86	6.13	50.00
9	Sulphur	33.27	30.41	28.47	26.52	35.11	31.83
10	Nickel	32.55	38	36.45	40.55	53.45	36.65
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	15.35	9.2	10.15	16.6	18	16.85
13	Chromium	38.8	51.85	45.45	55.1	71.75	113.85
14	Zinc	41.7	39.75	47.35	18.9	25.65	23.2
15	Copper	9.95	18.55	13.85	19.2	23.05	20.4
16	Manganese	621.5	752.5	780	790.5	774	799.5
17	Cobalt	3.65	0.6	5.7	5.9	3.85	1.3

3.1. Introduction

"Planet Earth is dominated by the seas". One of the most important natural resources that cover much of the earth's surface is Ocean. Earth surface contains more than 97% of water in which the oceans show biggest part of the life. The five oceans together constitute approximately 71% of the world's water bodies. Indian Ocean is the third largest ocean in the world with average depth of 3,890 meters (12,760 ft). The Indian ocean's connection is a very large scale, including the Red Sea, East Africa, the Persian Gulf, Southern Arabia, India and Other Indian sub continental countries. This connection network connected people from all the coastal areas of the Indian Ocean and beyond, trading in aromatics, textiles, spices, precious stones, industrial productions, grain and an incredible range of other commodities and substances. Gujarat state of India shows longest coastline compare to other Indian states. Gujarat coastline is famous for various coastal ecosystems and habitats such as estuary, coral reefs, marshes, mangroves, and lagoons, rocky and sandy areas. The Kachchh, largest district of the country with an area of 45,652 sq. km. Deendayal Port Authority is (DPT) one among the 12 major ports of the country and it is located in India's western coastal region

Benthos

Benthos is nothing but water bottom communities or the organisms (floral and faunal) live in a benthic region regarding the sediment, rock and other substratum. They include mollusca (gastropods and bivalves), coral, sponges, worms (mostly polychaetes and nematode), crustacean crabs, other crustaceans, echinoderms, oysters etc. Benthic animals are considered as the organism which lives in the bottom layer of all types of ecosystems including saline water as well as in freshwater. However, this term 'benthos' is used as an expressive term for the entire bottom community. On the basis of distribution of benthos in water, they can be classified into three types which are, Endo-benthos, Epi-benthos (Pearson and Rosenberg, 1978) and Hyper-benthos (Mees and Jones,1997). Benthos could also recognize as one of the best indicators to assess the health and productivity of aquatic ecosystems. The benthic particularly macro benthic communities are an integral part of the coastal biotic components. They can serve as important food resource for the diverse groups of various organisms particularly bottom feeding animals. They are sensitive to wide range of environmental challenges including water movements, pollutants and living spaces (Martin et al., 2011), which make them to be considered as the important biological indicator species, which are used for monitoring marine environment. Based on size, Benthos mainly divided into 3 types namely, Macrobenthos (> 1 mm), Meiobenthos (< 1 mm or > 0.1 mm) and Microbenthos (< 0.1 mm).

3.2. Methodology

To study the benthic organisms, triplicate samples were collected at each station using Van-Veen grab which covered an area of $0.1m^2$. The wet sediment was sieved with varying mesh sizes (0.5 mm-macrofauna) for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution for easy spotting at the time of sorting. The number of organisms in each grab sample was expressed as number/ meter square (No/m^2). All the species were sorted, enumerated and identified to the advanced taxonomic level possible with the consultation of available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; Subba Rao *et al.* (1991) and Ramakrishna (2003) for molluscs.

Further, the data were treated with univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clarke and Warwick, 1994)

a) Shannon – Wiener index

In the present study, the data were analyzed for diversity index (H’) by following Shannon – Wiener’s formula (1949):

$$H' = -\sum^{S} Pi \log 2 \, Pi \ldots\ldots \quad i = 1$$

which can be rewritten as

$$H' = \frac{3.3219\,(N \log N - \sum ni - \log ni}{N}$$

where, H’= species diversity in bits of information per individual ni = proportion of the samples belonging to the ith species

(number of individuals of the ith species)

N = total number of individuals in the collection and

∑ = sum

b) Species richness(S) was calculated using the following formula given by Margalef (1958)

c) Margalef index (d)

d = (S-1) / log N

d) Pielou's evenness index

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\ln S}$$

Where, J' = evenness; H' = species diversity in bits of information per individual and S = total number of species.

3.3. Results on Species Composition, Population density and Biomass of Macrofauna of selected sites

Species Composition, Population density and Biomass of Macrofauna at selected sites

1.Offshore

In Offshore region of Kandala port, total six sites were selected namely, (1A, 1B, 1C, 1D, 1E and 1- control). A total 4groups/species(of benthic community) of benthic animalswere observed in all stations at Offshore sites and they a Bivalves (Mollusca),Gastropods (Mollusca), Polychaeta worms (Annelida), Saccostrea sp (Bivalvia). All the data(Density and Biomass) expressed in (nos./m^2), (gm/m^2) respectively (Table 6). Crustacean animals (Bivalve), Placuna sp (Bivalvia), Pecten sp (Bivalvia), Razor clam (Bivalvia) and Scaphopoda (Mollusca) were totally absent in Offshore.

Highest population density of benthic organisms wasrecorded in station 1C-Offshore(975 nos/m^2), whereas lowest in station 1control-Offshore(125nos/m^2). The density range of all stations varied from 125 to 975nos./m^2. Bivalves and Polychaeta worms were more abundant among all the benthic organisms might be sandy-muddy or sandy substratum in bottom part of Offshore region. Low recorded benthos were Gastropods (Mollusca) and Saccostrea sp (Bivalvia) that indicated some part of substratum are hard (rocky) and algal growth association with animals. The highest biomass value (expressed wet weight) of benthic fauna was observed in station 1C-Offshore (3.11gm/m^2) and lowest value was 1control-Offshore(1.06 gm/m^2) (Table 6). Range of the Biomass was 1.06 to 3.11 gm/m^2 . Moderately Biomass values and also density values suggested mixing substratum, less availability of plenty food items and more predator pressure by higher animals. Intermediate association was also one responsible factor for the same. Variation in density and biomass in Offshore region because more influences by the Water Currents, Up welling - Down welling (Churning process of water) movements of water and Nutrients availability and Fluctuation in turbidity of water.

2. Cargo Jetty

In Cargo Jetty, frequently observed benthic groups were Bivalves, Gastropods, Crustacean animals and Saccostrea sp (Bivalvia). Less reported benthos were Placuna sp (Bivalvia), Pecten sp (Bivalvia) and Scaphopoda whereas Polychaeta worms (Annelida) was totally absent.The population density range noted between 100 to 3725(nos/m^2) among all the stations (Cargo Jetty-2A, 2B, 2C, 2D, 2E &2-Control) during the study period. Highest and Lowest density were recorded in station 2control- Cargo Jetty(1800nos./m^2) and 2D & 2E-Cargo Jetty (100 nos./m^2) respectively.

Pecten sp (Bivalvia) and Razor clams (Bivalve) were only seen in 2control-Offshore whereas Placuna sp (Bivalvia) only observed in 2A-Cargo Jetty.The Biomass value indicated a highestvalue in station 2control- Cargo Jetty (19.17gm/m^2) and lowest in 2D- Cargo Jetty (1.82gm/m^2) (Table 6).Average Biomass and Populationdensity value of all station were 7.74gm/m^2, 1083 nos./m^2 respectively which indicated the moderate favourable environment condition of biota, water quality as well as substratum (mostly rocky) and also substratum of cargo jetty not suitable for Annelids.

3. Phang creek

Six Stations of Phang creek were selected for the studynamely 3A, 3B, 3C, 3D, 3E and 3-control-Phang Creek.In this Phang Creek benthic organisms were mostly represented byGastropoda, Polychaeta worms (annelids) and Crustaceans.Other benthos like *Placuna sp, Pecten sp, Saccostrea sp* and Scaphopoda (Mollusca) were totally absent whereas Bivalves and Razor clams were rarely recorded.The population density was highest in station 3E-Phang Creek (2850nos./m^2) and on the other side, lowest density was recorded in 3C-Phang Creek (25nos./m^2).Station 3control-Phang Creek comprises highest wet wt (20.65 gm/m^2), whereas low value was recorded in3C-Phang Creek(0.03 gm/m^2).

Overall result (Offshore, Cargo Jetty and Phang creek) of macrofaunal community showed highest population density in 2control-Cargo Jetty (3725nos/m^2) and high biomasswas observed (20.65gm/m^2) in 3control-Phang creek. Table 6 showed highest population values of Bivalves in 2control- Cargo Jetty (2050nos/m^2) and same highest value of Gastropoda showed in 3E-Phang creek(1425nos/m^2).

The lowest value comprised by the *Pecten sp, Placuna sp,* Scaphopoda and Razor clam including some were totally absent in some sites.Some absent or less frequently observed benthosindicated extreme weather condition (may be suddenly change temperature of running season), more stress condition and unfavourable environment condition for their survival.Bivalves and Gastropods, dominant groups,werepreferred rocky, sandy or mix substratum, and any other hard substrata**.**Polychaete wormsare preferred sandy-muddy substratum or sandy habitat.

Table 6 showed that average population density and biomass higher in Offshore, Cargo Jetty and some sites of Phang Creek area wheremostly rocky, sandy or covered with muddy area providing a unique habitats for benthos.*Low density and biomass was observed in mostly Phang creek area nd some parts of Off shore and Cargo Jetty* (Table 6 and Figure 1) which indicated s*tressful environment, seasonal effect, more anthropogenic activities and also might be some chemical and biological changes in* *water*.The population density and biomass of benthic community largely affected by the symbiotic and intermediate relation between them or with other invertebrates and suitable rocky substratum or coral reef in bottom of sea. Availability of Plankton, as a food source, also affected the benthic animals (Table 6 and Fig. 1 & 2). Extremely hot weather condition (during April and May months) also more affected in Cargo Jetty and Phang creek regions of Kandla port area.

In benthic communities, recorded species at all sites were, *Pecten sp, Placuna sp, Umbonium vestiarium Tellina sp., Clypeomorus bifasciata, Trochus sp, Radix sp,Nassarius sp, Nerita sp, Donax sp, Turris sp,Marcia sp, Dosinia sp, Donax sp, Anadara sp, Turris sp, Solen, Nereis sp, Saccostrea sp, Optediceros breviculum,Euolica sp etc.The percentage of occurrence (Table 6) was revealed highest group present byBivalves- Mollusca (67%) next Gastropoda (61%) then following araePolychaeta worms (Annelida) (50%), Crustacean animals and Saccostrea sp (39%), Placuna sp (28%) and both Pecten sp and Scaphopoda (6%) respectively.Detail status of Population density, Group composition and biomass of the benthic community of all selected sites were depicted in (Table 6) and (Figure 1).*Among all the stations, highest percentage composition recorded by Bivalves(40%) followed by Gastropods (27%), Polychaeta worms &*Saccostrea sp* (10%), Crustaceans (7%), Razor clam (3%) and 1% by *Pecten sp*, Scaphopoda and *Placuna sp* (Figure.2).

Phytoplankton abundance and their size, zooplankton body composition, patchy distribution of zooplankton, water currents, ebb and flow tides, and water churning process, changing in structure of muddy, rocky and sandy habitats are the main reasonsfor biomass and density fluctuation in Benthic communities. In Crustacean most commonly observed species are Crabs and attached Barnacles. Main Mollucsa families recorded Trochidae, Cerithidea, Turritellidae, Tellinidae, Mitridae, Veneridae, Donacidae and Bucciniae etc. *Nereis sp* of anneliids was mostly observedin samples. More number of the broken bivalves, debris, plant items , broken gastropods, small pebbles and soil particles are frequently observed during benthic organism’s study.

Diversity Indices of Benthic Community

Various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.00-1.34) indicated very low diversity. Highest diversity indices were recorded in Station 2B-Cargojetty (1.34) where four groups/species of benthos presented where as Shannon indices nil (zero) observed in 3A & 3C- Phang creek where only one benthic group present and density value was very low. Comparatively less Shannon indices value very low in Phang creek area number of benthos group/species present between 1 to 4 nos. The evenness values ranged between (0.61 to 1). The highest evenness value (1) is observed in stations 2D & 2E (Cargo Jetty) and 3A,3B & 3C (Phang creek) where only 1 or 2 benthic groups were present with less population whereas the lowest evenness index value 0.61 was at 2control-Cargo Jetty. Evenness value "1" indicated all organisms occurred in same area or mostly same group.Simpson's Index value ranged between 0.00 to 0.73indicated to lower to very less moderate diversity. The Margalef value showed range of 0.00 to 0.61 indicated high variation in species/group numbers (Table 7).

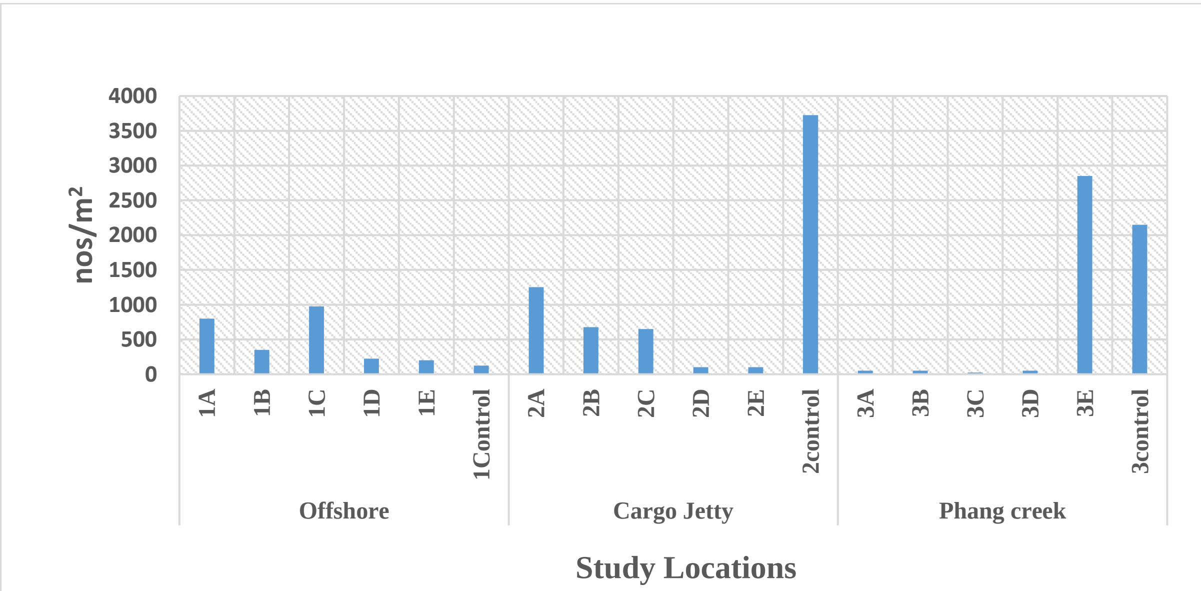

Figure 1. Population density of benthic organisms (nos/m^2) in various sites

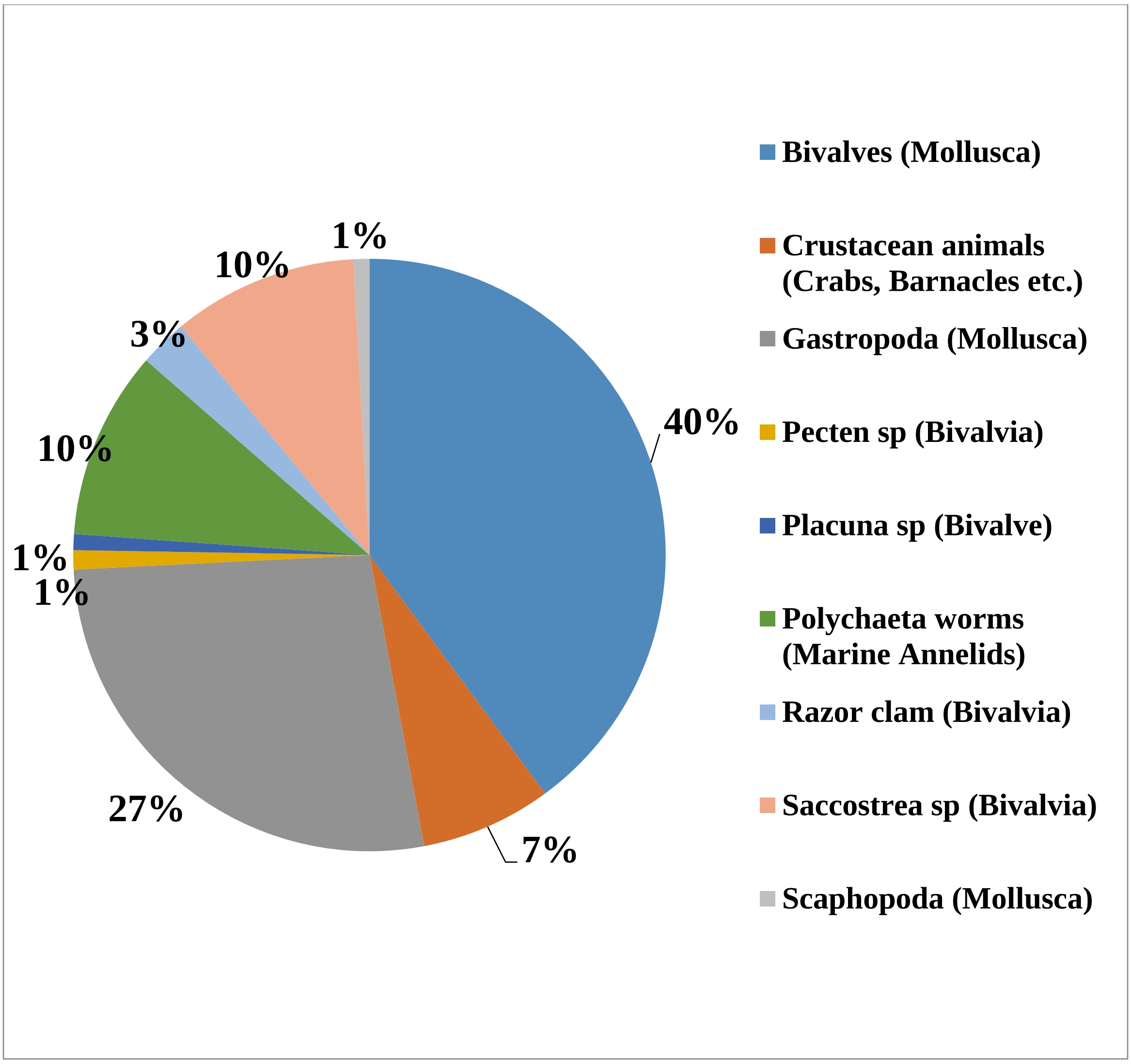

Figure 2. Percentage composition of benthic organisms in various sites

Table 6. Macrobenthos distribution in different sites of Deendayal Port

Name of Station	Offshore						Cargo Jetty						Phang creek						
	1A	1B	1C	1D	1E	1-Control	2A	2B	2C	2D	2E	2-Control	3A	3B	3C	3D	3E	3-Control	% of Occurrence
Name of Benthic Groups																			
Bivalves (Mollusca)	250	125	300	100	0	50	550	125	50	50	0	2050	0	0	0	0	1025	1050	67
Crustacean animals (Crabs, Mysis etc.)	0	0	0	0	0	0	0	175	300	50	50	0	0	0	0	25	300	125	39
Gastropoda (Mollusca)	50	100	25	0	0	0	325	250	50	0	50	750	0	25	0	0	1425	850	61
Pecten sp (Bivalvia)	0	0	0	0	0	0	0	0	0	0	0	150	0	0	0	0	0	0	6
Placuna sp (Bivalve)	0	0	0	0	0	0	125	0	0	0	0	0	0	0	0	0	0	0	28
Polychaeta worms (Marine Annelids)	500	125	650	0	50	25	0	0	0	0	0	0	50	25	25	25	0	0	50
Razor clam (Bivalvia)	0	0	0	0	0	0	0	0	0	0	0	150	0	0	0	0	100	125	17
Saccostrea sp (Bivalvia)	0	0	0	125	150	50	250	125	250	0	0	500	0	0	0	0	0	0	39
Scaphopoda (Mollusca)	0	0	0	0	0	0	0	0	0	0	0	125	0	0	0	0	0	0	6
Total Population Density Nos/m^2	800	350	975	225	200	125	1250	675	650	100	100	3725	50	50	25	50	2850	2150	
Biomass (wet weight) gm/m^2	2.06	2.14	3.11	1.28	1.38	1.06	11.14	7.2	5.24	1.82	1.88	19.17	0.56	0.96	0.03	0.6	15.65	20.65	

Table 7. Diversity indices of benthic faunal groups at various station of Deendayal Port

Variables	Offshore						Cargo Jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-control	2A	2B	2C	2D	2E	2-contrl	3A	3B	3C	3D	3E	3cont
Taxa_S	3	3	3	2	2	3	4	4	4	2	2	6	1	2	1	2	4	4
Individuals (Nos./m^2)	800	350	975	225	200	125	1250	675	650	100	100	3725	50	50	25	50	2850	2150
Dominance_D	0	0	1	1	1	0	0	0	0	1	1	0	1	1	1	1	0	0.40
Shannon Diversity Index (H)	0.83	1.09	0.73	0.69	0.56	1.06	1.26	1.34	1.12	0.69	0.69	1.29	0.00	0.69	0.00	0.69	1.07	1.05
Simpson_1-D	0.51	0.66	0.46	0.49	0.38	0.64	0.69	0.73	0.63	0.50	0.50	0.63	0.00	0.50	0.00	0.50	0.61	0.60
Evenness_e^H/S	0.76	0.99	0.69	0.99	0.88	0.96	0.88	0.96	0.77	1.00	1.00	0.61	1.00	1.00	1.00	1.00	0.73	0.71
Menhinick	0.11	0.16	0.10	0.13	0.14	0.27	0.11	0.15	0.16	0.20	0.20	0.10	0.14	0.28	0.20	0.28	0.07	0.09
Margalef	0.30	0.34	0.29	0.18	0.19	0.41	0.42	0.46	0.46	0.22	0.22	0.61	0.00	0.26	0.00	0.26	0.38	0.39

4.1. Introduction

In recent decades, there has been a notable deterioration in aquatic ecosystems primarily caused by the presence of a diverse array of organic and inorganic contaminants. Among these pollutants, heavy metals (HMs) and microplastics (MPs) have emerged as significant contributors to this environmental degradation (Frew et al., 2020; Saha et al., 2016). These substances are recognized for their capability to infiltrate and accumulate within the aquatic food chain, making them hazardous pollutants in aquatic environments (Olojo et al., 2005). Of particular concern are heavy metals due to their toxic nature, long-lasting presence, resistance to degradation, the potential for bioaccumulation, and the ability to magnify up the food chain, all of which have raised global alarms (Begum et al., 2013; Cai et al., 2017).

Heavy metal pollution in aquatic ecosystems can be attributed to a variety of sources, including natural factors such as atmospheric deposition and weathering (Ebrahimpour and Mushrifah, 2010; Hamidian et al., 2016) as well as human activities like mining, agricultural runoff, sewage discharge, industrial effluent release, gasoline leaks from fishing vessels, and accidental chemical waste spills (Arulkumar et al., 2017). It is essential to recognize that certain heavy metals, such as copper (Cu), iron (Fe), nickel (Ni), cobalt (Co), zinc (Zn), manganese (Mn), and chromium (Cr), play vital roles in physiological processes and are necessary for the proper biological functioning of organisms in trace amounts. However, exposure to nonessential heavy metals can lead to various health concerns, including renal, cardiovascular, nervous, and bone diseases, as well as immune-related issues (Abadi et al., 2018; Madreseh et al., 2018). It is crucial to acknowledge that all heavy metals become toxic when their concentration exceeds a certain threshold level (Makedonski et al., 2017). In light of these concerns, it is imperative to assess the various characteristics of water in order to determine the extent of pollutant presence in aquatic environments.

4.2. Materials and Methods

In this study, marine water and sediment samples were collected following standard protocols, and their analysis was conducted using established methods for marine water and sediment analysis as prescribed by APHA (2012), NIO manual (1982), and ICMAM Manual (2012). For general analysis, surface water samples were collected using a clean polyethylene bucket, while water samples from the bottom were collected using a weighted Niskin sampler. Water samples at a depth of 1 meter below the surface were collected using a 1-liter glass bottle sampler. Parameters such as pH, temperature, and salinity were measured on-site using handheld meters and verified in the laboratory.

The collected water samples were stored under refrigerated conditions until further analysis of other parameters. According to the standard protocol, fixatives and preservatives were added to the samples for specific parameters. For example, Winkler A&B solution was immediately added to measure dissolved oxygen, concentrated H2SO4 was used to bring the pH below 2 for chemical oxygen demand analysis, and nitric acid was used for the preservation of heavy metals. Formalin was added to marine water samples for planktonic analysis. In general, all water and sediment samples were stored in sterile polythene bottles and Ziplock bags and kept in an icebox to maintain suitable conditions until they were transported to the laboratory. The parameters to be analyzed (Table 8) and the methods used for the sample analysis are described below.

Table 8: Physico-chemical and biological characteristics of marine water samples

S. No	Physico-chemical and Biological parameters
1	pH
2	Salinity (ppt)
3	Total Dissolved Solids (mg/L)
4	Turbidity (NTU)
5	Dissolved Oxygen (mg/L)
6	Bio-Chemical Oxygen Demand (mg/L)
7	Chemical Oxygen Demand (mg/L)
8	Phenolic compound (µg/L)
9	Petroleum Hydrocarbons (µg/L)
10	Oil and grease (mg/L)
11	Cadmium (mg/L)
12	Lead (mg/L)
13	Chromium (mg/L)
14	Copper (mg/L)
15	Cobalt (mg/L)

16	Nickel (mg/L)
17	Zinc (mg/L)
18	Magnesium (mg/L)
19	Chlorophyll (mg/m^3)
20	Phaeophytin (mg/m^3)
21	Phytoplankton Phytoplankton cell counts (no/L) Total Genera (no.) Major Genera
22	Zooplankton Biomass (ml/100m^3) Population (no/100m^3) Total Group (no.) and Major Groups

4.2.1. pH, Temperature and Salinity

pH and temperature measurements were conducted using a Thermo Fisher pH/EC/Temperature meter. Prior to use, the instrument was calibrated with standard buffers. For pH determination, an appropriate volume of the sample was titrated against silver nitrate (20 g/l), with potassium chromate serving as an indicator. The chlorinity of the sample was estimated, and salinity values were derived using a specific formula.

Total Dissolved Solids (TDS)

To confirm the readings obtained from the handheld meter, the samples underwent a gravimetric procedure. Approximately 100 ml of the water sample was taken in a beaker and filtered. The filtered sample was then completely dried in a hot air oven at 105°C. The TDS values were calculated by measuring the difference between the initial and final weight of the dried sample.

Turbidity

For turbidity measurement, a sample tube (Nephelometric cuvette) was filled with distilled water and inserted into the sample holder. The lid of the sample compartment was closed, and the meter reading was adjusted to zero by manipulating the 'SET ZERO' knob. The sample tube containing the 40 NTU standard solution was then placed in the tube, and the meter reading was set to 100. Similar measurements were carried out for other standard solutions. To determine the turbidity of the marine water sample, the sample tube was filled with the water sample, and the corresponding reading was recorded.

Dissolved Oxygen (DO)

To determine the Dissolved Oxygen (DO) levels in a water sample obtained from a marine environment, the following procedure was employed. Collect sea water sample, ensuring that the sampling container is clean and free from any potential contaminants that may affect the accuracy of the results. Subsequently, transfer the water sample into a Winkler's bottle or a suitable container, taking care to eliminate any trapped air bubbles. It is crucial to completely fill the bottle to minimize any headspace that could potentially alter the DO readings. Next, add the appropriate volumes of Winkler's reagents, such as manganese sulfate and alkali-iodide-azide, to the water sample as per the specific instructions of the Winkler's method. Gently and thoroughly mix the contents of the bottle to ensure uniform distribution of the reagents without introducing any air bubbles. Allow the bottle to stand undisturbed for a designated incubation period, typically around 30 minutes, to enable the necessary reactions to occur. After the incubation period, perform a titration using a standardized sodium thiosulfate (Na2S2O3) solution until a faint yellow color appears, indicating the complete consumption of dissolved oxygen in the sample. Record the volume of sodium thiosulfate solution used for titration, which represents the amount of dissolved oxygen present in the water sample. To account for any dissolved oxygen in the reagents, it is essential to conduct the same procedure with blank samples that do not contain the water sample. This allows for an accurate calculation of the DO levels in the original water sample. Finally, employ the appropriate formula provided by Winkler's method to calculate the DO concentration in the water sample.

Biochemical Oxygen Demand (BOD)

To determine the Biochemical Oxygen Demand (BOD), the following procedure was employed using the direct unseeded method. Collect representative sea water sample from the desired location, ensuring the sampling container is clean and uncontaminated. Fill a BOD bottle with the water sample, leaving minimal headspace to prevent air contact that could affect BOD measurements. It's important to completely fill the bottle to minimize air bubbles. Record the initial Dissolved Oxygen (DO) level in the water sample using a dissolved oxygen meter or appropriate measurement method. Seal the BOD bottle tightly with the stopper to prevent air exchange. Incubate the sealed BOD bottle in a controlled environment, such as a BOD incubator, at a specified temperature (typically 20°C), for a designated incubation period, usually around 5 days. Throughout the incubation period, keep the BOD bottle in darkness to minimize the impact of photosynthetic activity. After the incubation period, measure the final DO level in the water sample using the same method or instrument as the initial measurement. Calculate the BOD by subtracting the final DO level from the initial DO level, accounting for any necessary dilution or blank corrections. This difference represents the amount of oxygen consumed by the organic matter in the water sample during the incubation period.

Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) test is a widely used method for quantifying the levels of organic and inorganic pollutants in water samples. The first step involves collecting representative water samples from the target site, ensuring proper labeling and record-keeping. Subsequently, these samples are placed into digestion vials or tubes, to which digestion reagents, typically potassium dichromate and sulfuric acid, are added. This step initiates the oxidation of organic matter in the sample. The sealed vials or tubes are then subjected to high-temperature heating, typically around 150-160°C, for a predetermined period, usually around 2 hours. This heating process breaks down complex organic compounds into simpler forms. After digestion, the samples are allowed to cool to room temperature. To determine the COD concentration, a colorimetric measurement is taken. A suitable reagent is added to the digested samples, reacting with any residual potassium dichromate, and generating a color change proportional to the COD concentration. This color intensity is measured using a colorimeter or spectrophotometer, and the results are calibrated using known COD standards. The final calculations yield the COD value, typically expressed in milligrams of oxygen per liter (mg/L) of the sample.

Phenolic compounds

To analyze phenolic compounds in water, the following procedure was followed. A 500 ml water sample containing phenols was treated with 4-aminoantipyrine, which converted the phenols into an orange-colored antipyrine complex. This complex was then extracted using 25 ml of chloroform. The absorbance of the extracted complex was measured at 460 nm using phenol as a standard for comparison. This measurement allowed for the quantification of phenolic compounds present in the water sample.

Petroleum Hydrocarbons (PHc)

The analysis of Petroleum Hydrocarbons (PHc) in a water sample involved the following protocol. One liter seawater sample was extracted using organic solvent, hexane. The mixture was then separated into an organic layer and an aqueous layer. The organic layer, containing the petroleum hydrocarbons, was isolated. To remove any remaining water, the organic layer was dried using anhydrous sulphate. The volume of the organic layer was subsequently reduced to 10 ml at a temperature of 30°C under low pressure. The fluorescence of the extracted organic compound was measured at 360 nm (with excitation at 310 nm) using Saudi Arabian crude residue as a standard. This residue was obtained by evaporating the lighter fractions of crude oil at 120°C. By comparing the fluorescence intensity of the extract with that of the standard, the concentration of petroleum hydrocarbons in the water sample could be determined.

Oil and Grease

To determine the content of Oil and Grease in a sample, the following procedure was followed. Approximately 500 ml of the sample was transferred to a separating funnel, and the sample bottle was rinsed with 30 ml of trichlorotrifluoroethane. The rinsing solvent was then added to the separating funnel. Next, 5 ml of 1:1 hydrochloric acid (HCl) was added to the mixture, and the contents were vigorously shaken for about 2 minutes. If a soluble emulsion was formed, the sample container was shaken for an additional 5 to 10 minutes. After shaking, the layers in the separating funnel were allowed to separate, and the lower layer (organic layer) was discarded.

The solvent layer was drained through a funnel containing a filter paper moistened with solvent, and it was collected in a clean distillation flask that had been pre-weighed. The solvent was then distilled from the flask using a water bath set at 70°C. The resulting residue was carefully transferred into a clean, pre-weighed, and dried beaker, using the minimum amount of solvent necessary. The beaker was placed on a water bath at 70°C for 15 minutes to evaporate off all the solvent. After the evaporation process, the beaker was cooled in a desiccator for 30 minutes to reach a consistent temperature, and its weight was then measured.

Heavy metals

Heavy metals are a significant concern, especially in coastal environments, since it is biomagnifying from lower organisms to higher organisms through water and sediment. Common heavy metals of concern include Cadmium (Cd), Lead (Pb), Chromium (Cr), Copper (Cu), Cobalt (Co), Nickel (Ni), Zinc (Zn), Magnesium (Mg) and Manganese (Mn). To release mineral elements from sediment and analyze them, a wet oxidation process is typically employed using oxidizing acids, such as a mixture of Tri / Di-acids.

The procedure begins by weighing 0.5 grams of the sediment sample and placing it in a 100 ml beaker, which is covered with a watch glass. Then, 12 ml of Aqua regia (a mixture of 1 part HNO3 and 3 parts HCl) is added to the beaker. The beaker is placed in a digestion apparatus and heated at 100°C for 3 hours on a hot plate using a sand bath. The sample is evaporated until it is nearly dry, and then allowed to cool for 5 minutes. Next, 20 ml of 2% nitric acid is added to the cooled sample in the beaker, and the mixture is further digested on the hot plate for 15 minutes. After digestion, the beaker is removed from the hot plate and allowed to cool. The sample is then filtered using a Whatman No. 42 mm filter paper to remove any solid particles. To make up the final volume, the filtrate is diluted with 2% nitric acid to a total volume of 50 ml. The resulting extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis of the heavy metal concentrations.

Results

In this First season study conducted in the present year, we closely monitored three distinct locations: Offshore, Cargo Jetty, and Phang Creek. A comprehensive analysis of physico-chemical characteristics in marine water samples was conducted at each of these sites. The collected data is thoughtfully presented in Tables 9-11. These findings serve as a significant source of information regarding the precise physico-chemical conditions prevailing at each of these locations. Consequently, they play a pivotal role in enhancing the comprehension of the environmental factors that exert influence on the quality of marine water in these specific areas. The description of the data in each station is detailed as below.

Location 1 - Offshore location

In the offshore location (Location 1), the recorded data shows that the mean value of temperature was recorded as 33.10±0.30°C. The pH values ranged between 7.77 and 7.97, with an average pH value of 7.91±0.06. The salinity of the seawater recorded the mean value as 37.83±1.94 ppt, while the TDS which indicates the presence of various anions and cations, had an average value of 47097.67±2199.72 mg/L. Turbidity values ranged from 35.6 to 151.4 NTU. The maximum Dissolved Oxygen and Biochemical Oxygen Demand were in the order of 7.60 mg/L and 3.30 mg/L respectively. The average COD value was determined to be 44.33±4.08 mg/L. The concentrations of Phenolic compounds and Petroleum hydrocarbons varied between 3.5 to 42.88 µg/L, and 0.28 to 0.44 µg/L, respectively. The concentration of oil and grease ranged from 1.50 mg/L to 8.40 mg/L. Additionally, the maximum concentrations of heavy metals were observed for Magnesium (335.45 mg/L), Nickel (1.34 mg/L), Cadmium (2.89 mg/L), Manganese (2.41 mg/L), and Cobalt (0.81 mg/L), as shown in Table 9.

Location 2 – Cargo Jetty

At the Cargo Jetty location, the recorded data shows that the mean value of temperature was recorded as 32.53±0.846°C, and the mean value of pH was observed as 7.91±0.02. The average salinity of the seawater was 37.11±1.478 ppt reflecting the salt content, while the TDS which indicates the presence of various anions and cations, had an average value of 45412.5±2503.78 mg/L. Turbidity values ranged from 40.7 to 185.63 NTU, which is quite lower than the previous season sample data. The maximum values recorded for Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were 8.2 mg/L and 3.0 mg/L respectively (as shown in Table 10). The average COD value was determined to be 42.00±7.03 mg/L. The concentrations of Phenolic compound were between 3.29 µg/L to 41.54 µg/L with an mean concentration of 21.23±11.91 µg/L. In case of Petroleum hydrocarbon, all the samples were well within the permissible limits set by CPCB and the maximum recorded concentration was 0.33 µg/L. The mean concentration of oil and grease in the marine water samples was 5.00±2.09 mg/L, which falls below the acceptable limit of 10 mg/L according to GPCB norms. Regarding heavy metal concentrations, the Mean±SD values for Magnesium, Nickel, Cadmium, Manganese and Cobalt were 237.658±92.402 mg/L, 1.293±0.839 mg/L, 2.263±0.770 mg/L, 1.560±1.193 mg/L, 0.705 respectively, whereas Chromium, Zinc and Copper recorded a Below Detection Limit (BDL) in all the sampling points in Station 2 as given in Table 10.

Location 3 - Phang Creek

During this winter sampling in the Phang creek near the port, all the samples were subjected for analysis for various characteristics (Table 11). The mean value of temperature was recorded as 33.20±0.89°C and the pH value was recorded between 7.93 to 8.04. The average salinity of the seawater in the vicinity was found to be 36.89±1.25 ppt, while the TDS which indicates the presence of various anions and cations, had an average value of 49053.83±4300.43 mg/L. Turbidity values ranged from 105.5 to 161.7 NTU. Pollution indices such as Dissolved Oxygen and Biochemical Oxygen Demand, Phenolic compounds, and Oil and grease concentrations had maximum values of 8.0 mg/L, 3.1 mg/L, 27.01 µg/L, and 7.6

mg/L, respectively. The average value of PHc was 0.294±0.020 µg/L. In case of heavy metals, the maximum concentrations of Magnesium, Nickel, Cadmium, Manganese and Cobalt recorded were 336.2 mg/L, 2.37 mg/L, 2.41 mg/L, 2.86 mg/L and 1.365 mg/L respectively. Few of the heavy metals such as Lead, Chromium, Zinc and Copper were in the Below Detection Limits.

Table 9: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore)

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	32.8	33.3	33.5	33.2	33.5	33.0	33.3	32.8	32.8	33.3	32.6	33.1
2	pH	7.87	7.87	7.96	7.77	7.91	7.92	7.94	7.95	7.91	7.96	7.91	7.97
3	Salinity (ppt)	35.87	40.00	37.60	38.84	37.17	35.87	38.84	36.74	41.06	36.74	40.20	35.01
4	Total Dissolved Solids (mg/L)	46235.00	52374.00	44674.00	49270.00	45684.00	48723.00	48486.00	45392.00	45570.00	46097.00	46520.00	46147.00
5	Turbidity (NTU)	66.7	62.2	42.8	35.6	53.2	81.4	135.2	151.4	103.1	93	106.3	103.3
6	Dissolved Oxygen(mg/L)	7.6	7.4	7.5	7.3	7.3	7.2	7.6	7.4	7.5	7.2	7	6.6
7	Bio-Chemical Oxygen Demand (mg/L)	0.6	1.1	0.4	1.7	0.7	1.1	0.3	0.6	1.0	1.1	1.9	1.6
8	Chemical Oxygen Demand (mg/L)	52.00	50.00	48.00	44.00	46.00	42.00	44.00	42.00	40.00	38.00	44.00	42.00
9	Phenolic Compounds (µg/L)	33.50	16.49	3.50	14.63	42.88	20.92	36.49	25.46	20.10	30.30	15.25	32.16
10	Petroleum Hydrocarbons (µg/L)	0.3226	0.4381	0.3274	0.3363	0.3148	0.29	0.3079	0.308	0.2752	0.2892	0.2963	0.281
11	Oil and grease (mg/L)	1.5	3.2	5.2	3.6	6.0	4.0	6.0	4.0	5.6	7.2	8.4	4.0
12	Magnesium (mg/L)	88.8	222.7	297	148.75	335.45	216.45	116.15	40.43	83.2	201.35	160.15	40.27
13	Nickel (mg/L)	BDL	BDL	BDL	BDL	0.495	1.34	0.63	BDL	BDL	BDL	BDL	BDL
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	0.565	BDL	2.385	BDL	1.305	2.245	2.455	0.665	2.21	2.45	2.89	2.43
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Zinc (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	BDL	BDL	BDL	BDL	2.11	BDL	BDL	BDL	BDL	BDL	2.405	2.22
20	Cobalt (mg/L)	BDL	BDL	BDL	BDL	0.405	0.81	0.775	BDL	BDL	BDL	BDL	0.33

Note: BDL denotes Below Detection Limit.

Table 10: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty)

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	33.1	33.1	30	32	32.9	32.8	32.8	32.7	32.8	32.6	32.8	32.8
2	pH	7.87	7.94	7.94	7.91	7.92	7.93	7.89	7.89	7.89	7.94	7.89	7.92
3	Salinity (ppt)	36.31	37.17	40.2	38.04	38.04	37.32	34.58	36.47	38.04	35.18	37.6	36.47
4	Total Dissolved Solids (mg/L)	48943	38489	46473	47007	45308	47425	45802	44846	44890	45207	45217	45343
5	Turbidity (NTU)	153.7	151.6	145.6	154.5	185.3	174.4	43.2	42.1	45.4	41.8	42.8	40.7
6	Dissolved Oxygen(mg/L)	5.8	7.5	8.2	7	6.1	6.2	6.7	7.8	6.4	7.1	5.5	6.5
7	Bio-Chemical Oxygen Demand (mg/L)	0.6	1.2	2	1.7	0.6	1	0.7	2.6	0.4	1.9	0.9	1.6
8	Chemical Oxygen Demand (mg/L)	48	44	52	50	44	40	32	30	48	36	42	38
9	Phenolic Compounds (µg/L)	33.29	23.91	29.89	33.81	41.54	26.08	16.28	9.7	16.28	10.82	9.89	3.29
10	Petroleum Hydrocarbons (µg/L)	0.2804	0.2884	0.2904	0.2977	0.2949	0.3322	0.2907	0.3112	0.3109	0.3325	0.3106	0.3039
11	Oil and grease (mg/L)	6	4.8	6.8	5.6	5.6	6.8	1.6	0.8	6.4	6.4	2.8	6.4
12	Magnesium (mg/L)	284.8	346.05	385.5	300.4	151.1	127.05	226.35	104.9	183.7	152.7	299.35	290
13	Nickel (mg/L)	0.3	1.32	BDL	BDL	BDL	BDL	BDL	1.05	2.51	BDL	1.995	0.585
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	2.195	3.04	2.83	1.275	BDL	2.22	2.665	1.14	3.02	2.16	1.175	3.175
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Zinc (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	BDL	2.45	2.025	BDL	BDL	BDL	BDL	0.205	BDL	BDL	BDL	BDL
20	Cobalt (mg/L)	0.705	0.705	0.705	0.705	0.705	0.705	0.705	0.705	0.705	0.705	0.705	0.705

Note: BDL denotes Below Detection Limit

Table 11. Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek)

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	**BW**	**SW**	**BW**	**SW**	**BW**	**SW**	**BW**	**SW**	**BW**	**SW**	**BW**
1	Temperature (^{0}C)	32.8	32.6	32.7	32.5	32.7	32.5	32.6	32.4	34.4	34.4	34.4	34.4
2	pH	7.99	7.94	7.98	7.93	8.04	7.98	8.01	7.95	8.03	7.98	7.97	7.97
3	Salinity (ppt)	39.9	36.47	36.47	36.47	35.61	38.61	37.75	36.04	36.04	36.9	36.47	36.04
4	Total Dissolved Solids (mg/L)	52643	47285	54530	46275	46001	46775	47722	43492	51862	58269	46465	47327
5	Turbidity (NTU)	161.7	140.7	146.6	105.5	140.1	150.1	109.2	115.4	115.8	120.3	138.1	124.5
6	Dissolved Oxygen(mg/L)	7	8	7	6.5	6.4	6.3	6	7.4	6.7	6.6	5.5	5.5
7	Bio-Chemical Oxygen Demand (mg/L)	1.8	2.0	2	1.6	1.3	1.1	0.2	1.2	1.6	1.1	0.1	0.7
8	Chemical Oxygen Demand (mg/L)	42	38.0	40	36	42	38	42	38	40	36	48	40
9	Phenolic Compounds (µg/L)	23.19	1.96	10.1	13.6	15.46	20.51	9.79	10.51	15.56	27.01	11.44	20
10	Petroleum Hydrocarbons (µg/L)	0.3003	0.3122	0.3097	0.2989	0.3164	0.2959	0.2992	0.2955	0.284	0.297	0.2835	0.2379
11	Oil and grease (mg/L)	2.4	4.4	5.2	3.2	4.8	6.4	5.6	4.4	7.6	3.2	2.8	4.8
12	Magnesium (mg/L)	272.85	231.75	206.05	336.2	274.45	60.95	234.25	42.48	320.65	328.7	214.95	195.7
13	Nickel (mg/L)	BDL	BDL	0.46	BDL	BDL	BDL	BDL	0.52	2.11	2.235	2.37	BDL
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	2.155	2.41	1.845	1.74	1.37	0.64	0.255	0.77	2.205	0.555	BDL	0.42
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Zinc (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	BDL	BDL	BDL	2.28	BDL	0.175	BDL	BDL	0.005	2.86	BDL	2.085
20	Cobalt (mg/L)	BDL	BDL	BDL	BDL	0.34	0.035	BDL	1.075	1.35	0.93	1.365	0.76

Note: BDL denotes Below Detection Limit

5.1. Introduction for Plankton

Plankton are divided in two parts which are phytoplankton and zooplankton (Brink. 1993). Phytoplanktons are the primary producers in marine ecosystems and form the basis of the food web. The animal portion of plankton is known as Zooplankton. Size is very important to understanding about the classification of both zooplankton and phytoplankton. Based on size, various categories of plankton are smallest one Picoplankton (0.2-2 µm), Nanoplankton (2-20 µm), Microplankton (20-200 µm), Mesoplankton (200 µm-2 mm), Macroplankton (2-20 mm) and Megaplakton(> 20 mm) . The population of plankton diversity is largely related to Seasonal and Monthly variability in Physical, Chemical and Biological parameters; Interspecific competition among the Zooplankton; Inter-relationship for prey and predator between zooplankton and their mostly predator animals; Grazing ratio of Zooplankton; Suspension of sediment; Fluctuation in Phytoplankton abundance; Waves, Currents and Tidal turbulence effect; Fluctuation in Chlorophyll a and Nutrients; Input of Organic and other Pollution creating sources; Fish potential ratio; Monsoon effect; Suddenly changes in atmosphere; Peak time of every seasons and it's effect; Vertical migration of Zooplankton; Food selection pattern of predator; Collection time and number of collected samples, mixing of water column, high surface action, Seasonal upwelling and down welling process in water column.

Population always remains either stable or fluctuating, depending on environment conditions surrounding it (Taylor, 1988; Garzke et al. 2017). Population of plankton and other marine living organisms on which the whole aquatic life depends directly or indirectly is largely governed by the interaction of a number of biological, chemical and physical processes and tolerance to one or more of these conditions (Reid and Wood 1976).

Phytoplankton

The meaning of the term phytoplankton is the plants which are made to wander (the word 'phyto' means plant and 'planktos' means are made to wander). These are single celled marine algae, among those a few can show movement by using their flagella while others drift with currents (Zohari et al, 2014). As a photosynthetic organism they are dependent on sunlight for photosynthesis and play the most important components of natural aquatic systems as the main primary producers.

Major phytoplankton in sea water is Diatoms (Tiwari and Nair, 1998; Thakur et al, 2015), Cocolithophores, Sillicoflagellates, Blue green algae (Cyanobacteria) and Dinoflagellates. Zooplankton comprises the second level in the food chain and includes Tintinnids, Foramonifers, Radiolarians, Amphipoda, Copepoda, Calanoida, Chaetognaths, larvae of benthic invertebrates and fish larvae etc. (Gajbhiye and Abidi, 1993; Thirunavukkarosu, 2013; Chakrabarty et al. 2017).

Diatoms are divided into two main types based on their shape- the Centric diatoms or Centrales, and the Pennate diatoms or Pennales (Tabassum, 2012). Dinoflagellates have plant like mechanisms such as photosynthetic activity, storage of energy (by synthesis of carbohydrates) etc. The Cyst-forming Dinoflagellates mostly occurred in all marine habitats. They are the most primitive eukaryotes. Some Dinoflagellates are responsible for Harmful Algal Blooms (multiplication of dinoflagellates cells) in sea which causes death of fishes in large numbers

Zooplankton

Most of the zooplankton are microscopic which can drift with the currents. Although most of them can swim, they have no ability to progress against water currents (Alcaraz and Calbet, 2003). They also play important role in food web by indirectly supporting a few large ocean predators such as tuna, sharks etc, which feed upon the small planktivorous fish. In this way they are the major link in the marine life in between phytoplankton and fish including commercially important species, their study is the important part for getting knowledge of the functioning of marine ecosystems (Alcaraz and Calbet, 2003).

Nearly all fish depend on zooplankton for food in both larval stages and entire life period (Madin et al., 2001). Holoplanktons are those which live permanently in the planktonic form, while meroplanktons are the temporary members in this form. The potential of zooplankton to respond quickly to environment changes and short generation life span, make them important bioindicator of water pollution and all variation occurred in their living environment. Their study is the important part for getting knowledge of the functioning of marine ecosystems (Mees and Jones, 1997).

Zooplankton comprises the second level in the food chain and includes Tintinnids, Foramonifers, Radiolarians, Amphipoda, Copepoda, Calanoida, Chaetognaths, larvae of benthic invertebrates and fish larvae etc. (Gajbhiye and Abidi, 1993; Thirunavukkarosu, 2013; Chakrabarty et al. 2017). The zooplankton may be classified according to their habitat and depth, distribution, size and duration of planktonic life period (Omori and lkeda, 1984). There are the two main classification on the bases of habitat which are Marine plankton or Haliplankton and Freshwater plankton or Limnoplankton. Metazooplankton copepods are considered the most numerous group among the various animal species; therefore, information about their biology and physiology is key to understanding the different metazooplankton functions in the marine ecosystems (Ikeda et al., 2001).

5.2. Methodology

5.2.1 Estimation of Chlorophyll and Phaeophytin

Estimating Chlorophyll and Phaeophytin was done using known volume of water (500 ml) was filtered through a 0.45μm Millipore membrane filter paper and the pigments retained on the filter paper were extracted in 90% acetone overnight at 50°C. The extinction of the acetone extract was measured using fluorimeter before and after treatment with dilute acid (0.1N HCI).

5.2.2. Phytoplankton sampling and analysis

Phytoplankton samples were collected in the ten prefixed sampling sites using a standard plankton net with a mesh size of 51 μm. Plankton nets are with a square mouth covering an area of 0.900 cm^2 (30 cm square mouth) fitted with a flow meter (Hydrobios). Nets were towed from a moving boat for 10 minutes and the plankton adhering to the net was concentrated in the net bucket. Plankton soup from the net bucket was transferred to a pre-cleaned and rinsed container and preserved with 5%

neutralized formaldehyde. The containers were appropriately labelled. The initial and final flow meter reading was noted down for calculating the amount of water filtered to estimate plankton density. As per flow meter reading, a total amount of 165m^3 of water was filtered by the net. One liter of water was separately collected for density estimation to counter check density estimation obtained by the flow meter reading. Quantitative analysis of phytoplankton (cell count) was carried out using a sedge wick-Rafter counting chamber. One ml of soup added to a Sedgwick counting chamber was observed under an inverted compound microscope. The number of cells present in individual cells of the counting chambers (1/1000) was noted and identified up to a generic level. Several observations were fixed to represent the entire quantity of the soup (generally more than30 times) and the recorded data were used to calculate the density (No/l) using the formula, N = n×v/V (where N is the total no/l; n is an average number of cells in 1 ml; v is the volume of concentrate; V is the total volume of water filtered). The phytoplankton diversity richness and evenness were past software.

5.3. Phytopigments

The concentration of phytopigments is inversely proportional to the turbidity of the waters and in general, waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.52 -0.78 mg/m^3 with a mean ± SD being 0.67±0.08 mg/m^3 in the Offshore (Table 12), 0.5 to 0.78 mg/m^3 with mean ± SD of 0.67±0.08 mg/m^3 in the Cargo Jetty (Table 13) and 0.47 to 0.72 mg/m^3 with mean ± SD being 0.61±0.08 mg/m^3 in the Phang creek location (Table 14).

Another phytopigment estimated was Phaeophytin, which is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.27-0.66 mg/m^3 with a Mean±SD of 0.55±0.12 mg/m^3 in the Offshore location (Table 12). In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.4 - 0.72 mg/m^3 with a Mean±SD of

0.579±0.098 mg/m^3 (Table 13) and in case of the creek location, the concentration of phaeophytin was almost similar when compared to the other two locations and was ranging between 0.36 – 0.69 mg/m^3 with a Mean±SD of 0.484±0.087 mg/m^3 (Table 14). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 12: Chlorophyll and Phaeophytin concentration observed in the Offshore site

Parameters	1A		1B		1C		1D		1E		1 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.65	0.72	0.75	0.78	0.52	0.65	0.59	0.71	0.64	0.59	0.74	0.750
Phaeophytin	0.270	0.560	0.640	0.660	0.480	0.580	0.480	0.650	0.550	0.430	0.640	0.640

Table 13: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site

Parameters	2A		2B		2C		2D		2E		2 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.740	0.780	0.742	0.600	0.650	0.620	0.720	0.620	0.500	0.750	0.650	0.720
Phaeophytin	0.680	0.720	0.630	0.550	0.400	0.580	0.440	0.580	0.480	0.660	0.580	0.650

Table 14: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site

Parameters	3A		3B		3C		3D		3E		3 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.520	0.680	0.720	0.720	0.600	0.570	0.479	0.660	0.620	0.530	0.720	0.580
Phaeophytin	0.480	0.480	0.52	0.570	0.480	0.430	0.370	0.470	0.480	0.360	0.690	0.480

Phytoplankton

The study was conducted at 3 sites (or regions) at Kandla Port and near area where dredging activities is going on Creek and the stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

In this site, frequently observed species were *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus wailesii, Ditylum brightwelli, Thalassionema frauenfeldii colony, Trieres mobiliensis, Pleurosigma sp, Rhizosolenia setigera, Odontella sinensis, Thalassiosira sp etc.* whereas less observed species were *Amphiprora sp, Biddulphia sp, Coscinodiscus granii, Entomoneis sp, Fragilariopsis sp colonies, Paralia sp chain, Planktoniella sol, Rhizosolenia clevei var.communi and some unidentified.*

Total 44 Phytoplankton were recorded in this Offshore area. Highest population density was recorded at site 1A-Offshore (375520nos./m^3) and lowest density was recorded at site 1B-Offshore (55840nos./m^3). The maximum number of species observed in site 1A-Offshore (30 nos.) followed by 1E (28nos.), 1Control (24 nos.), 1B&1C-Offshore (19nos.), 1D-Offshore(17nos.). The population density greatly varied between (55840nos./m^3 to 375520nos./m^3). *Biddulphia sp, Synedra ulna, Ulnaria ulna, Fragilariopsis sp colony, Pleurosigma sp, Nitzschia sp, Oocystis sp.* were recorded which are sometimes considering for pollution indicator species in water. Green algae sp and *Oocystis sp* were also recorded in some location of Offshore which may be indication of freshwater or polluted water mixing with seawater. Some Dinoflagellates were also like *Tripos furca, Tripos muelleri* . Golden brown naked biflagellate algae *Pyrophacus sp* also recorded in site 1A-Offshore. Highest population density contributor species was *Thalassionema frauenfeldii colonies (range 10240 to 90400* nos./m^3)

Cargo jetty

Total 48 Phytoplankton were recorded in this Cargo Jetty area. The population density greatly varied between 37280 Nos/m^3 to 72960 Nos/m^3.Highest density value recorded at 2control-Cargo Jetty (72960 nos./ m^3) and lowest value was at 2A-Cargo

Jetty (37280 nos./m^3). The lowest number of species noted in the site 2A-Cargo Jetty(19 nos.) whereas highest in 2control-CargoJetty (29 nos.).

In this Cargo Jetty station commonly or frequently observed species were *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus radiatus, Coscinodiscus wailesii, Gyrosigma sp, Nitzschia sp, Oocystis sp, Planktoniella blanda, Pleurosigma sp, Thalassionema frauenfeldii colony, Trieres mobiliensis, Tripos furca, Tripos muelleri* etc. The rarely found species were *Amphiprora sp, Biddulphia sp, Cerataulina sp, Chaetoceros sp, Noctiluca sp, Planktoniella sol, Proboscia sp, Pyrophacus sp, Thalassionema nitzschioides colony, Trachyneis sp etc.* The Dinoflagellates *like Noctiluca sp*(mostly consider deep sea species), *Tripos furca, Tripos muelleri* and *Protoperidinium sp* were also observed during microscopic analysis that may be indication of water circulation from deep water to upper surface. *Pyrophacus sp*. are golden brown naked bi-flagellates also recorded. Some unidentified species and *Silicoflagellates (protists)* were also recorded.

Phang Creek

The population density of phytoplankton ranged from 72480 nos./m^3 to 253280 nos./m^3 same way species availability ranged from 14 to 26 nos. Maximum and Minimum value of population density were recorded in site 3Control-Phang Creek (253280nos./m^3) and 3A-Phang Creek (72480 nos./m^3) respectively. Highest number of species recorded in site 3D & 3control-Phang Creek (26 nos.) and lowest in site 3C-Phang Creek (14 nos.). Total recorded phytoplankton was 45 in this creek area. *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus granii, Coscinodiscus radiatus, Nitzschia sp, Rhizosolenia sp , Synedra ulna, Thalassionema frauenfeldii colony, Thalassiosira sp, Trieres mobiliensis, Tripos muelleri etc.* were frequently noticed during microscopic work whereas less observed species were *Bellerochea sp chain, Green algae (unidentified), Paralia sp chain, Planktoniella sol, Protoperidinium sp, Silicoflagellates (protists), Tripos furca etc.* Green algae *were also recorded*, which are generally found in fresh water and estuarine area. Silicoflagellates (protists) generally recorded deep sea but also observed in creek area may be because of water circulation pattern.

Overall view of Phytoplankton showed that a total 62 species of Marine phytoplankton were identified during winter season of the year 2024. Among them,31-Centric diatoms, 19-Pennate diatoms, 7-Dinoflagellates, 1-Blue green algae, 2-Green algae and 1-silicoflagellates and some are not identified phytoplankton was included in unidentified. Some species like *Amphiprora sp, Bellerochea sp chain, Noctiluca sp, Paralia sp chain, Planktoniella sol, Rhizosolenia imbricata, Triceratium favus, Tripos furca* and *Trichodesmium sp* etc., were rarely recorded during sample analysis. Input of the fresh water indicated by the presence of some common fresh water species like *Green algae* and blue green algae - *Trichodesmium sp.*

Presence of *Dinoflagellates (Noctiluca sp, Protoperidinium sp, Pyrophacus sp and different type of Tripos sp.)* indication of bottom water circulation up to surface water layer in some level. Noctiluca genus is also considering bioluminescent organisms and deep water species. Silicoflagellates was also recorded in some sites Kandala region. Highest phytoplankton density was observed at the site 1A-Offshore (375520nos./m^3) and lowest was observed at site 2A-Cargo Jetty (37280 nos./m^3) (Table 15). Total number of highest species observed at site 1A-Offshore (30nos.) and lowest in site 3C-Phang Creek (17 Nos.).

The high population density composed by species like *Coscinodiscus centralis, Coscinodiscus radiatus, Planktoniella blanda, Odontella sinensis, Rhizosolenia sp, Rhizosolenia setigera, Synedra ulna, Thalassionema frauenfeldii colony, Trieres mobiliensis* and *Tripos muelleri* (Table 15). This result indicated that genus *Coscinodiscus sp. Rhizosolenia sp, Thalassiosira sp, Trieres sp* and *Tripos sp* were very common with good numbers in all sites. In some sites, least number of species and low density of phytoplankton might be responsible due to some factors like extreme cool weather because of winter season, high pre-predation ratio, marine pollution (anthropogenic pressure), high turbidity, total suspended solids, water current and suddenly changes in environment conditions etc. Diatoms, type of phytoplankton, constitute major part in total phytoplankton composition The individual density of species of sites viz. has been depicted in Table 15. All values of phytoplankton density, list of phytoplankton and others shown in (Table 15).

Diversity Indices of Phytoplankton

According to Table 16, diversity indices calculation for phytoplankton showed that the Shannon Index ranged from (0.86 to 2.85) indicated low level to moderate level of diversity status. High Shannon Index was recorded at 1E-Offshore (2.85) where 28 species were recorded and low at 1B-Cargo Jetty (0.86) where 19 species were recorded. Lowest evenness recorded at site 1B – Offshore (0.12) whereas highest was in at 2A-Cargo Jetty (0.69). Dominance D index ranged from 0.08 to 0.72where higher value in 1B-Offshore (0.72) and lowest was at in 1E- Offshore (0.08). Value of Margalef D (1.06 to 2.45) showed more variation in species numbers (Table 16.).

Table 15. Density of Phytoplankton at different sites of Deendayal Port

Name of Sites	Offshore						Cargo Jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1 control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2 control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3 control**
Genus of Phytoplankton																		
Actinocyclus sp	52000	320	4480	8320	960	7200	800	4160	800	6080	800	1600	6720	9120	14400	8320	11200	10240
Amphiprora sp	800	0	0	0	0	0	0	0	0	0	0	640	0	0	0	0	0	1120
Bacillaria paxillifera colonies	640	320	0	0	1280	0	640	0	0	800	960	480	0	0	0	1440	640	0
Bellerochea sp chain	960	0	0	0	640	640	0	640	960	0	0	0	0	0	0	800	0	0
Biddulphia sp	0	0	640	0	0	640	0	0	0	0	0	640	0	0	0	0	160	0
Cerataulina sp	0	0	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0
Chaetoceros decipiens	0	0	0	0	0	0	0	1120	0	0	480	0	0	0	0	0	0	0
Chaetoceros sp	5120	640	320	0	0	1120	800	0	0	0	0	800	0	0	0	0	0	0
Coscinodiscus centralis	16320	480	5280	6080	6560	7520	4960	5920	9120	3360	6400	10560	13920	59200	15840	11520	8800	19360
Coscinodiscus granii	64000	0	0	0	0	0	0	0	0	0	0	0	7200	88800	83200	50400	83200	48000
Coscinodiscus radiatus	68000	800	4320	5440	8320	8800	5920	4160	9120	6880	7520	15520	16800	65600	60800	69600	57600	63200
Coscinodiscus sp.	0	0	5920	0	3680	1440	1120	0	0	0	1600	1600	1600	3360	0	0	0	0
Coscinodiscus wailesii	0	1600	4480	4480	5120	3200	0	3360	4320	2720	6560	5920	0	0	0	0	0	0
Cyclotella sp	0	320	0	0	0	1120	0	0	0	0	0	0	0	0	0	0	0	0
Ditylum brightwelli	7520	480	960	1440	1440	0	640	1440	0	0	1280	0	800	0	640	0	0	0
Entomoneis sp	0	0	0	0	320	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilariopsis sp colonies	0	0	0	0	640	0	0	0	0	1120	0	0	0	0	0	640	0	640
Green algae (unidentified)	0	0	0	480	0	480	0	0	0	0	0	0	0	0	320	0	0	960
Gyrosigma sp.	1280	0	320	0	640	640	0	480	480	480	480	640	0	800	0	640	800	1280
Hemiaulus sp chain	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0	0	0	0
Melosira sp colony	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	800
Navicula sp	0	0	0	0	0	0	0	0	0	0	0	0	0	640	0	480	0	640
Nitzschia sigmoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	480	0	0	640
Nitzschia sp	320	0	480	0	0	3200	0	480	960	1120	1120	1120	800	960	0	2720	800	1440
Noctiluca sp	0	0	0	0	0	0	0	0	0	480	0	0	0	480	0	0	0	0
Odontella sinensis	12800	320	800	640	0	1120	0	640	1120	0	0	1600	1280	0	0	1920	0	320
Odontella mobiliensis	0	320	0	0	0	0	0	0	0	640	1280	0	0	1600	480	2080	2240	0
Oocystis sp	6400	320	0	0	0	0	2080	0	480	2240	1920	1280	1760	0	0	0	1600	0
Paralia sp chain	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0	0
Pinnularia sp	0	0	0	0	0	0	0	0	0	0	0	480	0	1120	0	0	0	
Planktoniella blanda	800	0	0	0	1600	1120	480	320	640	640	0	640	0	1760	0	1920	2400	640
Planktoniella sol	800	0	0	0	0	0	0	640	320	0	0	0	0	0	0	0	320	0

Pleurosigma angulatum	0	0	0	0	640	0	0	480	0	0	0	0	0	0	0	480	800	0
Pleurosigma sp.	1440	320	0	960	800	1760	1120	800	1600	0	1280	1120	800	480	0	0	3360	1440
Proboscia sp	640	640	0	2400	0	0	0	0	0	0	1600		0	0	0	0	0	0
Protoperidinium sp	0	0	0	0	0	0	0	0	0	640	320	800	480	0	0	0	960	0
Pseudo-nitzschia sp chain	0	0	0	0	480	0	0	0	0	0	1120	0	0	0	0	0	0	0
Pyrophacus sp	640	0	0	0	0	0	0	0	0	640	0	0	0	0	0	0	0	0
Rhizosolenia bergonii	0	0	0	0	0	0	0	0	0	1440	320	0	0	0	0	0	0	0
Rhizosolenia clevei var.communis	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0
Rhizosolenia imbricata	6720	480	0	0	2080	0	2080	0	640	960	0	1280	0	0	0	0	960	0
Rhizosolenia setigera	5120	0	640	960	1440	320	2400	0	1280	800	2400	1600	0	0	1600	1760	2080	2080
Rhizosolenia sp	0	320	960	2240	4000	960	0	0	1120	3200	4160	2720	2560	3840	0	3200	2400	2240
Silicoflagellates (protists)	0	0	0	0	1120	960	0	0	0	0	0	480	0	0	0	640	0	0
Surirella sp	0	0	0	0	0	0	0	0	0	0	0	0	480	480	0	0	480	0
Synedra sp	0	0	0	0	0	0	0	0	640	0	0	0	800	800	0	1120	0	1120
Synedra ulna	1600	320	480	320	1120	1440	960	800	480	480	640	1120	0	960	640	1760	2400	960
Thalassionema frauenfeldii colonies	90400	47200	30400	30400	10240	15200	7360	8320	8320	14560	12320	12960	12320	8320	14720	46400	28800	17920
Thalassionema nitzschioides colonies	0	0	0	0	0	0	0	0	0	640	0	0	0	0	0	0	0	0
Thalassiosira aculeata	8160	0	0	960	2400	1920	0	1280	0	0	0	1120	0	0	0	0	960	2400
Thalassiosira sp.	6080	0	640	3200	1760	4640	1600	1760	800	0	0	1600	960	800	6880	11520	9120	3200
Trachyneis sp	0	0	0	0	0	0	0	480	0	0	0	0	0	0	0	0	0	0
Triceratium favus	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0	0	0	0
Triceratium sp	2240	0	0	0	480	1600	0	0	0	0	0	640	0	0	0	0	1760	1440
Trichodesmium sp	0	0	0	0	0	0	0	0	0	0	1920	0	0	0	0	0	0	0
Trieres mobiliensis	7520	320	800	1440	2560	0	1120	1760	1120	1280	960	1280	1120	1440	2880	1920	2880	1440
Tripos azoricus	0	0	0	0	0	0	0	480	0	0	960	0	0	0	0	0	0	0
Tripos furca	5120	0	480	640	480	0	960	1120	1120	0	800	1600	0	0	0	2560	0	0
Tripos fusus	0	0	0	0	0	0	0	0	0	0	0	0	0	960	0	0	0	0
Tripos muelleri	1120	320	800	0	480	0	1760	960	800	960	960	1120	1760	1440	1920	1600	0	1120
Ulnaria (Synedra) ulna	480	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	320	0	0	0	0	160	2400	0	320	0	0	640	0	320
Density of Phytoplankton (diff. sites wise.)(no/m^3)	375520	55840	63200	70400	61600	67840	37280	41600	46240	52800	62560	72960	72480	253280	204800	226400	226720	184960
Total= 2176480 no/m^3																		
Total No Of Genus/Species=**62**																		

Table 16. Diversity Indices of Phytoplankton at different sites at Deendayal Port

Variables	Offshore						Cargo jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	30	19	19	17	28	24	19	23	22	25	27	29	19	23	14	26	25	26
Individuals (Nos/m^2)	375520	55840	63200	70400	61600	67840	37280	41600	46240	52800	62560	72960	72480	253280	204800	226400	226720	184960
Dominance_D	0.14	0.72	0.26	0.22	0.08	0.10	0.10	0.10	0.13	0.12	0.09	0.11	0.14	0.25	0.27	0.19	0.22	0.21
Shannon Diversity Index (H)	2.33	0.86	1.94	2.04	2.85	2.64	2.58	2.68	2.47	2.58	2.80	2.68	2.27	1.74	1.63	2.07	1.98	2.03
Simpson_1-D	0.86	0.28	0.74	0.78	0.92	0.90	0.90	0.90	0.87	0.88	0.91	0.89	0.86	0.75	0.73	0.81	0.78	0.79
Evenness_e^H/S	0.34	0.12	0.37	0.45	0.62	0.58	0.69	0.63	0.54	0.53	0.61	0.51	0.51	0.25	0.36	0.30	0.29	0.29
Menhinick	0.05	0.08	0.08	0.06	0.11	0.09	0.10	0.11	0.10	0.11	0.11	0.11	0.07	0.05	0.03	0.05	0.05	0.06
Margalef	2.26	1.65	1.63	1.43	2.45	2.07	1.71	2.07	1.96	2.21	2.35	2.50	1.61	1.77	1.06	2.03	1.95	2.06

Zooplankton

The study was conducted at 3 sites in Kandla Port and nearby areas where dredging activities are going on. The three selected study stations are Offshore, Cargo Jetty and Phang Greek.

Offshore

Calanoida (unidentified), Euterpina sp (Harpacticoida), Foraminifera (unidentified), Nauplius larva of Copepoda, Nauplius larvae of Barnacles, Ophiopluteus Larva (Echinodermata), Ostracoda, *Paracalanus sp* (Calanoida), Sponge Spicules, Zoea larva of Crab etc. were the mostly common zooplankton and throughout observed in all sites of Offshore area. Highest population density was recorded at site 1A-Offshore (144000 nos./100m^3) where number of species was highest (32 nos.) and lowest density in 1C-Offshore (26080 nos./100m^3) where number of species recorded lowest numbers (23 nos.). High biomass was observed in the site 1E-Offshore (44.92 ml/100m^3) and low biomass was recorded in site 1D-Offshore (15.24 ml/100m^3). The range of the population density, biomass and number of species were (26080 to 144000 nos./100m^3), (15.24 to 44.92 ml/100m^3) and (23 32 to 31 nos.) respectively in all sites.

Less observed species were Animal egg (Unidentified), *Appendicularia sp* (Tunicata), *Bestiolina sp* (Calanoida), Egg development stage, Jellyfish (small), *Leprotintinnus sp* (Tintinnida), Narcomedusae (Hydrozoa:Cnidaria), Protozoa and Zoothamnium sp (ciliate colony) in this station. Total 58 zooplankton was recorded in Offshore area adding that more composition of zooplankton by the Phylum Arthropoda (Crustacea), Tintinnids and Foraminifera and Sponge Spicules (Porifera).

Cargo Jetty

The population density of zooplankton varied from 33440 nos./100m^3 to 65440 nos./100m^3. Maximum density was noticed in site 2E-Cargo Jetty (65440 nos./100m^3) and minimum was at site 2D-Cargo Jetty (33440 nos./100m^3). Maximum number of species (29nos.) found 2E & 2C - Cargo Jetty minimum number of species was observed in site 2control-Cargo Jetty (25nos.). Biomass ranged between 8.22 to 66.67

ml/100m^3 where highest biomass noted in site2E-Cargo Jetty and lowest in 2D-Cargo Jetty. Frequently observed species were Calanoida (unidentified), *Clausocalanus sp* (Calanoida), *Corycaeus sp* (Calanoida), *Euterpina sp* (Harpacticoida), Medusa of Obelia sp (Hydrozoa), Mysids (shrimp like), Ophiopluteus Larva (Echinodermata), Polychaete larvae (Annelids), Protozoaea larva (Crustacea), Sagitta sp (arrow worm), Sponge Spicules, Zoea larva of Crab etc. whereas less observed species were Animal egg (Unidentified), *Bolivina sp* (Foraminifera), Cyclops sp (Cyclopoida), Harpacticoida (unidentified), Leprotintinnus sp (Tintinnida), Microsetella sp (Harpacticoida), *Pontella sp* (Calanoida), *Spiroloculina sp* (Foraminifera), *Temora sp* (Calanoida), *Tortanus sp* (Calanoida) etc. Some Unidentified species and larval stages were also reported. Total recorded zooplanktons were 47 in Cargo Jetty.

Phang Creek

This Creek area was represented by the zooplankton fauna majority of them were Acartia sp (Calanoida), Calanoida (unidentified), *Clausocalanus sp* (Calanoida), Foraminifera (unidentified), Nauplius larvae of Barnacles, *Sagitta sp* (arrow worm), *Subeucalanus sp* (Calanoida), Veliger larvae of Bivalve, Zoea larva of Crab.Very less time or rarely recorded species were *Acrocalanus sp* (Calanoida), *Cyclops sp* (Cyclopoida), Cyphonautes larva (Bryozoan), *Favella sp* (Tintinnida), Gnathiid isopoda larvae, Larva Of Isopoda, *Leprotintinnus simplex* (Tintinnida), Medusa of Obelia sp (Hydrozoa), *Oncaea sp* (Cyclopoida), *Pontella sp* (Calanoida), Radiolaria skeleton etc. The range of zooplankton biomass was between 8.06 to 20.97 ml/100m^3. Highest Biomass was recorded in site 3D-Phang creek (20.97 ml/100m^3) and lowest in site 3A-Phang creek (8.06 ml/100m^3). Maximum and Minimum species count was at in site 3B-Phang creek (31nos.) and 3D-Phang Creek (08nos.) respectively. Population density was maximum recorded in site 3B-Phang Creek (40320 nos./100m^3) and minimum in site 3D-Phang Creek (8000 nos./100m^3). In site 3D-Phang creek comparatively low density according to other sites may be because of high predator pressure or some environment changes.

Overall assessment of zooplankton showed that the total number of 79 Zooplankton recorded during winter season. Out of these (79) zooplankton, 58 zooplankton recorded in Offshore region, 47 zooplankton at Cargo Jetty and 48 zooplankton in Phang Creek region. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea), Protozoa (mainly foraminifera and tintinnids), Porifera (sponge spicules). Crustacean zooplankton was the dominant due to the dominance of different larval stages and Copepods which mainly feed phytoplankton. More larval stage of crustacean and other animals observed in samples that indicated reproduction and development season of animals from larval to mature animal.Generally zooplankton population dynamics and studies emphasize is given up to group level rather than to species level because of microscopic size of zooplankton so owing to the difficulty in identifying the zooplankton as some species are considered as a group or genus level. The most dominant or frequently observed species(all 3 station) were Calanoida (unidentified), *Clausocalanus sp* (Calanoida), *Euterpina sp* (Harpacticoida), Foraminifera (unidentified), Nauplius larva of Copepoda, Nauplius larvae of Barnacles, Nauplius larvae of Crustacea, Ophiopluteus Larva (Echinodermata), Ostracoda, *Paracalanus sp* (Calanoida), Sponge Spicules, Veliger larvae of Bivalve, Zoea larva of Crab etc. Foraminifera belonging to the meroplankton were present at all three stations.

Overall range of Population density, Biomass and Number of species were (8000 to 144000no/100 m^3), (8.06 to 66.67 ml/100m^3) and (08 to 32 nos) respectively. Average high biomass noted at Cargo Jetty (31.42 ml/100m^3) followed by Offshore (26.16 ml/100m^3) than Phang Creek (13.56 ml/100m^3) (Table 17, 18, 19). Highest population density was recorded in site 1A-Offshore (144000 Nos/100m^3) and lowest was recorded in site 3D-Phang Creek (8000 No/100m3). Among all recorded zooplankton, majority dominance occurrence was by the Copepoda, Crustacean larvae, Spong Spicules, Foraminifera (Protozoa), Tintinnids (Protozoa), Zoea larva of Crab, Mysids (shrimp like),Egg capsules of Littorinids (Mollusca).

Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda, Mollusca, Protozoa, Porifera. The Fish larva (Ichthyoplankton) was also recorded in all 3 locations. The Zooplankton of Chaetognatha, Tunicata, Cnidaria, Amoebozoa were only represented by the species namely *Sagitta sp (arrow worm),* *Appendicularioa sp, Narcomedusae (Hydrozoa), Arcella sp.* respectively. Veliger larva of Bivalve and Gastropoda shells include in Phylum Mollusca. The Echinodermata phylum represented by the Ophiopluteus larva and Gastrula larva of Sea star.

In Offshore**,** maximum Occurrence (%) was by the Nauplius larva of Barnacles (11.14%) and minimum by the Hydrozoa larva (Cnidaria) (0.05%). In Cargo Jetty, maximum Percentage of Occurrence (%) by the Nauplius larva of Copepoda (9.27%) and minimum by some unidentified species (0.06%). In Phang Creek, maximum occurrence by the Nauplius larva of Copepoda (9.89%) and minimum (0.19%) by the *Acrocalanus sp* (Calanoida), Cyphonautes larva (Bryozoan), Gnathiid isopoda larvae, Harpacticoida (unidentified), *Oncaea sp* (Cyclopoida), Zoea larva of Procelain crab and some Unidentified species (Table 17, 18, 19).

During microscopic sample analysis more number of species varieties of Foraminifera, Sponge spicules, Crustacean larva and Tintinnidswere observed. These all three are very important for paleontological study aspects and also for evolutionary, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Some deep sea species also recorded that is indication of water circulation pattern. Data on zooplankton density, list of zooplankton is shown in Table 17, 18 and 19.

Plankton identification, both zooplankton and phytoplankton, were done by using relevant identification and taxonomic keys and with standard literatures, monographs and research articles.(Kasturirangan, 1963; APHA, 1992; Mitra et al., 2003;Goswami, 2005; Carling et al., 2004; Mandal, 2004; Hussain & Kalaiyarasi, 2013; Guglielmo et al., 2015; Hussain et al., 2016; Sreenivasulu et al., 2017; NIO,1998; NIO,2002) ,etc

Diversity Indices of Zooplankton

Table 20 *shows* diversity indices of zooplankton.The Shannon-wiener diversity index (H') fluctuated between 1.82 to 3.17 indicated moderate to quite high range of diversity added indication of healthy body of water with a maximum value in site 1D-Offshore (3.17) where maximum number of species noted (31 nos.) after 1D-Offshore

(32 nos.) and minimum value in site 3D-Phang Creek (1.82) where species number was 8.Range of the evenness was 0.50 to 0.82 where lowest and highest recorded in site 1A-Offshore (0.50) and 2A-Cargo Jetty (0.82) respectively. Range of Simpson index was 0.80 to 0.95. The range value of Margalef indices was 0.78 to 2.83 that means high species number variations. (Table 20).

Table 17.Density of Zooplankton at Offshore site of Deendayal Port

Name of Genera/Group	1A	1B	1C	1D	1E	1 Control	Individual total density (no/100m^3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	1120	480	0	480	480	0	2560	0.75
Animal egg (Unidentified)	0	160	0	480	0	0	640	0.19
Appendicularia sp (Tunicata)	0	0	0	0	0	320	320	0.09
Arcella sp (Amoebozoa)	800	0	0	1280	4000	0	6080	1.77
Bestiolina sp (Calanoida)	0	480	0	0	0	0	480	0.14
Bolivina sp (Foraminifera)	0	0	320	0	0	0	320	0.09
Calanoida (unidentified)	5600	4320	800	1760	2400	7360	22240	6.48
Centropages sp (Calanoida)	0	480	0	0	0	480	960	0.28
Clausocalanus sp (Calanoida)	2560	2880	0	0	0	3040	8480	2.47
Copepoda eggs sac(egg pouch)	0	480	0	320	640	0	1440	0.42
Cyclopoida (unidentified)	2560	1440	640	640	0	0	5280	1.54
Cyclops sp (Cyclopoida)	23520	0	0	640	0	0	24160	7.04
Cyphonautes larva (Bryozoan)	640	640	0	320	0	0	1600	0.47
Egg capsules of Littorinids	640	0	0	480	0	800	1920	0.56
Egg development stage	640	0	0	0	0	0	640	0.19
Euchaeta sp (Calanoida)	0	0	0	0	480	640	1120	0.33
Euterpina sp (Harpacticoida)	2240	800	0	640	960	1920	6560	1.91
Fish larva	320	320	0	0	320	320	1280	0.37
Foraminifera (unidentified)	9120	800	800	1600	640	800	13760	4.01
Gastrula larva of Sea star	640	0	0	640		0	1280	0.37
Globigerina sp (Foraminifera)	0	0	640	0	1600	0	2240	0.65
Heteropoda shells (gastropods)	960	0	0	1280	480	0	2720	0.79
Hydrozoa larva (Cnidaria)	0	0	0	0	0	160	160	0.05
Jellyfish (small)	0	0	0	320	0	0	320	0.09
Leprotintinnus pellucidus (Tintinnida)	0	0	480	0	0	0	480	0.14
Leprotintinnus sp (Tintinnida)	0	0	0	0	0	640	640	0.19
Microsetella sp (Harpacticoida)	4960	0	960	0	0	0	5920	1.72
Mysids (shrimp like)	1120	1440	960	0	0	480	4000	1.16
Mysis larva of Lucifera sp	0	0	0	0	0	480	480	0.14
Mysis larva of Prawn	0	0	0	0	800	1600	2400	0.70
Narcomedusae (Hydrozoa:Cnidaria)	0	480	0	0	0	0	480	0.14
Nauplius larva of Copepoda	8160	4800	2880	3520	2400	6400	28160	8.20
Nauplius larvae of Barnacles	7200	7360	2560	5120	6560	9440	38240	11.14
Nauplius larvae of Crustacea	10400	3040	640	0	0	0	14080	4.10
Ophiopluteus Larva	800	320	800	800	480	640	3840	1.12

(Echinodermata)								
Ostracoda	4480	800	800	640	640	800	8160	2.38
Paracalanus sp (Calanoida)	3200	3200	2560	2400	1600	2400	15360	4.47
Parvocalanus sp (Calanoida)	0	2720	2080	0	1280	1920	8000	2.33
Polychaete larvae (Annelids)	2560	800	960	640	640	480	6080	1.77
Pontellid nauplius larva (Calanoida)	0	0	320	0	0	0	320	0.09
Protozoa	0	320	0	0	0	0	320	0.09
Protozoaea larva (Crustacea)	0	0	0	640	0	480	1120	0.33
Radiolaria skeleton	0	0	0	640	0	0	640	0.19
Sagitta sp (arrow worm)	2240	0	1440	640	1600	0	5920	1.72
Spirillina limbata	960	0	0	0	0	0	960	0.28
Sponge Spicules	1120	1120	1600	800	1760	2720	9120	2.66
Subeucalanus sp (Calanoida)	3520	2560	0	2560	0	2880	11520	3.36
Tardigrade (Water bear)	0	0	0	0	0	320	320	0.09
Tintinnids (unidentified)	0	480	0	0	0	0	480	0.14
Tintinnopsis beroidea (Tintinnida)	0	0	640	960	0	0	1600	0.47
Tintinnopsis cylindrica (Tintinnida)	3840	320	480	640	0	0	5280	1.54
Tintinnopsis orientalis (Tintinnida)	33600	0	0	640	0	0	34240	9.97
Tintinnopsis sp (Tintinnida)	0	0	0	2400	0	0	2400	0.70
Veliger larvae of Bivalve	1440	480	0	480	960	320	3680	1.07
Zoea larva of Crab	2400	960	2400	1600	6240	6560	20160	5.87
Zoea larva of Procelain crab	0	0	320	480	0	0	800	0.23
Zoothamnium sp(ciliate colony)	640	0	0	0	0	0	640	0.19
Unidentified larva	0	160	0	0	800	0	960	0.28
Total No. Of Genera/Groups=58								
Site-wise Total Density (no/100m^3)	144000	44640	26080	36480	37760	54400	**Total Density =343360**	**100%**
Biomass (ml/100m^3)	**17.86**	**19.29**	**18.99**	**15.24**	**44.92**	**40.63**		

Table 18. Density of Zooplankton at Cargo Jetty site of Deendayal Port

Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Individual total density ($no/100m^3$))	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	640	0	1280	0	2560	1440	5920	2.20
Ammonia sp (Foraminifera)	320	0	0	480	0	640	1440	0.54
Animal egg (Unidentified)	0	320	0	0	0	0	320	0.12
Bolivina sp (Foraminifera)	0	0	320	0	0	160	480	0.18
Calanoida (unidentified)	2080	3200	2720	0	8160	4800	20960	7.79
Clausocalanus sp (Calanoida)	1920	3040	480	1760	1920	2080	11200	4.16
Corycaeus sp (Calanoida)	2400	3360	640	960	4160	1440	12960	4.82
Cyclops sp (Cyclopoida)	480	0	0	0	0	0	480	0.18
Cyphonautes larva (Bryozoan)	0	960	320	0	320	0	1600	0.59
Egg capsules of Littorinids	0	640	320	800	480	480	2720	1.01
Euterpina sp (Harpacticoida)	1440	2240	800	2720	2720	1600	11520	4.28
Fish larva	640	640	0	0	0	0	1280	0.48
Foraminifera (unidentified)	1280	960	0	0	320	1600	4160	1.55
Globigerina sp (Foraminifera)	800	0	800	320	640	0	2560	0.95
Harpacticoida (unidentified)	0	0	0	0	320	0	320	0.12
Heteropoda shells (gastropods)	1280	1760	0	640	0	0	3680	1.37
Leprotintinnus sp (Tintinnida)	0	0	0	320	0	0	320	0.12
Medusa of Obelia sp (Hydrozoa)	320	4320	1600	0	4160	2080	12480	4.64
Microsetella sp (Harpacticoida)	0	0	0	640	0	0	640	0.24
Mysids (shrimp like)	1600	1440	2240	0	3520	2240	11040	4.10
Mysis larva of Lucifera sp	0	320	320	0	0	0	640	0.24
Nauplius larva of Copepoda	1760	4800	2720	4000	7520	4160	24960	9.27
Nauplius larvae of Barnacles	3520	0	4160	2400	0	2400	12480	4.64
Nauplius larvae of Crustacea	1920	0	0	960	0	0	2880	1.07
Ophiopluteus Larva (Echinodermata)	480	800	320	640	1280	960	4480	1.66
Ostracoda	800	480	320	480	640	320	3040	1.13
Paracalanus sp (Calanoida)	960	1120	640	800	1280	0	4800	1.78
Parvocalanus sp (Calanoida)	0	0	1120	0	4000	1600	6720	2.50
Polychaete larvae (Annelids)	640	2240	4160	1120	320	1600	10080	3.75
Pontella sp (Calanoida)	0	0	0	0	480	0	480	0.18
Pontellid nauplius larva (Calanoida)	0	320	0	160	320	480	1280	0.48
Prawn brood eggs	0	10080	0	0	0	0	10080	3.75

Prawn larvae (premature stage)	0	3680	1920	1600	4160	6240	17600	6.54
Protozoaea larva (Crustacea)	1600	480	1600	960	2560	0	7200	2.68
Sagitta sp (arrow worm)	480	1440	320	320	2880	1600	7040	2.62
Spirillina sp (Foraminifera)	0	0	0	480	480	0	960	0.36
Spiroloculina sp (Foraminifera)	0	0	0	0	0	320	320	0.12
Sponge Spicules	640	3200	800	960	1920	640	8160	3.03
Subeucalanus sp (Calanoida)	1120	3520	640	1760	0	0	7040	2.62
Tardigrade (Water bear)	0	0	480	0	0	640	1120	0.42
Temora sp (Calanoida)	0	0	960	0	0	0	960	0.36
Tintinnopsis radix (Tintinnida)	0	0	0	0	320	0	320	0.12
Tortanus sp (Calanoida)	0	320	0	0	0	0	320	0.12
Veliger larvae of Bivalve	1120	320	800	800	1280	0	4320	1.61
Zoea larva of Crab	3360	0	2240	6720	6400	5280	24000	8.92
Unidentified	0	0	0	160	0	0	160	0.06
Unidentified larva	0	0	640	480	320	160	1600	0.59
Total No. Of Genera/Groups=47								
Site-wise Total Density (no/100m^3)	33600	56000	35680	33440	65440	44960	**Total Density =269120**	**100%**
Biomass (ml/100m^3)	**19.09**	**24.59**	**32.89**	**8.22**	**66.67**	**37.04**		

Table 19. Density of Zooplankton at Phang Creek site of Deendayal Port

Name of Genera/Group	3A	3B	3C	3D	3E	3 Control	Total density (no/100m3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	1920	1280	1760	0	2560	2240	9760	5.74
Acrocalanus sp (Calanoida)	0	0	320	0	0	0	320	0.19
Arcella sp (Amoebozoa)	0	0	0	2080	480	0	2560	1.51
Calanoida (unidentified)	4160	2240	3040	480	4160	960	15040	8.85
Clausocalanus sp (Calanoida)	2720	2560	1120	0	1280	480	8160	4.80
Corycaeus sp (Calanoida)	1440	1120	1280	0	0	1440	5280	3.11
Cyclopoida (unidentified)	0	320	480	0	800	0	1600	0.94
Cyclops sp (Cyclopoida)	320	0	0	0	0	320	640	0.38
Cyphonautes larva (Bryozoan)	0	320	0	0	0	0	320	0.19
Egg capsules of Littorinids	0	480	800	0	320	800	2400	1.41
Euchaeta sp (Calanoida)	0	1440	1120	0	1280	0	3840	2.26
Euterpina sp (Harpacticoida)	1440	1760	1600	0	1120	0	5920	3.48
Favella sp (Tintinnida)	0	0	640	0	0	0	640	0.38
Fish larva	0	800	0	0	320	0	1120	0.66
Foraminifera (unidentified)	1120	960	640	320	960	1280	5280	3.11
Globigerina sp (Foraminifera)	0	480	0	0	0	0	480	0.28
Gnathiid isopoda larvae	320	0	0	0	0	0	320	0.19
Harpacticoida (unidentified)	0	160	160	0	0	0	320	0.19
Heteropoda shells (gastropods)	1280	2400	1440	0	640	0	5760	3.39
Larva Of Isopoda	0	0	0	640	0	0	640	0.38
Larva of Stomatopoda (Arthropoda)	0	320	480	0	0	0	800	0.47
Leprotintinnus simplex (Tintinnida)	0	0	0	0	480	0	480	0.28
Leprotintinnus sp (Tintinnida)	0	640	480	2400	0	640	4160	2.45
Medusa of Obelia sp (Hydrozoa)	1760	0	0	0	0	320	2080	1.22
Mysids (shrimp like)	480	1120	0	0	320	0	1920	1.13
Mysis larva of Lucifera sp	640	320	0	0	320	0	1280	0.75
Nauplius larva of Copepoda	4320	4320	3360	0	1600	3200	16800	9.89
Nauplius larvae of Barnacles	3040	800	3840	0	2400	1440	11520	6.78
Nauplius larvae of Crustacea	0	0	0	640	0	0	640	0.38
Oncaea sp (Cyclopoida)	0	0	0	0	320	0	320	0.19
Ophiopluteus Larva (Echinodermata)	640	0	800	0	0	320	1760	1.04
Ostracoda	480	320	480	0	640	640	2560	1.51
Paracalanus sp (Calanoida)	0	960	0	0	320	640	1920	1.13
Parvocalanus sp (Calanoida)	0	1280	800	0	1120	0	3200	1.88
Polychaete larvae (Annelids)	0	960	960	0	1440	1120	4480	2.64

Pontella sp (Calanoida)	0	0	0	0	480	0	480	0.28
Prawn larvae (premature stage)	640	1600	0	0	0	0	2240	1.32
Protozoaea larva (Crustacea)	1440	1760	1280	0	800	1120	6400	3.77
Radiolaria skeleton	0	800	0	0	0	0	800	0.47
Sagitta sp (arrow worm)	1440	3040	1120	0	2240	800	8640	5.08
Small Gastropoda shells	800	0	480	0	0	320	1600	0.94
Sponge Spicules	640	480	800	1120	480	320	3840	2.26
Subeucalanus sp (Calanoida)	1440	0	1600	0	1760	1280	6080	3.58
Tintinnids (unidentified)	0	0	0	0	0	480	480	0.28
Veliger larvae of Bivalve	2080	2240	800	0	320	320	5760	3.39
Zoea larva of Crab	2400	3040	1600	0	1120	480	8640	5.08
Zoea larva of Procelain crab	0	0	0	0	0	320	320	0.19
Unidentified	0	0	0	320	0	0	320	0.19
Total No. Of Genera/Groups=48								
Site-wise Total Density (no/100m^3)	36960	40320	33280	8000	30080	21280	**Total density =169920**	**100%**
Biomass (ml/100m^3)	**8.06**	**15**	**10.71**	**20.97**	**8.46**	**18.18**		

Table 20. Diversity indices of Zooplankton at different sites of Deendayal Port

Variables	Offshore						Cargo jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-control	2A	2B	2C	2D	2E	2-contrl	3A	3B	3C	3D	3E	3-control
Taxa_S	32	30	23	32	23	27	26	27	29	27	29	25	24	31	28	8	28	24
Individuals (nos. /m^2)	144000	44640	26080	36480	37760	54400	33600	56000	35680	33440	65440	44960	36960	40320	33280	8000	30080	21280
Dominance_D	0.10	0.07	0.06	0.06	0.09	0.09	0.05	0.07	0.06	0.08	0.07	0.07	0.06	0.05	0.06	0.20	0.06	0.07
Shannon Diversity Index(H)	2.77	2.92	2.92	3.15	2.74	2.72	3.06	2.89	3.04	2.87	2.93	2.86	2.95	3.17	3.10	1.82	3.05	2.94
Simpson_1-D	0.90	0.93	0.94	0.94	0.91	0.91	0.95	0.93	0.94	0.92	0.93	0.93	0.94	0.95	0.94	0.80	0.94	0.93
Evenness	0.50	0.62	0.80	0.73	0.67	0.56	0.82	0.67	0.72	0.65	0.65	0.70	0.79	0.77	0.79	0.77	0.76	0.78
Menhinick	0.08	0.14	0.14	0.17	0.12	0.12	0.14	0.11	0.15	0.15	0.11	0.12	0.12	0.15	0.15	0.09	0.16	0.16
Margalef	2.61	2.71	2.16	2.95	2.09	2.38	2.40	2.38	2.67	2.50	2.53	2.24	2.19	2.83	2.59	0.78	2.62	2.31

6.0. References

Airoldi, L., and Beck, M. (2007). Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology: An Annual Review, 45, 345–405.

Alcaraz, M.and Calbet, A. (2003). Zooplankton ecology, inMa rine Ecology. Encyclopedia of Life Support Systems (EOLSS), eds C. Duarte and A. Lott Helgueras (Oxford: Developed under the Auspices of the UNESCO, EolssPublishers), 295–318.

APHA (1992). Standard Methods for the Examination of Water and Waste water 18th Ed, American Public Health Association. Awwa, Wpcf, Washington D.C.

Baird, R. and L. Bridgewater, 2017. Standard methods for the examination of water and wastewater. 23rd edition. Washington, D.C.: American Public Health Association.

Barbier Edward, B., Hacker Sally, D., Kennedy, C., Koch, E. W., Stier, A. C., and Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. Ecol. Monogr. 81, 169–193. doi: 10.1890/10-1510.1**.**

Barnes, R D, 1980. Invertebrate Zoology Saunders College, Philadelphia 108pp**.**

Besiktepe, S., Tang, K. W., Mantha, G. (2015). Seasonal variation of abundance and live/dead compositions of copepods in Mersin Bay, northeastern Levantine Sea (eastern Mediterranean). Turk Zool. 39: 494-506. doi:.10.3906/zoo-1405-23.

Bhaskar P. V., Roy R., Gauns M., Shenoy D. M., Rao V. D., Mochemadkar S., 2011. “Identification of non-indigenous phytoplankton species dominated bloom off Goa using inverted microscopy and pigment (HPLC) analysis”, J Earth Syst Sci, pp.1145–1154.

Bhunia, A.B. and Choudhury, A., 1998. Studies on the seasonal abundance and biomass of Crustacean Zooplankton and Chaetognaths in relation to ecological parameter of a tidal Creek (Mooriganga), of Sagar Island (north), Sunderbans, West Bengal. *Indian Journal of. Marine Science 28*, 93-198.

Boyd, S. E., Limpenny, D. S., Rees, H. L., & Cooper, K. M. (2005). The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). *ICES Journal of Marine Science*, *62*(2), 145–162.

Brink, K.H. (1993). The coastal ocean progresses effort. Oceanus, 36, pp. 47-49.

Carling, K. J., Ater, I. M., Pellam, M. R., Bouchard, A. M., Mihue, T. B. (2004). A Guide to the Zooplankton of Lake Champlain. Plattsburgh State University of New York. Scientia Discipulorum. 1: 38-66.

Chakrabarty, M., Banerjee, A., Mukherjee, J., Rakshit, N., Ray, S. (2017) Spatial pattern analysis of zooplankton community of Bakreswar reservoir, India. Energ. Ecol. Environ. 2(3): 193-206. doi:. 10.1007/s40974-017-0057-8.

Chattopadhyay, J., R.R. Sarkar & S. Pal 2003. Dynamics of nutrient–phytoplankton interaction in the presence of viral infection. *BioSystems*, 68: 5–7.

Clark, K R and Warwick, R M 1994. Change in Marine Communities, An Approach to Statistical Analysis and Interpretation Natural Environment Research Council, Plymouth Marine Laboratory, Plymouth, pp144.

Cloern J. E., “Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Fransisco Bay”, California. 1996. Rev Geophys, 34(2), pp.127–168, 1996.

Covich, A. P., Palmer, M. A. and T. A. Crowl (1999): The Role of Benthic Invertebrate Species in Freshwater Ecosystems. Bio Science, 49 (2): 119-127.

Davies, O.A., C. C. Tawari and J. F. N. Abowei, 2008. Zooplankton of Elechi Creek, Niger Delta, Nigeria. Environ. Ecol., 26 (4c): 2346 - 2441.

Davis, B. J. 1977. Distribution and temperature adaptation in the teleost fish genus Gibbonsia. Mar. Biol., 42: 315-320.

Day, J H 1967. A monograph on the Polychaeta of Southern Africa Pts I and II, Brit Mus. Nat. Hist, 656, 1-878.

Dekker, R. 1989. The macrozoobenthos of the subtidal western Dutch Wadden Sea. I. 468 Biomass and species richness. Netherlands Journal of Sea Research 23: 57–68.

Desai, S. R, 2008. Subashchandran, MD, Ramachandra TV; Phytoplankton Diversity in Sharavati River Basin, Central Western Ghats. Journal of Sediment and Water Sciences, 2008; 1(1):7- 66.

Descy, J. P, 1993. Ecology of the phytoplankton of river Moselle: Effect of disturbance on community structure and diversity. Hydrobiologia, 249(1-3): 111-116.

Dodson, S. (1992). Predicting crustacean zooplankton species richness. Limnol Oceanogr. 37(4): 848-856.

Dodson, S.I. and Frey, D. G. (2001). Cladocera and other branchiopoda. Ecology and classification of North American Freshwater Invertebrates. Academic Press. London. 850 – 914.

Fauvel, P, 1953 The Fauna of India Including Pakistan, Ceylon, Burma and Malaya Annelida, Polychaeta, Allahabad pp507.

Figueredo, C. C. & A. Giani 2001. Seasonal variation in the diversity and species richness of phytoplankton in a tropical eutrophic reservoir. *Hydrobiologia*, 445: 165-174.

Gajbhiye, S.N. & Abidi, S.A.H. (1993). Zooplankton distribution in the polluted environment around Bombay. Environment Impact on Aquatic & Terrestrial Habitats. pp. 127-142.

Gao, X. and J. Song 2005. Phytoplankton distributions and their relationship with the environment in the Changjiang Estuary, China. *Marine Poll. Bull.*, 50: 327-335.

Garzke, J., Sommer, U., Ismar, S.M.H. (2017). Is the chemical composition of biomass the agent by which ocean acidification influences on zooplankton ecology. Aquat Sci. 79(3): 733-748. doi:. 10.1007/s00027-017-0532-5.

Goswami, S. C. (2005). Zooplankton Methodology collection & identification manual. Published by National Institute of Oceanography, Dona Paula, Goa. Edited by V.K.Dhrgalkar & X.N.Veriecar.

Goswami, S.C and Padmavathi, G. (1996). Zooplankton production, composition and diversity in the coastal water of Goa. *Indian Journal of. Marine Science25,* 91-97.

Gray, J. S. (1997). Marine biodiversity: Patterns, threats and conservation needs. Biodiversity and Conservation, 6, 153–175.

Guglielmo, L., Granata, A., Guglielmo, R. (2015). Class Malacostraca Order Euphausiacea. Revista IDE@- SEA. 86(B): 1-20. ISSN 2386-7183.

GUIDE, (2011). Comprehensive Terrestrial EIA (including Mangroves) for the Proposed Multi-Project SEZ at Kandla. EIA report submitted to Mumbai Regional Centre of National Institute of Oceanography, Dona Paula, Goa.

Hambler, C and Speight, M R 1995. Biodiversity conservation in Britain, science replacing tradition British Wildlife, 6, 137-147yla, P S, S Velvizhi and S Ajmal Khan 1999 A Monograph on the amphipods of Parangipettai coast Annamalai University, India 78.

Harkantra, S. N., A. Nair, Z. A. Ansari and A. H. Parulekar, 1980. Benthos of the shelf region along the West coast of India. *Indian J. Mar. Sci.*, 9: 106-110.

Hussain, S. M., Joy, M. M., Rajkumar, A., Nishath, N. M & Fulmali, S. T. (2016). Distribution of calcareous microfauna (Foraminifera and Ostracoda) from the beach sands of Kovalam, Thiruvananthapur, Kerala, Southwest coast of India.Journal of the Palaeontological Society of India. 61(2). 267-272. ISSN 0522- 9630.

Hussain, S. M., Kalaiyarasi, A. (2013). Distribution of Ostracoda in the Mullipallam Lagoon, near Muthupet, Tamil Nadu, Southeast Coast of India —Implications on Microenvironment. In: Sundaresan J., Sreekesh S.,230 Ramanathan A., Sonnenschein L., Boojh R. (eds) Climate Change and Island and Coastal Vulnerability. Springer, Dordrecht.

Hussain, S. M., Kalaiyarasi, A. (2013). Distribution of Ostracoda in the MullipallamLagoon, near Muthupet, Tamil Nadu, Southeast Coast of India —Implications on Microenvironment. In: Sundaresan J., Sreekesh S.,230Ramanathan A., Sonnenschein L., Boojh R. (eds) Climate Change and Islandand Coastal Vulnerability. Springer, Dordrecht.

Ikeda, T., Kanno, Y., Ozaki, K., Shinada, A., 2001. Metabolic rates of epipelagic marine copepods as a function of body mass and temperature. Mar. Biol. 139, 587–596.

Ingole B, Sivadas S, Goltekar R, Clemente S, Nanajkar M, Sawant R, D'Silva C, Sarkar A, Ansari Z (2006) Ecotoxicological effect of grounded MV River Princess on the intertidal benthic organisms of Goa. Environ. Internat. 32:284-289.

Jagadeesan, L., Jyothibabu, R., Anjusha, A., Arya, P. M., Madhu, N. V., Muraleedharan, K. R., and Sudheesh, K., 2013. Ocean currents structuring the mesozooplankton in the Gulf of Manner and the Palk Bay, southeast coast of India. *Progress in Oceanography*, 110: 27-48.

Jegadeesan, P., 1986. Studies on environmental inventory of the marine zone of Coleroon estuary and inshore waters of Pazhayar, Southeast coast of India. *Ph. D., Thesis*, *Annamalai University*, India.

Jha, D. K., Devi, M. P., Vidyalakshmi, R., Brindha, B., Vinithkumar, N. V., and Kirubagaran, R. (2015). Water quality assessment using water quality index and geographical information system methods in the coastal waters of Andaman Sea, India. Mar. Pollut. Bull. 100, 555–561. doi: 10.1016/j.marpolbul.2015.08.032.

Jickells, T. D. (1998). Nutrient biogeochemistry of the coastal zone. Science 281, 217–222. doi: 10.1126/science.281.5374.217.

Jones, G., and Candy, S. (1981). Effects of dredging on the macrobenthic infauna of Botany Bay. *Marine and Freshwater Research*, *32*(3), 379–398.

Kadam S.S. and L. R. Tiwari, 2012. Zooplankton Composition in Dahanu Creek-West Coast of Ind. Res. J. Rec. Sci., 1(5): 62-65.

Karr, J. R., J D. Allen, and A. C. Benke 2000 River conservation in the United States and Canada. In P. J. Boon, Davies and B. R. Petts, G E (Ed.), Global perspectives on River conservation, pp 3–39 Science, Policy, and Practice. Wiley, New York.

Kasturirangan, L. R (1963). A key for the identification of the more common planktonic Copepoda of Indian coastal waters. Publication No .2. Indian National Committee on Oceanic Research. p. 87.

Krishnamurthy, K. and Santhanam, R. (1975). Ecology of Tintinids (Protozoa: Ciliata) in Porto Novo region. *Indian Journal of. Marine Science 4,* 181-184.

Kumar, A., 1995 Studies of pollution in river Mayurakshi in south Bihar. Indian Journal of Environmental Pollution, 2(1): 21-26.

Levandowsky, M., 1972. An ordination of phytoplankton population in ponds of varying salinity and temperature. *Ecology*, 53(3): 398-407.

Lyla, P S., Velvizhi, S and Ajmal Khan, S 1999. A Monograph on the amphipods of Parangipettai coast Annamalai University, India pp78.

Madin, L.P., Horgan, E.F., and D.K. Steinberg. 2001.Zooplankton at the Bermuda Atlantic Timeseries Study (BATS) station: diel, seasonal and inerannual variation in biomass, 1994-1998. Deep-Sea Research II. 48 (8-9): 2063-2082.

Magurran, A 1991. Ecological Diversity and Its Measurement Princeton University Press, Princeton, pp178.

Mahapatro, D R C., Panigrahy, K and Samal, R N 2011. Macrobenthos of shelf zone off Dhamara estuary, Bay of Bengal. J Oceanog Mar Sci 22, pp 32-42.

Mandal, S.K. (2004). Studies on the Effect of Ship Scrapping Industry Wastes on Marine Phytoplankton at Alang, Gujarat, Ph. D thesis. M. K. Bhavnagar University, Bhavnagar.

Margalef, R 1958. Information theory in ecology. Gen Syst, 3, 36–71.

Marine Biology Organization (MBO), 2007. Zooplankton Retrieved from: http://www.marinebio.com/oceans/zooplankton.Askp. 62k, (Accessed on: September 29, 2006).

Martin G.D, P.A. Nisha, K.K. Balachandran and G.V.M. Gupta (2011). Eutrophication induced changes in benthic community structure of a flow-restricted tropical (Cochin backwaters), India. Environ. Monit. Assess. 176(1-4):427-438.

Maurer, D., Watling, L., Kinner, P., Leathem, W and Wethe, C 1978. Benthic invertebrate assemblages of Delaware Bay. Mar Biol, 45, 65-78.

Maya, M. V., M. A. Soares, R. Agnihotri, A. K. Pratihary, S. Karapurkar, H. Naik & S. W. A. Naqvi 2011. Variations in some environmental characteristics including C and N stable isotopic composition of suspended organic matter in the Mandovi estuary. *Environ. Monit. Assess.,* 175: 501–517.

Mees, J. and Jones, M. B. (1997): The Hyperbenthos. Oceanography and Marine Biology: an Annual Review, 35, 221-255.

Mishra, S., and Panigrahy, R. C. (1999). Zooplankton ecology of the Bahuda estuary (Orissa), east coast of India. *Indian Journal of. Marine Science 28,* 297-301.

Mitra A., Davidson, K. and Flynn, K. J. (2003) The influence of changes in predation rates on marine microbial predator/prey interactions: a modelling study. *Acta Oecol* (Suppl. 1), S359–S367.

Mitra, A., Zaman, S., Sett, S., Raha, AK and Banerjee, AK 2014. Phytoplankton cell volume and diversity in Indian sundarban. Ind J Mar Sci 43, 2 208-215.

MitraA., Davidson, K. and Flynn, K. J. (2003) The influence of changes in predation rates on marine microbial predator/prey interactions: a modelling study.*cta Oecol* (Suppl. 1), S359–S367.

Moura, A. N., Bittencourt-Oliveira, M. C & Nascimento, E. C. (2007). Benthic Bacillariophyta of the Paripe River estuary in Pernambuco state, Brazil. Braz. J. Biol. 67(3): 393-401.

Murugan, A., 1989. Ecobiology of Cuddalore, Uppanar backwaters, Southeast coast of India. *Ph.D., Thesis, Annamali Universtiy*, India.

Murugesan, P., 2002. Benthic biodiversity in the marine zone of Vellar estuary (Southeast Coast of India). *Ph. D., Thesis Annamalai University,* India, 359pp.

Nair, VR 2002. Status of flora and fauna of Gulf of Kachchh, India NIO, Goa, pp 1-258.

Newell, R. C., Seiderer, L. J., & Hitchcock, D. R. (1998). The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and Marine Biology: An Annual Review, 36,* 127–178.

NIO, (2002). Status of flora and fauna of Gulf of Kachchh, India. National Institute of Oceanography, Goa.

NIO, 1998. Environmental studies for proposed BPCL jetty and associated facilities at Kandla Part-I Rapid marine EIA, May1998 NIO Mumbai.

NIO. (1980). Technical Report, National Institute of Oceanography, Goa.

Omori, M. and lkeda. T. (1984). Methods in Marine Zooplankton ecology. John Wiley & Sons, New York.

Parasharya D and Patel B. (2014). Spawning aggregation of Melibe viridis Kellart (1858) from Gulf of Kachchh-Western India. International Journal of Scientific and Research Publication, 4(3), ISSN 2250-3153.

Parulekar, A. H., Dhargalkar, V. K., & Singbal, S. Y. S. (1980). Benthic studies in Goa estuaries. Part 3. Annual cycle of macrofaunal distribution, production and trophic relations. *Indian J Mar Sci*.

Pearson, T. H. and Rosenberg, R. (1978): Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. Oceanography and Marine Biology-An Annual Review, 16: 229-311.

Perumal P, Sampathkumar P, Karuppasamy PK (1999) Studies on the bloom-forming species of phytoplankton in the Vellar estuary, southeast coast of India. Ind J Mar Sci 28: 400-403.

Pielou, E C 1966. The measurement of diversity in different types of biological collections. J Theoret Biol 13, 131-144.

Plafkin, J. L., Barber, M. T., Poter, K. D., Gross, S. K. and Highes, R. M. 1989. *Rapid bioassessment protocol for use in streams and rivers for benthic macro invertebrates and fish.* EPA/444/ 4-89/001**.** Office of water regulation and standards. U.S. Environmental Protection Agency, Washingaton DC, USA.

Prabhahar. C., K. Saleshrani & Enbarasan 2011. Studies on the ecology and distribution of phytoplankton biomass in Kadalur coastal zone Tamil Nadu, India. *Curr. Bot.*, **2(3):** 26-30.

Ramakrishna, D A 2003. Manual on identification of schedule molluscs from India 40pp.

Ramakrishna, T C R., Sreeraj, C., Raghunathan, R., Raghuraman, P and Yogesh Kumar, J S 2011. An account of additions to the Icthyofauna of Andaman and Nicobar Islands Records of the Zoological Survey of India, Occasional Paper no 326, 1-140 Published-Director, Zool Surv India.

Rao, K.K and Balasubramanian, T. (1996). Distribution of Foraminifera in the Cochin Estuary. J.mar.biol. Ass. India. 38(1 and 2): 50-57.

Reid, G. K, 1961. Ecology in inland waters and estuaries. New York.375.

Reid, G. K., Wood, R. D. (1976). Ecology of inland waters and estuaries. Toronto, Ontario, D. Van Nostrand Co., pp. 138–146.

Reid, G. K., Wood, R. D. (1976). Ecology of inland waters and estuaries. Toronto, Ontario, D. Van Nostrand Co., pp. 138–146.Thakur, B., Chavda, C., & Salvi, H. (2015). Phytoplankton diversity at some selected sites of the Gulf of Kachchh, Gujarat, India. Bulletin of Environmental and Scientific Researcch. 4(4): 7-12. ISSN. 2278-5205.

Saravanan, K. R., Sivakumar, K., and Choudhury, B. C. (2013). "Important coastal and marine biodiversity areas of India," in Coastal and Marine Protected Areas in India: Challenges and Way Forward, ENVIS Bulletin: Wildlife & Protected Areas, Vol. 15, ed. K. Sivakumar (Dehradun: Wildlife Institute of India), 134–188. doi: 10.1007/978-3-642-38200-0_30

Shannon, C E and Wiener, W 1949. The Mathematical theory of Communication Univ of Ilinois Press, Urbana.

Sinha B. and M. R. Islam, 2002. Seasonal variation in zooplankton population of two lentic bodies and Assam State Zoo cum Botanical Garden, Guwahati, Assam, Eco.Environ. Cons., 8: 273-278.

Sivasamy, S.N., 1990. Plankton in relation to coastal pollution at Ennore, Madras coast. Indian J. Marine Sci., 19: 115-119.

Sreenivasulu, G., Jayaraju, N., Raja Reddy, B.C.S., Prasad, T. L., Nagalakshmi, K., Lakshmanna, B. (2017). Foraminiferal research in coastal ecosystems of India during the past decade: A review. Geo ResJ. 13: 38–48.

SubbaRao, N V., Surya Rao, K V and Maitra, S 1991. Marine molluscs State Fauna Series 1, Part 3 Fauna of Orissa. Zool Surv India, Kolkata, 1–175.

Tabassum, A. and Saifullah, S. (2012). Centric Diatoms from the North Arabian Sea Shelf of Pakistan. LAP. BOOK Lambert Academic Publishing. ISBN: 978-3-659-28532-5.

Takai N, Mishima Y, Yorozu A, Hoshika A (2002) Carbon sources for demersal fishes in the western Seto Inlan Sea, Japan, examined by delta 13C and delta 15N
analyses. *Limnol Oceanogr.* 47(3):730-741.

Taylor, B. E. (1998). Analyzing population dynamics of zooplankton. Published by the American Society of Limnology and Oceanography, Inc. Limnol.Oceanogr 33(6, part 1): 1266-1273.

Thakur, B., Chavda, C., & Salvi, H. (2015). Phytoplankton diversity at some selected sites of the Gulf of Kachchh, Gujarat, India. Bulletin of Environmental and Scientific Researcch. 4(4): 7-12. ISSN. 2278-5205.

Thangaraja, G. S., 1984. Ecobiology of the marine zone of the Vellar estuary. *Ph. D. Thesis, Annamalai University, India*.

Thirunavukkarasu, K., Soundarapandian, P., Varadharajan, D., Gunalan, B. (2013). Zooplankton Composition Structure and Community Structure of Kottakudi and Nari Backwaters, South East of Tamilnadu. J. Environ. Anal. Toxicol. 4(1): 200. doi:.10.4172/2161-0525. 1000200.

Tiwari, L.R and Nair, V.R. (1998). Ecology of Phytoplankton from Dharmatar creek, West Coast of India. Indian. J. MarineScience. 27 (3 & 4).

Uptake, A. (1999). Primary production by phytoplankton and microphytobenthos in estuaries. *Estuaries, 29*, 93.

Zohary T, Yacobi YZ, Alster A, Fishbein T, Sh L, Tibor G.(2014). Phytoplankton. In: Zohary T, Sukenik A, BermanT, Nishri A, editors. Lake Kinneret – ecology and management. Dordrecht (Netherlands): Springer; p. 161–190.

Second Season Report
(2023 - 2024)

Studies on Dredged Materials for the presence of Contaminants and suggesting suitable disposal options

(As per EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific Condition No. vii)

DPA Work order No. EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021.

Submitted by

Gujarat Institute of Desert Ecology
P.B. No. 83, Mundra Road, Bhuj-Kachchh,
Gujarat - 370001, India

Submitted to

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

Project Team

Project Co-Ordinator : Dr. V. Vijay Kumar, Director

S. No	Name and Designation	Role	Background
1.	Dr. K. Karthikeyan Assistant Director	Principal Investigator	M.Sc., Ph.D. in Environmental Science; 15 years of experience in Marine Environmental Monitoring and Pollution Assessment studies.
2.	Dr. G. Jayanthi Scientist	Co-Investigator	MSc., MPhil., PhD in Botany; 13 years of Research and teaching experience inclusive of Post-Doctoral experience for 5 years.
3.	Dr. Krushnakant. D. Baxi Scientific Officer	Co-Investigator	Ph.D in Zoology (Marine Biology) with 5 years of experience
4.	Ds. Monika Sharma Sr. Scientific Asst.	Team member	M.Sc. in Environmental Sciences; 7 years of experience in Marine water and sediment analysis
5.	Ms. Dipti Parmar Scientific Assistant	Team member	M.Sc. in Environmental Sciences; 6 years of experience in sediment and water analysis.

Dr. V. Vijay Kumar
Director

Gujarat Institute of Desert Ecology

Certificate

This is to state that the **Second Season Report** of the work entitled, **"Studies on Dredged Material for the presence of contaminants"** has been prepared in line with the Work order issued by DPT vide No. EG/WK/4751/Part (EC & CRZ-1)/84. Dt.18.09.2021 as per the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016, Specific Condition No. vii.

This work order is for a period of Three years from 2021 –2024 for the above-mentioned study.

Institute of Desert Ecology Gujarat Bhuj

Authorized Signatory **Institute Seal**

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CONTENTS

Among the twelve major ports across the nation, Deendayal Port Authority, formerly known as Deendayal Port Trust, erstwhile called as Kandla Port Trust, holds a prominent position as a significant maritime gateway in India, situated within Gujarat's Kutch district. This stands out as the largest Creek-based port, positioned at the southwestern tip of the Gulf of Kachchh, on India's north-western coastline within the state of Gujarat. Deendayal Port Authority (DPA) serves as a pivotal hub for maritime trade, facilitating the transportation needs of several hinterland states. It boasts excellent connectivity through an extensive rail and road network, functioning as a crucial gateway for the export and import activities of northern and western Indian states, including Jammu & Kashmir, Delhi, Punjab, Himachal Pradesh, Haryana, Rajasthan, Gujarat, as well as parts of Madhya Pradesh, Uttaranchal, and Uttar Pradesh. This port ranks among the largest and most essential ports in the country, playing a vital role in India's international trade and maritime infrastructure. The administration and operations of the port are overseen by the Deendayal Port Trust (DPT), an autonomous entity established under the Major Port Trusts Act of 1963.

The Deendayal Port Trust is entrusted with the comprehensive management, development, and administration of the port. The authority is comprised of a dedicated team of professionals and experts who work diligently to ensure the efficient operation of the port and all related activities. About 35% of the country's total export takes place through the ports of Gujarat in which the contribution by Deendayal port is considerable. The port handled a total cargo of 105 MMTPA during 2016-17, 110 MMTPA during 2017-18, 115 MMTPA during 2018-19, 122.5 MMTPA during 2019-2020, 117.5 MMTPA during 2020-21 and 137 MMTPA during 2022-23. DPA is the only major Indian port to handle more than 127 MMT cargo throughput, and it has also registered the highest cargo throughput in its history. The port has handled a total of 3151 vessels during FY 2021-22. Over the years, the port has witnessed significant growth and development, becoming a crucial gateway for India's international trade.

Deendayal Port has a strategic location on the west coast of India, offering direct access to the Arabian Sea. It serves as a vital link for India's trade with countries in the Middle East, Africa, Europe, and Asia. The port handles a wide range of cargoes, including petroleum products, chemicals, coal, iron ore, fertilizers, salt, and general cargo.

Further, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. With such capacity, the Port ranks No. 1 among all the major ports in India for 12th Consecutive year. Further, a regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. The port has high commercial importance in the Indian maritime trade as it handled 36.1 million tons (17%) of Cargo out of total Cargo of 213.1 million tons of the maritime Cargo of India during 2015. In addition, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements.

Deendayal Port Authority (DPA) has taken up Development of 7 Integrated facilities, and the Ministry of Environment, Forest and Climate Change (MoEF & CC), has put up some conditions while according Environmental and CRZ clearance. One of the conditions is to carry out the *"Study on Dredged Material for presence of contaminants"* as accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific condition no. vii)" which states that ***"Dredged materials should be analyzed for presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted and the findings should be shared with the Gujarat SPCB and Regional Office of the Ministry"***.

1.1 Need of the study

Considering the aforementioned condition, DPA has assigned the task of carrying out the study to Gujarat Institute of Desert Ecology (GUIDE), Bhuj. This study will be attempted three times in a year at two specified locations. Further, the study will envisage the evaluation of physico-chemical constituents in the dredged materials in the dumped locations in the study area. GUIDE has been entrusted with the project, which has duration of three years (01.11.2021 – 31.10.2024) as specified in the work order. Accordingly, the study was initiated to evaluate the dredged materials for potential contamination, employing a systematic investigation that encompasses the analysis of physical, chemical, and biological characteristics with special reference to pollutants including heavy metal, Petroleum hydrocarbon etc.

1.2. Scope of the study

a. To monitor the locations where dredged materials are dumped will be conducted.
b. Dredged materials in the area will be analyzed for the presence of contaminants in two different locations.
c. Detailed assessment of the dredged materials for physical, chemical and biological characteristics will be studied.
d. Suggesting suitable disposal options for the dredged material will be made.

1.3. Sampling locations for 2023-24

The study focused on investigating the presence of contaminants in the dredged materials during the year 2023-24. The specific locations for sampling can be found in Table 1 and Plate 1. The selection of these sampling sites was based on information supplied by the Hydraulic and Dredging Division to the Department of Port Administration (DPA), concerning the locations of dumping grounds. These location details were subsequently shared with the Gujarat Institute of Desert Ecology (GUIDE) via an email dated October 24, 2018. Three seasonal studies covering Location 1, Location 2 and Location 3 with the second season of the study was conducted during 10.06.2024 – 12.06.2024.

Table 1: GPS Co-ordinates of sampling locations

Station	Latitude (N)	Longitude (E)
Location 1 (Offshore)	22° 51' 00" N	70° 10’ 00" E
Location 2 (Cargo jetty)	22°56' 31" N	70 13' 00" E
Location 3 (Phang Creek)	23° 04' 28" N	70°13’ 28" E

1.4. Details of work done during 3rd Quarter (May 2024 – July 2024)

The second season sampling of the project was conducted in the 1st Quarter of the project period, i.e., 2023-24. The second season sampling was performed in the month of January 2024. During the sampling, the surface and bottom marine water samples and bottom marine sediment samples were collected from the three designated locations, *i.e.,* Offshore, Cargo Jetty and Creek systems which was pre-designated locations as earmarked by CPWRS was conducted.

After the collection, the samples were preserved using standard protocols and stored in an Ice box and brought to the laboratory within 2-3 hrs of collection Comprehensive analysis was performed on all the samples, both water (36 samples) and sediment (18 samples), to determine various physical, chemical, and biological characteristics. The analysis followed the standard methods prescribed by the Integrated Coastal and Marine Area Management (ICMAM) in 2012. All samples were analysed in triplicates, and the obtained data was compared against the marine water limits specified by the Central Pollution Control Board (CPCB) and other relevant standards.

Plate 1: Map showing locations of proposed sampling (2023-2024)

Chapter 2 Physico-Chemical Characteristics of the Sediment

The sediment samples from the study area were collected for the purpose of characterization employing standard methodology and the analysis of the samples were also performed as per standard protocol and the data of sediment analysis is presented in this Chapter 1. The sediment samples were collected in pre-fixed stations using a Van-Veen type of grab sampler. After collection, the sediment samples were preserved with Rose Bengal and formalin to avoid decomposition of samples and processed for analysis and the samples after collection were brought to the laboratory on the same day of collection and air dried and used for further analysis for the test parameters (Table 2).

Table 2: Physico-chemical and biological characteristics of sediment samples

S. No	Physico-chemical and biological parameters
1	pH (1: 10 suspension)
2	Salinity (ppt)
3	Sand (%)
4	Silt (%)
5	Clay (%)
6	Total organic carbon (%)
7	Phosphorus (mg/kg)
8	Sulphur (mg/kg)
9	Petroleum Hydrocarbon (µg/kg)
10	Cadmium (mg/kg)
11	Lead (mg/kg)
12	Chromium (mg/kg)
13	Copper (mg/kg)
14	Cobalt (mg/kg)
15	Nickel (mg/kg)
16	Zinc (mg/kg)
17	Magnesium (mg/kg)
18	Macrobenthos

2.1. pH and Salinity (1: 10 suspension)

The pH of the sediment suspension is a measure of the activity of H+ ions within the sediment-water system. It indicates whether the sediment is acidic, neutral or alkaline in nature. Since ions are the carrier of electricity, the electrical conductivity (EC) of the sediment-water system rises according to the content of soluble salts. The EC measurement directly corresponds to the concentration of soluble salts in the sediment at any particular temperature. To conduct the analysis, ten grams of the finely sieved sediment was dissolved in 100ml of distilled water to prepare leachate. This leachate was taken for shaking using a rotator shaker for one hour to ensure proper homogenization of the suspension. Following this, the suspension was allowed to settle for two hours, and the supernatant was collected after filtration for the subsequent analysis of pH and salinity using the pH and EC meter (Make: Systronics 361) and Refractometer (Make: Atago) respectively. Each sample was analyzed in triplicates to ensure accuracy, and the mean values were considered for further evaluation.

2.2. Textural analysis (Sand/Silt/Clay)

Sediment samples were collected using Van Veen grab whereas intertidal sediments will be collected using a handheld shovel. After collection, the scooped samples are transferred to polythene bags, labelled and stored under refrigerated conditions. The sediment samples are thawed, oven dried at 40ºC and ground to a fine powder before analyses.

For texture analysis, specified unit of sediment samples were sieved using sieves of different mesh size as per Unified Sediment Classification System (USCS). Cumulative weight retained in each sieve will be calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves. The percent retained will be calculated from the weight retained and the total weight of the sample. The cumulative percent will be calculated by sequentially subtracting percent retained from 100%.

2.3. Total organic carbon

Total organic carbon refers to the carbon content stored within sediment organic matter. It is derived from various sources such as the decomposition of plant and animal residues, root exudates, living and deceased microorganisms, sediment biota etc. To measure total organic carbon in sediment, a process of oxidation is employed using potassium dichromate in the presence of concentrated sulfuric acid. During the analysis, potassium dichromate generates nascent oxygen, which reacts with the carbon present in organic matter, resulting in the production of carbon dioxide (CO2). The excess volume of potassium dichromate is then titrated against a standardized solution of ferrous ammonium sulfate in the presence of phosphoric acid, using Ferroin indicator to detect the initial appearance of unoxidized ferrous iron. This titration allows the determination of the volume of potassium dichromate required to oxidize the organic carbon present in the sample.

2.3.1. Procedure

The determination of the percentage of total organic carbon in sediment involves oxidizing the organic matter within the sediment samples using chromic acid. The excess chromic acid is then estimated by titrating it against ferrous ammonium sulfate, with ferroin serving as an indicator. The step-by-step procedure is outlined as follows:

To begin, 1 gram of sediment sieved to a particle size of 0.5 mm is weighed and transferred into a 500 ml conical flask. Then, 10 ml of 1N $K_2Cr_2O_7$ is added to the flask with pipette followed by gentle swirling to ensure thorough mixing. Next, 20 ml of concentrated H2SO4 is added, and the sediment and reagents are mixed gently. This mixture is allowed to react for 30 minutes on a marble stone to avoid any damage caused by the release of intense heat from the sulfuric acid reaction. Afterward, 200 ml of distilled water is slowly added to the flask, along with 10 ml of concentrated orthophosphoric acid and approximately 0.2 grams of NaF. The sample and reagent mixture is left to stand for 1.5 hours, as the titration endpoint is better observed in a cooled solution. Just before the titration, 1 ml of ferroin indicator is added to the conical flask. The excess $K_2Cr_2O_7$ is then titrated with 0.5 N ferrous ammonium sulfate until the color changes from yellowish green to greenish, and finally to a brownish-red color indicating the endpoint. A blank test without the sediment sample is also performed simultaneously for reference. Through this procedure, the percentage of total organic carbon in the sediment can be accurately determined.

2.4. Total Phosphorus

The determination of total phosphorus in sediment is commonly conducted using Bray's extraction method. This method involves the formation of specific-colored compounds by adding appropriate reagents to the solution, with the intensity of the color being directly proportional to the concentration of phosphorus being estimated. The color intensity is measured spectrophotometrically. In the spectrophotometric analysis, a light source emitting light of a specific wavelength (usually within a band width of 0.1 to 1.0 nm) in the ultraviolet region of the spectrum is used. The photoelectric cells in spectrophotometer measure the light transmitted by the solution allowing for quantitative analysis.

2.4.1. Procedure

To perform the analysis, 50 ml of the Bray's extractant is added to a 100 ml conical flask containing 5 grams of sediment sample. The flask is shaken for 5 minutes and then filtered. Exactly 5 ml of the filtered sediment extract is transferred to a 25 ml measuring flask using a bulb pipette. Subsequently, 5 ml of the molybdate reagent is added using an automatic pipette, followed by dilution to 20 ml with distilled water and shaken well. Furthermore, 1 ml of dilute Stannous Chloride solution is added, and the volume is made up to the 25 ml mark. Thorough shaking is performed to ensure proper mixing. The mixture is then allowed to develop color, and after 10 minutes, readings are taken in the spectrophotometer at a wavelength of 660 nm. Prior to the readings, the instrument is zeroed using a blank prepared similarly but without the sediment.

2.5. Total Sulphur

Total sulphur in the sediment extract was determined using a turbidimetric method with a spectrophotometer. A series of standards containing sulphur at concentrations of 2, 4, 6, 8, and 10 ppm were prepared from a stock solution. Each flask in the series received 25 ml of the respective standard solution, and 2.5 ml of conditioning reagent solution was added. Additionally, 5 ml of extraction solution was added to the mixture. To facilitate the reaction, 0.2-0.3 grams of barium chloride were included and thoroughly mixed. The volume was adjusted to 25 ml with distilled water, and readings were taken at 340 nm using a spectrophotometer.

For the sample analysis, 5 grams of marine sediment were placed in a 100 ml conical flask. To this, 25 ml of a 0.15% CaCl2 solution was added and shaken for 30 minutes. The mixture was then filtered through Whatman No. 42 filter paper. Subsequently, 5 ml of the sample aliquot was transferred into a 25 ml volumetric flask. Conditioning reagent (2.5 ml) and 0.2 to 0.3 grams of barium chloride powder were added, followed by making up the volume to 25 ml with distilled water. The flask contents were shaken for 2 minutes, and the absorbance was measured using the same procedure as the standard solutions.

2.6. Petroleum Hydrocarbons

To analyze petroleum hydrocarbons in sediment, the following procedure will be conducted. First, the sediment will undergo reflux with a mixture of KOH and methanol, allowing for the extraction of petroleum hydrocarbons. This reflux process helps release the hydrocarbons from the sediment matrix. Next, the sediment will be subjected to extraction using hexane, which selectively dissolves the hydrocarbons present in the sediment. The excess hexane will be carefully removed, leaving behind a residue containing the concentrated hydrocarbons of interest. To further purify the sample and remove any impurities, a clean-up procedure will be performed using silica gel column chromatography. This column chromatography process helps separate the hydrocarbons from other compounds present in the residue, resulting in a cleaner sample for analysis. Finally, the hydrocarbon content in the sediment will be estimated by measuring fluorescence, following the standard method for petroleum hydrocarbon analysis. This fluorescence measurement allows for quantification and determination of the hydrocarbon levels present in the sediment sample. By following this procedure, accurate analysis of petroleum hydrocarbons in sediment can be achieved.

2.7. Heavy metals

Heavy metals, such as Cadmium (Cd), Lead (Pb), Chromium (Cr), Nickel (Ni), Cobalt (Co), Copper (Cu), Zinc (Zn), Manganese (Mn), and others, are of particular concern in relation to the environment. To release mineral elements from sediment samples, wet oxidation is commonly employed, utilizing oxidizing acids, such as tri/di-acid mixtures.

In the analysis procedure, a sediment sample weighing 1.0 gram is taken in a 100 ml beaker, which is covered with a watch glass. A mixture of Aqua regia (1:3 HNO_3:HCl) in the amount of 12 ml is added to the beaker. The beaker is then subjected to digestion for 3 hours at 100°C on a hot plate using a sand bath. Afterward, the samples are evaporated to near dryness, allowed to cool for 5 minutes, and then 20 ml of 2% nitric acid is added. The beaker is placed on a hot plate for digestion for 15 minutes, after which it is removed from the hot plate and allowed to cool. The mixture is then filtered using Whatman No. 42 mm filter paper. Finally, the volume is adjusted to 50 ml with 2% nitric acid to make up the final solution. The extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis. By following this procedure, the heavy metal content in the sediment can be accurately analyzed using wet oxidation, filtration, and AAS techniques.

2.8. Results

2.8.1. pH (Hydrogen Ion)

When any characteristics study of water or sediment is concerned, pH is considered to be one of the major variable especially in marine sediments as it influences various biogeochemical processes and ecosystem dynamics. These values are influenced by various factors, including the carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron, and manganese cycles. They are closely associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and the dissolution of calcium carbonate in marine water and sediments. In our investigation, we conducted measurements of average pH values at different locations. All three locations show slightly alkaline pH levels in sediments. Offshore has the lowest average pH (7.46 ± 0.14), followed by Cargo Jetty (7.50 ± 0.11) and Phang Creek (7.51 ± 0.08). The differences are minimal, indicating relatively stable and similar pH conditions across all locations. The data on individual values at all the locations and stations are given in Table 3.

2.8.2. Salinity

Salinity of seawater is subject to fluctuations influenced by temperature changes, following diurnal and seasonal cycles that correspond to variations in atmospheric temperature. Salinity levels in marine water and sediment exhibit a wide range, typically spanning from 0 to 36 in most estuaries. Semi-enclosed bays can experience hyper-salinity conditions. In the present study, it was observed that a broader range of salinity concentrations at different stations. Phang Creek shows the highest average salinity (37.36 ± 11.41 ppt), followed by Cargo Jetty (22.65 ± 6.35 ppt) and Offshore (20.77 ± 7.15 ppt), respectively. These findings are summarized in Tables 3-5, where all the data is presented.

2.8.3. Sediment Texture

Understanding the sediment texture at different stations provides valuable insights into the habitat characteristics and ecological dynamics of the marine environment. The sediment texture plays a significant role in determining the physical and chemical properties of the marine sediment, influencing the distribution and abundance of benthic organisms at the offshore station. The sediment composition across the three locations—Offshore, Cargo Jetty, and Phang Creek—shows distinct patterns in the distribution of sand, silt, and clay. In terms of sand content, the Cargo Jetty has the highest percentage at 53.60% ± 16.99%, which indicates a more dynamic, high-energy environment. This could be due to the influence of strong currents or wave action that tends to carry away finer particles, leaving behind coarser sand. Offshore has a lower sand content at 41.73% ± 7.85%, while Phang Creek lies in between with 49.38% ± 20.40%. The silt content is fairly consistent between Offshore and the Cargo Jetty, with 22.32% ± 15.55% and 21.88% ± 14.11%, respectively. Phang Creek, however, shows a notably lower silt percentage at 13.62% ± 4.26%. Clay content is highest in Phang Creek at 37.00% ± 21.57%. Offshore also has a significant clay percentage at 35.95% ± 20.85%, while the Cargo Jetty has the lowest clay content at 24.52% ± 14.72%. These findings are summarized in Tables 3-5, which presents the data from all the stations.

2.8.4. Total organic Carbon

Total Organic carbon in sediments primarily originates from the decomposition of animals, plants, and anthropogenic sources such as chemical waste, fertilizers, and organic-rich waste. These sources contribute to the enrichment of the marine environment with organic material, which subsequently settles to the bottom sediments from the water column. This pathway leads to an increase in Total Organic Carbon (TOC) values and can have implications for the faunal communities inhabiting the sediments. In our study, during this second season, it was investigated the TOC concentrations at different stations. The mean ± standard deviation (SD) TOC percentages were determined to be Total Organic Carbon which is reported as 0.60±0.10% at the offshore station, 0.39±0.12% at the cargo jetty station, and 0.79±0.45% at the Phang creek station. The TOC concentrations at all stations are presented in Tables 3-5. Understanding the dynamics of organic carbon in marine sediments is vital for assessing the health and ecological integrity of marine environments. It helps in monitoring anthropogenic influences and their potential impacts on the marine ecosystem.

2.8.5. Organic matter

Organic matter serves as the primary reservoir of organic carbon in marine sediments, encompassing the chemical, physical, and biological degradation processes that contribute to the formation of organic material in the marine environment. It consists of a mixture of materials derived from various planktonic and benthic species, forming the ecological foundation for primary producers and consumers in the overlying surface sediment. In our study conducted during the second season, we investigated the levels of organic matter in different locations. The organic matter percentages ranged 1.06± 0.22% in the offshore location, 0.67% ± 0.21% at the cargo jetty, and 1.41% ± 0.88% in the Phang creek area and the findings are summarized in the below tables (3-5), which illustrates the variation in organic matter content across the studied locations. Understanding the presence and dynamics of organic matter in marine sediments is crucial for assessing the overall health and ecological functioning of marine ecosystems. Phang Creek shows the highest organic matter suggesting higher inputs of organic material, possibly from terrestrial sources or higher productivity. The Cargo Jetty area shows the lowest organic matter, which might be due to higher energy conditions preventing organic matter accumulation.

2.8.6. Phosphorus and Sulphur

Sulphur (S) is involved in dissimilatory sulfate reduction by microbial activity, which is a primary pathway for organic matter mineralization in anoxic sea beds. This process leads to the production of sulfide. Subsequently, chemical or microbial oxidation of the produced sulfide forms a complex network of pathways in the sulfur cycle, resulting in intermediate sulfur species and partial conversion back to sulfate. On the other hand, Phosphorus (P) is an essential nutrient for life and plays a crucial role in regulating primary productivity within marine systems. It serves as a key element in various biological processes. In marine sediments, phosphorus availability influences primary productivity, affecting the growth and development of marine organisms. In the present study, the highest concentration of sulphur was recorded as Phang Creek shows the highest average sulphur content (54.98 ± 2.63 mg/kg), followed by Cargo Jetty (43.37 ± 8.43 mg/kg) and Offshore (39.10 ± 8.40 mg/kg). The concentrations of phosphorus and sulphur at all stations are presented in Tables 3,4 and 5. The offshore has the highest average phosphorus content (11.15 ± 2.89 mg/kg), followed by Cargo Jetty (10.72 ± 4.33 mg/kg) and Phang Creek (6.98 ± 1.03

mg/kg). This could reflect differences in nutrient inputs or cycling across the locations.

Phosphorus levels are highest in the offshore and cargo jetty areas. This could indicate different sources of phosphorus, such as upwelling in offshore areas or anthropogenic inputs near the cargo jetty. The lower levels in Phang Creek might be due to higher uptake by organisms or different sediment characteristics that don't retain phosphorus as effectively. Phang Creek shows the highest sulphur content with the least variability. This could indicate more reducing conditions in the sediments, possibly due to higher organic matter content and limited oxygen penetration. The lower levels in offshore and cargo jetty areas might reflect more oxidizing conditions due to better water circulation. These elements influence the availability of essential nutrients and can have implications for primary productivity and the overall functioning of marine ecosystems.

2.8.7. Petroleum hydrocarbon (PHC)

Petroleum hydrocarbons in general have low solubility in marine water and tend to adsorb onto particulate matter, leading to their long-term persistence in sediment bottoms. This persistence can have significant negative impacts on benthic aquatic communities within the marine ecosystem. PHCs are a major source of contamination in marine environments, primarily comprising compounds from three classes: alkanes, olefins, and aromatics. In the present study, the levels of PHCs in different locations were measure.

Phang Creek has the highest average petroleum hydrocarbon content (5.82 ± 3.81 µg/kg), followed by Cargo Jetty (5.05 ± 4.00 µg/kg) and Offshore (2.36 ± 1.32 µg/kg). This suggests more anthropogenic oil-related inputs in the nearshore areas. The presence of petroleum hydrocarbons in marine environments is of great concern due to their potential harmful effects on marine organisms and ecosystems. These contaminants can bioaccumulate in organisms and disrupt their physiological processes, as well as cause long-lasting damage to the benthic communities. The higher levels of petroleum hydrocarbons in Phang Creek and Cargo Jetty compared to the offshore location suggest more significant anthropogenic inputs in these areas. This could be due to boat traffic, urban runoff, or industrial activities near these locations. The offshore area, being further from these sources, shows lower contamination levels.

2.8.8. Magnesium

Understanding the distribution and dynamics of magnesium in marine sediments provides valuable insights into the geochemical processes occurring within the sediment column and their impact on the marine ecosystem. Continuous monitoring of magnesium levels is crucial for assessing the health and ecological integrity of marine environments. Dissolved magnesium flux from the overlying ocean into marine sediments is primarily driven by molecular diffusion. This process occurs as pore water magnesium is depleted during the formation of authigenic minerals within the sediment column. Additionally, direct burial of seawater occurs as sediment accumulates on the seafloor, contributing to the input of magnesium into the sediment. Its concentration in sediments can have implications for nutrient availability, sediment mineralogy, and the diverse organisms inhabiting the sediment environment.

In our study conducted during the second season at Deendayal Port, we determined the concentrations of magnesium at different stations. Phang Creek shows the highest average magnesium content (5018.75 ± 1443.26 mg/kg), followed by Offshore (4324.83 ± 957.00 mg/kg) and Cargo Jetty (3508.50 ± 1786.51 mg/kg). Highest magnesium content in sediments of Phang Creek could be due to differences in sediment sources, with Phang Creek possibly receiving more magnesium-rich materials from terrestrial sources. The high variability in the Cargo Jetty area suggests a more heterogeneous sediment composition, possibly due to varied inputs from both marine and terrestrial sources.

2.8.9. Heavy metals

The heavy metal concentration in the sediment samples were examined for the presence of heavy metals from the samples collected from various stations at different locations at Deendayal Port. The analysis of sediment samples from three locations *viz*., offshore, cargo jetty, and Phang Creek revealed varying concentrations of heavy metals. In the offshore samples, Nickel ranged from 14.20 to 70.55 mg/kg (mean 49.75 mg/kg), while Chromium, Zinc, and Copper showed moderate levels with 10.15 ± 0.49; 22.53 ± 28.89; 23.87 ± 4.17. Manganese was notably high, averaging 639.88 ± 223.92 mg/kg. The concentration of cobalt was found to be 19.21 ± 1.81 mg/kg. Lead and Cadmium were consistently below detectable limits in offshore location. The cargo jetty location exhibited below detectable limits with lead, chromium, cadmium but showed a high variability in copper levels (11.65 to 123.90 mg/kg). The concentration of zinc, manganese, cobalt was found to be 6.83 ± 5.48 mg/kg; 622.15 ± 184.51 mg/kg; 12.72 ± 6.21 mg/kg. The concentration of nickel showed 13.94 ± 8.45 mg/kg. The Phang Creek location demonstrated the highest variability in Nickel (4.55 to 105.70 mg/kg) and contained below detectable limits with lead and cadmium. Manganese concentrations were consistently high across all three locations, with Phang Creek showing the highest average at 723.92 ± 17.13 mg/kg. Cobalt levels were relatively consistent across sites, ranging from 8.20 to 37.95 mg/kg. These results indicate site-specific variations in metal contamination, with some metals showing notably high concentrations in certain areas. The concentration of chromium, zinc and copper is 29.48 ± 10.78 mg/kg; 16.72 ± 14.12 mg/kg; 31.27 ± 23.13 mg/kg. The data is presented in Tables 3-5.

Table 3: Physico-chemical characteristics of sediment samples collected from Offshore location

S. No	Parameters	1A	1B	1C	1D	1E	Control 1
1	pH (1: 10 suspension)	7.44	7.33	7.41	7.39	7.45	7.73
2	Salinity	21.10	23.40	24.20	27.60	21.30	7.00
3	Petroleum Hydrocarbon	2.30	0.80	1.56	BDL	2.88	4.25
4	Magnesium	2993.5	3830.5	4445	4989	5730	3961
5	Sand (%)	49.9	37.2	28.9	40.7	48.1	45.6
	Silt (%)	30.6	9.3	10.6	20.3	13.4	49.7
	Clay (%)	19.5	53.5	60.5	39.0	38.5	4.7
6	Organic matter (%)	1.08	1.13	1.03	0.93	1.42	0.77
7	Total organic carbon	0.63	0.66	0.6	0.54	0.73	0.45
8	Phosphorus	15.97	10.41	9.95	11.34	12.03	7.17
9	Sulphur	32.90	33.24	37.55	52.13	46.71	32.06
10	Nickel	70.55	14.2	63.65	49.3	51.05	BDL
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	BDL	BDL	BDL	BDL	BDL	BDL
13	Chromium	9.8	BDL	BDL	BDL	10.5	BDL
14	Zinc	BDL	BDL	42.95	2.1	BDL	BDL
15	Copper	27.25	17.55	21.9	25.25	27.4	BDL
16	Manganese	727	717	741.5	754	716	183.8
17	Cobalt	19.2	20.05	19.3	16.3	21.2	BDL

Table 4: Physico-chemical characteristics of sediment samples collected from Cargo jetty

S. No	Parameters	2A	2B	2C	2D	2E	Control 2
1	pH (1: 10 suspension)	7.4	7.33	7.53	7.59	7.6	7.54
2	Salinity	16.60	25.20	13.60	24.50	25.20	30.80
3	Petroleum Hydrocarbon	1.02	BDL	2.88	3.54	11.25	6.58
4	Magnesium	5105	3491.5	5950	1710	1463.5	3331
5	Sand (%)	60.7	43.8	82.6	36.2	41.6	56.7
	Silt (%)	10.0	46.2	14.8	30.9	18.5	10.9
	Clay (%)	29.3	10.0	2.6	32.9	39.9	32.4
6	Organic matter (%)	0.41	0.72	0.41	0.88	0.72	0.88
7	Total organic carbon	0.24	0.42	0.24	0.51	0.42	0.51
8	Phosphorus	7.17	14.35	3.93	13.65	10.87	14.35
9	Sulphur	31.29	40.91	37.51	46.06	50.53	53.89
10	Nickel	BDL	9	BDL	10.95	26.55	9.25
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	BDL	BDL	BDL	BDL	BDL	BDL
13	Chromium	BDL	BDL	BDL	BDL	BDL	BDL
14	Zinc	BDL	2.95	BDL	10.7	BDL	BDL
15	Copper	123.9	22.25	BDL	22	11.65	17.8
16	Manganese	618	730.5	254.9	718.5	720	691
17	Cobalt	BDL	17.6	3.25	11.3	12.5	18.95

Table 5: Physico-chemical characteristics of sediment samples collected from Phang creek

S. No	Parameters	3A	3B	3C	3D	3E	Control 3
1	pH (1: 10 suspension)	7.40	7.43	7.54	7.61	7.53	7.57
2	Salinity	29.90	41.80	35.87	24.30	57.30	35.00
3	Petroleum Hydrocarbon	3.56	2.85	BDL	BDL	5.62	11.25
4	Magnesium	6075	2798	5030	6825	4024.5	5360
5	Sand (%)	67.2	72.5	62.8	34.9	24.7	34.2
	Silt (%)	13.8	13.9	17.2	12.8	18.0	6.0
	Clay (%)	19.0	13.6	20.0	52.3	57.3	59.8
6	Organic matter (%)	1.29	2.22	2.71	1.13	0.62	0.51
7	Total organic carbon	0.75	1.29	1.36	0.65	0.36	0.3
8	Phosphorus	8.56	6.94	6.25	7.87	6.01	6.25
9	Sulphur	55.53	56.18	57.32	54.50	56.41	49.96
10	Nickel	21.05	64.5	105.7	13.4	BDL	4.55
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	BDL	BDL	BDL	BDL	BDL	BDL
13	Chromium	BDL	BDL	37.1	BDL	BDL	21.85
14	Zinc	BDL	BDL	32.2	13.4	BDL	4.55
15	Copper	44.3	38.75	66.45	15.1	2.35	20.65
16	Manganese	739.5	725.5	734.5	703.5	702	738.5
17	Cobalt	23.1	20.25	37.95	14.25	8.2	15.05

3.1. Introduction

Earth surface contains more than 97% of water in which the oceans show biggest part of the life. The five oceans together constitute approximately 71% of the world's water bodies. Indian Ocean is the third largest ocean in the world with average depth of 3,890 meters (12,760 ft). As having at long coastline of almost 8000 km, India has vast marine resources. The Indian Ocean's connection is a very large scale, including the Red Sea, East Africa, the Persian Gulf, Southern Arabia, India and Other Indian sub continental countries Gujarat state of India shows longest coastline in India which is famous for various coastal ecosystems. Gujarat coasts having different coastal ecosystems like mangrove, sandy shores, muddy shores, rocky shores, mixed shores, wet sand shore, coral reefs and intertidal mudflats (Brink, 1993; Parasharya and Patel, 2014). Gujarat state is the only state in India bestowed with two gulfs, Gulf of Kachchh and Gulf of Khambhat. The Kachchh, largest district of the country with an area of 45,652 sq. km. Deendayal Port Authority is (DPT) one among the 12 major ports of the country and it is located in India's western coastal region.

3.1.1. Benthos

Benthos is nothing but water bottom communities or the organisms (floral and faunal) live in a benthic region regarding the sediment, rock and other substratum. They include mollusca (gastropods and bivalves), coral, sponges, worms (mostly polychaetes and nematode), crustacean crabs, other crustaceans, echinoderms, oysters etc. The faunal benthic organisms are called as zoo-benthos, while floral benthic organisms are called as phyto-benthos. They play an important role in conversion of organic detritus from the sedimentary storage into the dissolved nutrients. Their distribution in water bodies can be varies and, on that basis, they can be classified into three types which are Endo-benthos, Epi-benthos (Pearson and Rosenberg, 1978) and Hyper-benthos (Mees and Jones,1997). They are the food source of diverse groups of various organisms including the bottom feeding animals. They are one of the best indicators to assess the health and productivity of aquatic ecosystems. They are sensitive to wide range of environmental challenges including water movements, pollutants and living spaces (Martin et al., 2011). Their variations to tolerate changes in various environmental factors make them to be considered as an important bio-indicator for monitoring and research of marine environment.

3.2. Methodology

To study the benthic organisms, triplicate samples were collected at each station using Van-Veen grab which covered an area of $0.1m^2$. The wet sediment was sieved with varying mesh sizes (0.5 mm-macrofauna) for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution for easy spotting at the time of sorting. The number of organisms in each grab sample was expressed as number/ meter square (No/m^2). All the species were sorted, enumerated and identified to the advanced taxonomic level possible with the consultation of available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; Subba Rao *et al.* (1991) and Ramakrishna (2003) for molluscs.

Further, the data were treated with univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clarke and Warwick, 1994)

a) Shannon – Wiener index

In the present study, the data were analyzed for diversity index (H') by following Shannon – Wiener's formula (1949):

$H' = -\sum^{S} Pi \log 2\, Pi \ldots\ldots \quad i = 1$

which can be rewritten as

$$H' = \frac{3.3219\,(N \log N - \sum ni - \log ni}{N}$$

where, H'= species diversity in bits of information per individual

ni = proportion of the samples belonging to the ith species

(number of individuals of the ith species)

N = total number of individuals in the collection and

$\sum$ = sum

b) Species richness(S) was calculated using the following formula given by Margalef (1958).

c) Margalef index (d)

$$d = (S-1) / \log N$$

d) Pielou's evenness index

The equitability (J') was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\ln S}$$

Where, J' = evenness; H' = species diversity in bits of information per individual and S = total number of species.

3.3. Results on Species Composition, Population density and Biomass of Macrofauna of selected sites

3.3.1.Offshore

In Offshore region of Kandala port, total six sites were selected namely, (1A, 1B, 1C, 1D, 1E and 1- control). A total 6 groups/species(of benthic community) of benthic animals were observed in all stations at Offshore sites and they a Bivalves (Mollusca),Gastropods (Mollusca), Placuna sp (Bivalvae), Crustacean animals, Polychaeta worms (Annelida), Saccostrea sp (Bivalvia). All the data (Density and Biomass) expressed in (nos./m^2), (gm/m^2) respectively (Table 6). Pecten sp (Bivalvia), Worm snails and Scaphopoda (Mollusca) were totally absent in Offshore.

Highest population density of benthic organisms was recorded in station 1A-Offshore(675 nos/m^2), whereas lowest in station 1C-Offshore (75nos/m^2). The density range of all stations varied from 75 to 675nos./m^2. Bivalves and Gastropods were more abundant among all the benthic organisms might be sandy-muddy or rocky substratum in bottom part of Offshore region. Low recorded benthos were Polychaeta worms and Saccostrea sp (Bivalvia) that indicated less part of substratum are muddy and not suitable attachement. The highest biomass value (expressed wet weight) of benthic fauna was observed in station 1D-Offshore (4.36gm/m^2) and lowest value was

1C-Offshore (0.06 gm/m^2) (Table 6). Range of the Biomass was 0.06 to 4.36 gm/m^2 . Moderately Biomass values and also density values suggested mixing substratum, less availability of plenty food items and more predator pressure by higher animals. Intermediate association was also one responsible factor for the same. Variation in density and biomass in Offshore region because more influences by the Water Currents, Up welling - Down welling (Churning process of water) movements of water and Nutrients availability and Fluctuation in turbidity of water.

3.3.2.Cargo Jetty

In Cargo Jetty, frequently observed benthic groups were Bivalves, Gastropods, *Placuna sp* (Bivalvae), *Pholas sp* and less reported benthos were Razor clam, *Saccostrea sp* , Worm snail and Scaphopoda. Crustacean animal group was totally absent. The population density range noted between 150 to 3300(nos/m^2) among all the stations (Cargo Jetty-2A, 2B, 2C, 2D, 2E &2-Control) during the study period. Highest and Lowest density were recorded in station 2C- Cargo Jetty(3300nos./m^2) and 2E-Cargo Jetty (150nos./m^2) respectively.

Biomass value indicated a highest value in station 2C- Cargo Jetty (40.9gm/m^2) and lowest in 2control- Cargo Jetty (2.27gm/m^2) (Table 6). Average Biomass and Population density value of all station were 12.08gm/m^2, 1020 nos./m^2 respectively which indicated the moderate favourable environment condition of biota, water quality as well as substratum (mostly rocky).

3.3.3. Phang creek

Six Stations of Phang creek were selected for the study namely 3A, 3B, 3C, 3D, 3E and 3-control-Phang Creek. In this Phang Creek benthic organisms were mostly represented by Polychaeta worms (annelids). Only three groups were present namely Polychaeta worms, Bivalve and Gastropods whereas Other were totally absent. The population density was highest in station 3A and 3B -Phang Creek (75nos./m^2) and on the other side, lowest density was recorded in 3D-Phang Creek (25nos./m^2). Station

3B-Phang Creek comprises highest wet wt (0.86gm/m^2), whereas low value was recorded in3D & 3E-Phang Creek(0.03 gm/m^2).

Overall result (Offshore, Cargo Jetty and Phang creek) of macrofaunal community showed highest population density in 2C-Cargo Jetty (3300nos/m^2) and high biomass was observed (40.9gm/m^2) in 2C-Cargo Jetty . Table 6 showed highest population values of Bivalves in 2C- Cargo Jetty (1750nos/m^2) and same highest value of Gastropoda showed in 2C- Cargo Jetty (625nos/m^2).

The lowest value comprised by the *Pecten sp, Placuna sp, Pholas sp,* Scaphopoda , Worm snails, Razor clam including some were totally absent in some sites. Some absent or less frequently observed benthos indicated extreme weather condition (may be suddenly change temperature of running season), more stress condition and unfavourable environment condition for their survival. Bivalves and Gastropods, dominant groups were preferred rocky, sandy or mix substratum, and any other hard substrata**.** Polychaete worms are preferred sandy-muddy substratum or sandy habitat mostly in Phang creek.

Table 6 showed that average population density and biomass higher in Cargo Jetty and after Offshore where mostly rocky, sandy or covered with muddy area and algal growth providing a unique habitats for benthos. Low density and biomass was observed in mostly Phang creek area and some parts of Off shore (Table 6 and Figure 1) which indicated stressful environment, seasonal effect, more anthropogenic activities and also might be some chemical and biological changes in water. The population density and biomass of benthic community largely affected by the symbiotic and intermediate relation between them or with other invertebrates and suitable rocky substratum or coral reef in bottom of sea. Availability of Plankton, as a food source, also affected the benthic animals (Table 6 and Fig. 1 & 2). Extremely mix weather condition (during May and June months) also more affected in Offshore and Phang creek regions of Kandla port area.

In benthic communities, recorded species at all sites were, *Pecten sp, Placuna sp, Umbonium vestiarium Tellina sp., Clypeomorus bifasciata, Trochus sp, Radix* *sp,Nassarius sp, Nerita sp, Donax sp, Turris sp,Marcia sp, Dosinia sp, Donax sp, Anadara sp, Turris sp, Solen, Nereis sp, Saccostrea sp, Optediceros breviculum,Euolica sp etc.* The percentage of occurrence (Table 6) was revealed *highest group present by Bivalves and Gastropoda (72%)* then following area *Polychaeta worms (Annelida) (56%), Placuna sp (33%) and then others. Detail status of Population density,* Group composition and biomass of the benthic community of all selected sites were depicted in (Table 6) and (Figure 1). *Among* all the stations, highest percentage composition recorded by Bivalves (43%) followed by Gastropods (22%), *Placuna sp* (14%) and others (Figure.2).

Phytoplankton abundance and their size, zooplankton body composition, patchy distribution of zooplankton, water currents, ebb and flow tides, and water churning process, changing in structure of muddy, rocky and sandy habitats are the main reasons for biomass and density fluctuation in Benthic communities. In Crustacean most commonly observed species are Crabs and attached Barnacles. Main Mollucsa families recorded Trochidae, Cerithidea, Turritellidae, Tellinidae, Mitridae, Veneridae, Donacidae and Bucciniae etc. *Nereis sp* of anneliids was mostly observedin samples. More number of the broken bivalves, debris, plant items, broken gastropods, small pebbles and soil particles are frequently observed during benthic organism's study.

3.4. Diversity Indices of Benthic Community

The data in table 7 showed various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.00-1.52) indicated very low diversity. Highest diversity indices was recorded in Station 2B-Cargojetty (1.52) where six groups/species of benthos presented where as Shannon indices nil (zero) observed in 3C, 3D, 3E, 3Control- Phang creek where only one benthic group present and density value was very low. Comparatively less Shannon indices value very low in Phang creek area number of benthos group/species present between 1 to 2 nos. The evenness values ranged between (0.53 to 1). The highest evenness value (1) is observed in stations 3C, 3D, 3E and 3 Control (Phang creek) where only 1 or 2 benthic groups.

Evenness value “1” indicated all organisms occurred in same area or mostly same group. Simpson’s Index value ranged between 0.00 to 0.75 indicated to lower to very less moderate diversity. The Margalef value showed range of 0 - 0.86 indicated high variation in species/group numbers (Table 7).

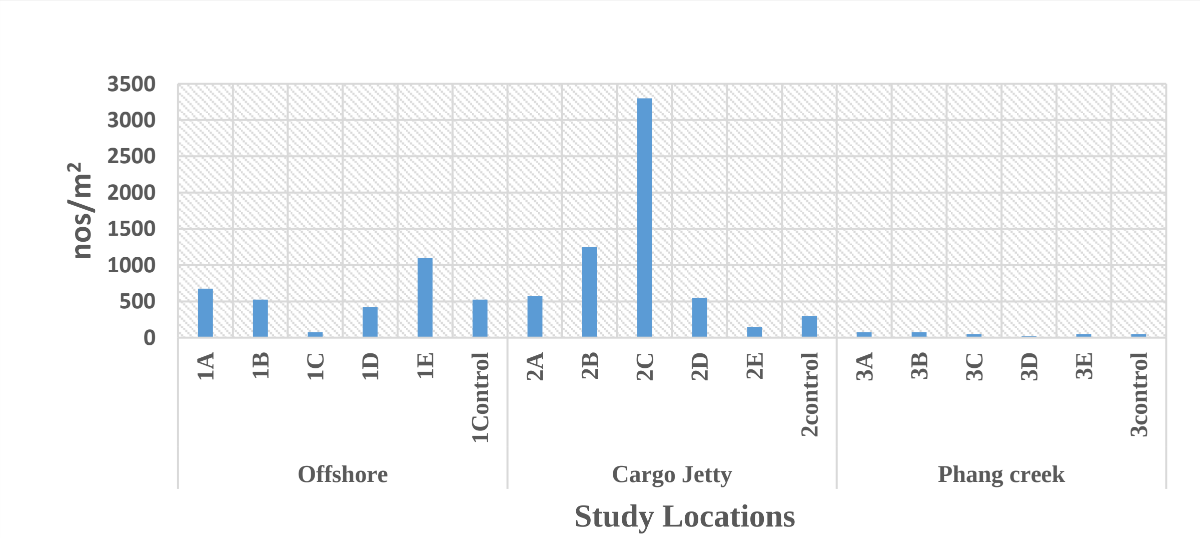

Figure 1. Population density of benthic organisms (nos/m^2) in various sites

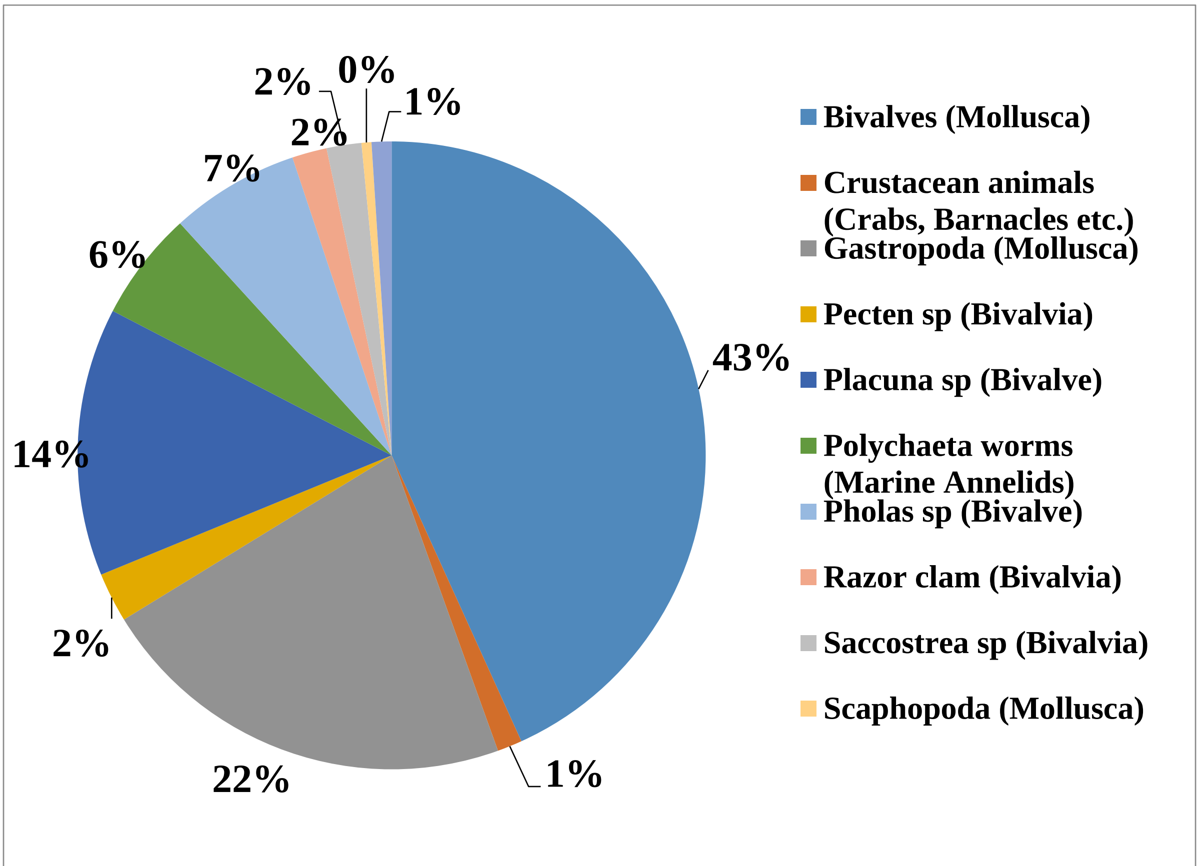

Figure 2. Percentage composition of benthic organisms in various sites

Table 6. Macrobenthos distribution in different sites of Deendayal Port

Name of Station	Offshore						Cargo Jetty						Phang creek						
	1A	1B	1C	1D	1E	1-Control	2A	2B	2C	2D	2E	2-Control	3A	3B	3C	3D	3E	3-Control	% of Occurrence
Name of Benthic Groups																			
Bivalves (Mollusca)	350	225	50	250	500	175	125	250	1750	250	100	175	25	0	0	0	0	0	72
Crustacean animals (Crabs, Mysis etc.)	0	0	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Gastropoda (Mollusca)	175	125	25	50	175	225	175	150	625	175	50	125	0	50	0	0	0	0	72
Pecten sp (Bivalvia)	0	0	0	0	0	0	0	0	250	0	0	0	0	0	0	0	0	0	6
Placuna sp (Bivalve)	150	175	0	0	300	0	175	250	300	0	0	0	0	0	0	0	0	0	33
Polychaeta worms (Marine Annelids)	0	0	0	125	0	50	0	50	0	75	0	0	50	25	50	25	50	50	56
Pholas sp (Bivalve)	0	0	0	0	0	0	50	500	50	50	0	0	0	0	0	0	0	0	22
Razor clam (Bivalvia)	0	0	0	0	0	0	0	0	175	0	0	0	0	0	0	0	0	0	6
Saccostrea sp (Bivalvia)	0	0	0	0	0	75	0	0	100	0	0	0	0	0	0	0	0	0	11
Scaphopoda (Mollusca)	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	6
Worm snail (Vermitidae)	0	0	0	0	0	0	50	50	0	0	0	0	0	0	0	0	0	0	11
Total Population Density Nos/m^2	675	525	75	425	1100	525	575	1250	3300	550	150	300	75	75	50	25	50	50	
Biomass (wet weight) gm/m^2	4.24	2.02	0.06	4.36	2.94	1.02	14.32	7.34	40.9	5.1	3.2	2.27	0.76	0.86	0.07	0.03	0.03	0.08	

Table 7. Diversity indices of benthic faunal groups at various station of Deendayal Port –Kandla (Benthos)

Variables	Offshore						Cargo Jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-control	2A	2B	2C	2D	2E	2-contrl	3A	3B	3C	3D	3E	3cont
Taxa_S	3	3	2	3	4	4	5	6	8	4	2	2	2	2	1	1	1	1
Individuals (Nos./m^2)	675	525	75	425	1100	525	575	1250	3300	550	150	300	75	75	50	25	50	50
Dominance_D	0.39	0.35	0.56	0.45	0.32	0.32	0.25	0.26	0.34	0.33	0.56	0.51	0.56	0.56	1.00	1.00	1.00	1.00
Shannon Diversity Index (H)	1.03	1.07	0.64	0.92	1.25	1.23	1.48	1.52	1.45	1.21	0.64	0.68	0.64	0.64	0.00	0.00	0.00	0.00
Simpson_1-D	0.61	0.65	0.44	0.55	0.68	0.68	0.75	0.74	0.66	0.67	0.44	0.49	0.44	0.44	0.00	0.00	0.00	0.00
Evenness_e^H/S	0.93	0.97	0.94	0.84	0.87	0.86	0.88	0.76	0.53	0.84	0.94	0.99	0.94	0.94	1.00	1.00	1.00	1.00
Menhinick	0.12	0.13	0.23	0.15	0.12	0.17	0.21	0.17	0.14	0.17	0.16	0.12	0.23	0.23	0.14	0.20	0.14	0.14
Margalef	0.31	0.32	0.23	0.33	0.43	0.48	0.63	0.70	0.86	0.48	0.20	0.18	0.23	0.23	0.00	0.00	0.00	0.00

Chapter 4 Physico-Chemical Characteristics of Marine Water

4.1. Introduction

In recent decades, there has been a notable deterioration in aquatic ecosystems primarily caused by the presence of a diverse array of organic and inorganic contaminants. Among these pollutants, heavy metals (HMs) and microplastics (MPs) have emerged as significant contributors to this environmental degradation (Frew et al., 2020; Saha et al., 2016). These substances are recognized for their capability to infiltrate and accumulate within the aquatic food chain, making them hazardous pollutants in aquatic environments (Olojo et al., 2005). Of particular concern are heavy metals due to their toxic nature, long-lasting presence, resistance to degradation, the potential for bioaccumulation, and the ability to magnify up the food chain, all of which have raised global alarms (Begum et al., 2013; Cai et al., 2017).

Heavy metal pollution in aquatic ecosystems can be attributed to a variety of sources, including natural factors such as atmospheric deposition and weathering (Ebrahimpour and Mushrifah, 2010; Hamidian et al., 2016) as well as human activities like mining, agricultural runoff, sewage discharge, industrial effluent release, gasoline leaks from fishing vessels, and accidental chemical waste spills (Arulkumar et al., 2017). It is essential to recognize that certain heavy metals, such as copper (Cu), iron (Fe), nickel (Ni), cobalt (Co), zinc (Zn), manganese (Mn), and chromium (Cr), play vital roles in physiological processes and are necessary for the proper biological functioning of organisms in trace amounts. However, exposure to nonessential heavy metals can lead to various health concerns, including renal, cardiovascular, nervous, and bone diseases, as well as immune-related issues (Abadi et al., 2018; Madreseh et al., 2018). It is crucial to acknowledge that all heavy metals become toxic when their concentration exceeds a certain threshold level (Makedonski et al., 2017). In light of these concerns, it is imperative to assess the various characteristics of water in order to determine the extent of pollutant presence in aquatic environments.

4.2. Materials and Methods

In this study, marine water and sediment samples were collected following standard protocols, and their analysis was conducted using established methods for marine water and sediment analysis as prescribed by APHA (2012), NIO manual (1982), and ICMAM Manual (2012). For general analysis, surface water samples were collected using a clean polyethylene bucket, while water samples from the bottom were collected using a weighted Niskin sampler. Water samples at a depth of 1 meter below the surface were collected using a 1-liter glass bottle sampler. Parameters such as pH, temperature, and salinity were measured on-site using handheld meters and verified in the laboratory.

The collected water samples were stored under refrigerated conditions until further analysis of other parameters. According to the standard protocol, fixatives and preservatives were added to the samples for specific parameters. For example, Winkler A&B solution was immediately added to measure dissolved oxygen, concentrated H2SO4 was used to bring the pH below 2 for chemical oxygen demand analysis, and nitric acid was used for the preservation of heavy metals. Formalin was added to marine water samples for planktonic analysis. In general, all water and sediment samples were stored in sterile polythene bottles and Ziplock bags and kept in an icebox to maintain suitable conditions until they were transported to the laboratory. The parameters to be analyzed (Table 8) and the methods used for the sample analysis are described below.

Table 8: Physico-chemical and biological characteristics of marine water samples

S. No	Physico-chemical and Biological parameters
1	pH
2	Salinity (ppt)
3	Total Dissolved Solids (mg/L)
4	Turbidity (NTU)
5	Dissolved Oxygen (mg/L)
6	Bio-Chemical Oxygen Demand (mg/L)
7	Chemical Oxygen Demand (mg/L)
8	Phenolic compound (µg/L)
9	Petroleum Hydrocarbons (µg/L)
10	Oil and grease (mg/L)
11	Cadmium (mg/L)
12	Lead (mg/L)
13	Chromium (mg/L)
14	Copper (mg/L)
15	Cobalt (mg/L)
16	Nickel (mg/L)
17	Zinc (mg/L)
18	Magnesium (mg/L)
19	Chlorophyll (mg/m^3)
20	Phaeophytin (mg/m^3)
21	Phytoplankton Phytoplankton cell counts (no/L) Total Genera (no.) Major Genera
22	Zooplankton Biomass (ml/100m^3) Population (no/100m^3) Total Group (no.) and Major Groups

4.2.1. pH, Temperature and Salinity

pH and temperature measurements were conducted using a Thermo Fisher pH/EC/Temperature meter. Prior to use, the instrument was calibrated with standard buffers. For pH determination, an appropriate volume of the sample was titrated against silver nitrate (20 g/l), with potassium chromate serving as an indicator. The chlorinity of the sample was estimated, and salinity values were derived using a specific formula.

4.2.2. Total Dissolved Solids (TDS)

To confirm the readings obtained from the handheld meter, the samples underwent a gravimetric procedure. Approximately 100 ml of the water sample was taken in a beaker and filtered. The filtered sample was then completely dried in a hot air oven at 105°C. The TDS values were calculated by measuring the difference between the initial and final weight of the dried sample.

4.2.3. Turbidity

For turbidity measurement, a sample tube (Nephelometric cuvette) was filled with distilled water and inserted into the sample holder. The lid of the sample compartment was closed, and the meter reading was adjusted to zero by manipulating the 'SET ZERO' knob. The sample tube containing the 40 NTU standard solution was then placed in the tube, and the meter reading was set to 100. Similar measurements were carried out for other standard solutions. To determine the turbidity of the marine water sample, the sample tube was filled with the water sample, and the corresponding reading was recorded.

4.2.4. Dissolved Oxygen (DO)

To determine the Dissolved Oxygen (DO) levels in a water sample obtained from a marine environment, the following procedure was employed. Collect sea water sample, ensuring that the sampling container is clean and free from any potential contaminants that may affect the accuracy of the results. Subsequently, transfer the water sample into a Winkler's bottle or a suitable container, taking care to eliminate any trapped air bubbles. It is crucial to completely fill the bottle to minimize any headspace that could potentially alter the DO readings. Next, add the appropriate volumes of Winkler's reagents, such as manganese sulfate and alkali-iodide-azide, to the water sample as per the specific instructions of the Winkler's method. Gently and thoroughly mix the contents of the bottle to ensure uniform distribution of the reagents without introducing any air bubbles. Allow the bottle to stand undisturbed for a designated incubation period, typically around 30 minutes, to enable the necessary reactions to occur. After the incubation period, perform a titration using a standardized sodium thiosulfate ($Na_2S_2O_3$) solution until a faint yellow color appears, indicating the complete consumption of dissolved oxygen in the sample. Record the volume of sodium thiosulfate solution used for titration, which represents the amount of dissolved oxygen present in the water sample. To account for any dissolved oxygen in the reagents, it is essential to conduct the same procedure with blank samples that do not contain the water sample. This allows for an accurate calculation of the DO levels in the original water sample. Finally, employ the appropriate formula provided by Winkler's method to calculate the DO concentration in the water sample.

4.2.5. Biochemical Oxygen Demand (BOD)

To determine the Biochemical Oxygen Demand (BOD), the following procedure was employed using the direct unseeded method. Collect representative sea water sample from the desired location, ensuring the sampling container is clean and uncontaminated. Fill a BOD bottle with the water sample, leaving minimal headspace to prevent air contact that could affect BOD measurements. It's important to completely fill the bottle to minimize air bubbles. Record the initial Dissolved Oxygen (DO) level in the water sample using a dissolved oxygen meter or appropriate measurement method. Seal the BOD bottle tightly with the stopper to prevent air exchange. Incubate the sealed BOD bottle in a controlled environment, such as a BOD incubator, at a specified temperature (typically 20°C), for a designated incubation period, usually around 5 days. Throughout the incubation period, keep the BOD bottle in darkness to minimize the impact of photosynthetic activity. After the incubation period, measure the final DO level in the water sample using the same method or instrument as the initial measurement. Calculate the BOD by subtracting the final DO level from the initial DO level, accounting for any necessary dilution or blank corrections. This difference represents the amount of oxygen consumed by the organic matter in the water sample during the incubation period.

4.2.6. Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) test is a widely used method for quantifying the levels of organic and inorganic pollutants in water samples. The first step involves collecting representative water samples from the target site, ensuring proper labeling and record-keeping. Subsequently, these samples are placed into digestion vials or tubes, to which digestion reagents, typically potassium dichromate and sulfuric acid, are added. This step initiates the oxidation of organic matter in the sample. The sealed vials or tubes are then subjected to high-temperature heating, typically around 150-160°C, for a predetermined period, usually around 2 hours. This heating process breaks down complex organic compounds into simpler forms. After digestion, the samples are allowed to cool to room temperature. To determine the COD concentration, a colorimetric measurement is taken. A suitable reagent is added to the digested samples, reacting with any residual potassium dichromate, and generating a color change proportional to the COD concentration. This color intensity is measured using a colorimeter or spectrophotometer, and the results are calibrated using known COD standards. The final calculations yield the COD value, typically expressed in milligrams of oxygen per liter (mg/L) of the sample.

4.2.7. Phenolic compounds

To analyze phenolic compounds in water, the following procedure was followed. A 500 ml water sample containing phenols was treated with 4-aminoantipyrine, which converted the phenols into an orange-colored antipyrine complex. This complex was then extracted using 25 ml of chloroform. The absorbance of the extracted complex was measured at 460 nm using phenol as a standard for comparison. This measurement allowed for the quantification of phenolic compounds present in the water sample.

4.2.8. Petroleum Hydrocarbons (PHc)

The analysis of Petroleum Hydrocarbons (PHc) in a water sample involved the following protocol. One liter seawater sample was extracted using organic solvent, hexane. The mixture was then separated into an organic layer and an aqueous layer. The organic layer, containing the petroleum hydrocarbons, was isolated. To remove any remaining water, the organic layer was dried using anhydrous sulphate. The volume of the organic layer was subsequently reduced to 10 ml at a temperature of 30°C under low pressure. The fluorescence of the extracted organic compound was measured at 360 nm (with excitation at 310 nm) using Saudi Arabian crude residue as a standard. This residue was obtained by evaporating the lighter fractions of crude oil at 120°C. By comparing the fluorescence intensity of the extract with that of the standard, the concentration of petroleum hydrocarbons in the water sample could be determined.

4.2.9. Oil and Grease

To determine the content of Oil and Grease in a sample, the following procedure was followed. Approximately 500 ml of the sample was transferred to a separating funnel, and the sample bottle was rinsed with 30 ml of trichlorotrifluoroethane. The rinsing solvent was then added to the separating funnel. Next, 5 ml of 1:1 hydrochloric acid (HCl) was added to the mixture, and the contents were vigorously shaken for about 2 minutes. If a soluble emulsion was formed, the sample container was shaken for an additional 5 to 10 minutes. After shaking, the layers in the separating funnel were allowed to separate, and the lower layer (organic layer) was discarded.

The solvent layer was drained through a funnel containing a filter paper moistened with solvent, and it was collected in a clean distillation flask that had been pre-weighed. The solvent was then distilled from the flask using a water bath set at 70°C. The resulting residue was carefully transferred into a clean, pre-weighed, and dried beaker, using the minimum amount of solvent necessary. The beaker was placed on a water bath at 70°C for 15 minutes to evaporate off all the solvent. After the evaporation process, the beaker was cooled in a desiccator for 30 minutes to reach a consistent temperature, and its weight was then measured.

4.2.10. Heavy metals

Heavy metals are a significant concern, especially in coastal environments, since it is biomagnifying from lower organisms to higher organisms through water and sediment. Common heavy metals of concern include Cadmium (Cd), Lead (Pb), Chromium (Cr), Copper (Cu), Cobalt (Co), Nickel (Ni), Zinc (Zn), Magnesium (Mg) and Manganese (Mn). To release mineral elements from sediment and analyze them, a wet oxidation process is typically employed using oxidizing acids, such as a mixture of Tri / Di-acids.

The procedure begins by weighing 0.5 grams of the sediment sample and placing it in a 100 ml beaker, which is covered with a watch glass. Then, 12 ml of Aqua regia (a mixture of 1 part HNO3 and 3 parts HCl) is added to the beaker. The beaker is placed in a digestion apparatus and heated at 100°C for 3 hours on a hot plate using a sand bath. The sample is evaporated until it is nearly dry, and then allowed to cool for 5 minutes. Next, 20 ml of 2% nitric acid is added to the cooled sample in the beaker, and the mixture is further digested on the hot plate for 15 minutes. After digestion, the beaker is removed from the hot plate and allowed to cool. The sample is then filtered using a Whatman No. 42 mm filter paper to remove any solid particles. To make up the final volume, the filtrate is diluted with 2% nitric acid to a total volume of 50 ml. The resulting extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis of the heavy metal concentrations.

4.3. Results

In this second season study conducted in the present year, we closely monitored three distinct locations: Offshore, Cargo Jetty, and Phang Creek. A comprehensive analysis of physico-chemical characteristics in marine water samples was conducted at each of these sites. The collected data is thoughtfully presented in Tables 9-11. These findings serve as a significant source of information regarding the precise physico-chemical conditions prevailing at each of these locations. Consequently, they play a pivotal role in enhancing the comprehension of the environmental factors that exert influence on the quality of marine water in these specific areas. The description of the data in each station is detailed as below.

4.3.1. Location 1 - Offshore location

The offshore water samples exhibited moderate levels of salinity (40.90 ± 5.06 ppt) and total dissolved solids (42,279.25 ± 1,658.75 mg/L). The water was relatively warm (30.49° ± 0.22°C) with a slightly alkaline pH (7.87 ± 0.07). Turbidity was notable (141.13 ± 57.37 NTU), which could be due to suspended particles or plankton. Dissolved oxygen levels (5.48 ± 0.41 mg/L) were adequate for marine life but the lowest BOD (1.70 ± 0.44 mg/L), suggesting less biodegradable organic matter. However, it shows the highest levels of COD (34.50 ± 5.92 mg/L). The presence of petroleum hydrocarbons (17.12 ± 8.10 μg/L) indicating potential anthropogenic inputs from marine activities and phenolic compounds (22.93 ± 9.68 μg/L) suggests some level of anthropogenic influence. Nutrient indicators like chlorophyll (0.51 ± 0.10 mg/m^3) and phaeophytin (0.32 ± 0.06 μg/L) were present in low concentrations. The mean value of Oil and Grease exhibited 6.10 ± 1.41 mg/L. Most heavy metals were either below detectable limits or present in low concentrations, with cadmium (1.72 ± 1.11 μg/L) showing the highest levels among the detected metals. Lead, zinc and copper showed Below Detectable Limit (BDL). The concentration of heavy metals observed for Magnesium (301.91 ± 109.91 mg/L); Nickel (1.84 ± 0.82 mg/L); Chromium (0.23 ± 0.30 mg/L); Manganese (0.32 ± 0.27 mg/L); Cobalt (0.92 ± 0.70 mg/L) were shown in Table 9. Overall, the offshore waters showed signs of moderate anthropogenic impact but maintained conditions generally suitable for marine life.

4.3.2. Location 2 – Cargo Jetty

At the Cargo Jetty location, the recorded data shows that the mean value of temperature was recorded as 30.82 ± 0.10°C, and the mean value of pH was observed as 7.93 ± 0.03. The average salinity of the seawater was 39.35 ± 2.44 ppt reflecting the salt content, while the TDS which indicates the presence of various anions and cations, had an average value of 44,775.08 ± 4,693.04 mg/L. Turbidity values ranged from 130.76 ± 19.35 NTU. The maximum values recorded for Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were 5.75 ± 0.36 mg/L and 2.08 ±

0.65 mg/L respectively (as shown in Table 10). The average COD value was determined to be 32.00 mg/L ± 4.26 mg/L. The concentrations of Phenolic compound with mean concentration is 18.90 ± 6.99 μg/L. In case of Petroleum hydrocarbon, all the samples were well within the permissible limits set by CPCB and the maximum recorded concentration was 15.80 ± 8.34 μg/L. The mean concentration of oil and grease in the marine water samples was 7.67 ± 3.34 mg/L, which falls below the acceptable limit of 10 mg/L according to GPCB norms. Regarding heavy metal concentrations, the Mean values for Magnesium, Nickel, Cadmium, Manganese and Cobalt were 279.89 ± 130.92 mg/L, 2.15 ± 1.48 mg/L, 0.98 ± 0.81 mg/L, 0.30 ± 0.12 mg/L, 1.39 ± 0.58 mg/L respectively. The concentration of Chromium was found to be 0.055 mg/L with only one detectable value. The concentration of lead, Zinc and Copper recorded a Below Detection Limit (BDL) in all the sampling points in Station 2 as given in Table 10.

4.3.3. Location 3 - Phang Creek

During this winter sampling in the Phang creek near the port, all the samples were subjected for analysis for various characteristics (Table 11). The mean value of temperature was recorded as 31.46 ± 0.28°C and the pH value was recorded between 7.88 ± 0.05. The average salinity of the seawater in the vicinity was found to be 39.95 ± 2.40 ppt while the TDS which indicates the presence of various anions and cations, had an average value of 42,749.17 ± 3,004.49 mg/L. Turbidity values ranged 329.73 ± 25.94 NTU. Pollution indices such as Dissolved Oxygen and Biochemical Oxygen Demand, Phenolic compounds, and Oil and grease concentrations had maximum values of 5.34 ± 0.21 mg/L, 2.49 ± 0.29 mg/L, 13.23 ± 4.59 μg/L, and 6.18 ± 2.90 mg/L, respectively. The average value of Petroleum hydrocarbon was 13.80 ± 7.02 μg/L. The average COD value was determined to be 30.50 ± 4.83 mg/L. In case of heavy metals, the maximum concentrations of Magnesium, Nickel, Cadmium, Manganese and Cobalt recorded were 276.17 ± 167.43 mg/L, 2.34 ± 1.66 mg/L, 0.98 ± 0.38 μg/L, 0.20 ± 0.22 μg/L and 1.74± 0.55 mg/L respectively. The mean value of Chromium is 0.29 ± 0.31 μg/L. Few of the heavy metals such as Lead, Zinc and Copper were in the Below Detection Limits.

Table 9: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore)

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	30.6	30.5	30.3	30.3	30.3	30.3	30.3	30.5	30.5	30.5	30.9	30.9
2	pH	7.79	7.72	7.86	7.88	7.90	7.80	7.92	7.88	7.93	7.91	7.92	7.93
3	Salinity (ppt)	38.61	38.61	38.18	42.47	39.04	38.61	55.35	41.61	44.19	40.33	36.47	37.32
4	Total Dissolved Solids (mg/L)	41818	44920	41748	42724	41091	41275	41098	39817	43694	43052	45168	40946
5	Turbidity (NTU)	225	260.2	151.6	152	150.1	145.8	86	88.5	49.8	130.1	127.7	126.7
6	Dissolved Oxygen(mg/L)	5.9	5.8	5.3	5.2	6.2	6.1	5.3	5	5.2	5.1	5.4	5.2
7	Bio-Chemical Oxygen Demand (mg/L)	1.40	1.30	1.30	1.20	2.00	1.80	1.40	1.30	1.80	2.10	2.40	2.40
8	Chemical Oxygen Demand (mg/L)	36.00	32.00	34.00	30.00	32.00	30.00	36.00	32.00	48.00	44.00	32.00	28.00
9	Phenolic Compounds (µg/L)	14.20	32.29	36.40	32.91	33.30	32.70	17.18	13.02	15.72	17.50	10.31	19.58
10	Petroleum Hydrocarbons (µg/L)	12.56	10.85	25.23	18.65	22.21	10.56	11.52	10.28	32.65	28.54	12.50	9.86
11	Oil and grease (mg/L)	5.6	2.8	7.6	5.6	7.2	7.6	5.2	6.8	6.4	7.6	5.2	5.6
12	Magnesium (mg/L)	339.45	414.50	237.55	93.9	234	291	218.95	349.15	269.5	449.5	245.85	479.55
13	Nickel (mg/L)	BDL	2.305	BDL	BDL	0.44	BDL	1.795	BDL	BDL	2.185	2.455	BDL
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	BDL	BDL	1.52	2.055	2.75	BDL	2.875	2.285	0.16	2.925	0.42	0.515
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.57	BDL	0.05	0.06	BDL
17	Zinc (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	BDL	BDL	BDL	0.335	0.105	0.92	0.51	0.35	0.21	0.29	0.11	0.02
20	Cobalt (mg/L)	BDL	1.655	BDL	0.39	0.225	BDL	0.7	0.365	0.41	1.945	1.87	0.73

Note: BDL denotes Below Detection Limit.

Table 10: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty)

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	30.6	30.9	30.9	30.8	30.8	30.7	30.8	30.7	30.9	30.9	30.9	30.9
2	pH	7.89	7.87	7.92	7.92	7.94	7.95	7.96	7.95	7.93	7.94	7.95	7.96
3	Salinity (ppt)	36.28	42.9	39.47	40.33	38.61	36.28	40.33	37.75	42.47	39.04	36.28	42.47
4	Total Dissolved Solids (mg/L)	41756	43689	46079	50188	36643	41043	51710	51507	42176	41859	42913	47738
5	Turbidity (NTU)	130.8	125.7	101.5	115.2	135.7	140	104.8	110.8	153.9	152.7	140.9	157.1
6	Dissolved Oxygen(mg/L)	6.2	5.8	5.6	5.2	5.8	5.6	5.6	5.3	6.3	5.4	6.1	6.1
7	Bio-Chemical Oxygen Demand (mg/L)	2.6	2.9	1.1	1.1	1.9	1.2	2.4	2.3	2.9	2.5	2	2.1
8	Chemical Oxygen Demand (mg/L)	36	30	28	22	32	32	34	34	36	30	38	32
9	Phenolic Compounds (µg/L)	6.56	17.39	17.81	13.85	29.06	14.47	21.66	15.72	28.54	23.95	14,27	19,27
10	Petroleum Hydrocarbons (µg/L)	10.85	9.26	25.87	19.82	10.52	9.52	15.46	10.42	35.28	22.22	10.85	9.56
11	Oil and grease (mg/L)	7.2	6.4	4.8	8.8	16	6.4	12	5.2	5.6	7.2	8	4.4
12	Magnesium (mg/L)	BDL	209.2	131.55	132.95	387.4	453.9	149	247.7	341.3	164.3	439.45	422
13	Nickel (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4.365	1.495	1.3	1.435
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	0.735	0.365	BDL	1.75	BDL	0.9	BDL	0.77	0.17	0.53	2.595	BDL
16	Chromium (mg/L)	0.055	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
17	Zinc (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	0.325	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.425	0.1	0.35	0.285
20	Cobalt (mg/L)	BDL	BDL	BDL	0.605	BDL	BDL	BDL	0.96	2.305	1.58	1.46	1.435

Note: BDL denotes Below Detection Limit

Table 11. Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek)

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1	Temperature (^{0}C)	31	31.1	31.1	31.3	31.5	31.6	31.6	31.5	31.6	31.5	31.9	31.8
2	pH	7.86	7.83	7.82	7.8	7.88	7.91	7.9	7.92	7.93	7.91	7.92	7.92
3	Salinity (ppt)	38.61	39.04	36.61	41.61	37.75	42.9	38.61	41.61	36.47	40.76	42.04	43.33
4	Total Dissolved Solids (mg/L)	42690	40452	43570	42072	43750	43943	43651	44879	38455	37123	43840	48565
5	Turbidity (NTU)	263.3	353.2	330.2	336.6	373	325.9	338.6	341.5	315	322	326.8	330.7
6	Dissolved Oxygen(mg/L)	5.2	5	5.5	5.1	5.4	5.7	5.4	5.1	5.5	5.3	5.5	5.4
7	Bio-Chemical Oxygen Demand (mg/L)	2	2.1	2.4	2.6	2.3	2.4	2.4	2.5	2.6	2.7	2.9	3
8	Chemical Oxygen Demand (mg/L)	32	28.0	36	30	28	22	36	32	28	24	38	32
9	Phenolic Compounds (µg/L)	19.79	16.56	20.83	16.35	14.89	5.72	11.77	10.41	8.43	11.77	13.02	9.27
10	Petroleum Hydrocarbons (µg/L)	25.25	13.84	20.85	18.57	12.58	10.87	21.25	10.85	9.85	5.62	2.30	BDL
11	Oil and grease (mg/L)	12.0	7.2	4.4	4.8	5.2	6.4	4.4	5.2	2.0	5.6	10.8	4.8S
12	Magnesium (mg/L)	56.55	350.75	BDL	70.3	108.8	557.5	244.8	407.6	276.95	474	151.3	339.35
13	Nickel (mg/L)	1.91	1.77	BDL	2.06	4.125	BDL	BDL	0.295	3.235	4.93	BDL	0.37
14	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15	Cadmium (mg/L)	BDL	BDL	0.815	BDL	0.87	1.535	BDL	BDL	BDL	BDL	BDL	0.69
16	Chromium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	0.115	BDL	0.175	0.09	0.22	0.84
17	Zinc (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
18	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19	Manganese (mg/L)	0.255	0.1	0.12	0.02	0.205	0.075	0.03	0.425	0.07	0.735	BDL	BDL
20	Cobalt (mg/L)	2.425	1.515	1.42	1.195	1.725	1.95	0.69	2.255	1.695	2.535	BDL	1.725

Note: BDL denotes Below Detection Limit

Chapter 5 Biological Characteristics of Marine Water

5.1. Introduction for Plankton

Plankton is defined as all those living organisms which are suspended and drifting in water. The planktonic communities encompass of aquatic organisms which drift passively and also have limited mobility to move contrary of the water mass. Plankton are divided in two parts which are phytoplankton and zooplankton (Brink. 1993). The tiny flora or plants are called as Phytoplankton, and weak swimming tiny fauna or animals are called as Zooplankton. Phytoplankton are the primary producers in marine ecosystems and form the basis of the food web. Zooplankton are pelagic animals play a role in the food chain in aquatic ecosystem to provide a food resource to various organisms. Major phytoplankton in sea water is Diatoms (Tiwari and Nair, 1998; Thakur et al, 2015), Cocolithophores, Sillicoflagellates, Blue green algae (Cyanobacteria) and Dinoflagellates. Zooplankton comprises the second level in the food chain and includes Tintinnids, Foramonifers, Radiolarians, Amphipoda, Copepoda, Calanoida, Chaetognaths, larvae of benthic invertebrates and fish larvae etc. (Gajbhiye and Abidi, 1993; Thirunavukkarosu, 2013; Chakrabarty et al. 2017). Size is very important to understanding about the classification of both zooplankton and phytoplankton. Based on size, various categories of plankton are smallest one Picoplankton (0.2-2 μm), Nanoplankton (2-20 μm), Microplankton (20-200 μm), Mesoplankton (200 μm-2 mm), Macroplankton (2-20 mm) and Megaplakton(> 20 mm) . The population of plankton diversity is largely related to seasonal and monthly variability in Physical, Chemical and Biological parameters; Interspecific competition among the Zooplankton; Inter-relationship for prey and predator between zooplankton and their mostly predator animals; Grazing ratio of primary-secondary consumers; Suspension of sediment; Fluctuation in Phytoplankton abundance; Waves, Currents and Tidal turbulence effect; Fluctuation in Chlorophyll a and Nutrients; Input of Organic and other Pollution creating sources; Fish potential ratio; Monsoon effect; Suddenly changes in atmosphere; Peak time of every seasons and it’s effect; Vertical migration of Zooplankton; Food selection pattern of predator; Collection time and number of collected samples, mixing of water column, high surface action, Seasonal up welling and down welling process in water column.

5.1.1. Phytoplankton

Phytoplankton are single celled marine algae with great difference in shape, size and form, either use flagella for movement in water or just drift with currents (Zohari et al, 2014). These photosynthetic organisms need sunlight for photosynthesis. With trapping carbon in the process of photosynthesis, they can control the atmospheric carbon dioxide and help in combating the global climate change. With this, they have significant role in the management of nutrients cycles in the ocean systems. Their role as primary producers in aquatic ecosystem, in the process of nutrients cycling in the ocean systems, also in calcification, silicification, nitrogen-fixing, etc. made them important marine component for marine life study. Their sensitiveness for various anthropogenic activities in the marine environment such as Eutrophication, introduction of invasive species, overfishing etc, make them one of the best indicators to analyse these activities.

5.1.2. Zooplankton

The faunal species particularly microscopic fauna, living inside the water bodies are known as zooplankton. Zooplankton is tiny-small animals found in all water bodies particularly the pelagic and littoral zone in the ocean. They are classified by size and or by development stages. Zooplankton community is composed of both primary consumers (which eat phytoplankton) and secodanry (which feed on the other zooplankton). Nearly all fish depend on zooplankton for food in both larval stages and entire life period (Madin et al., 2001). They are attractive, various and plentiful group of faunal species which can swim or generally drift with water currents but have no potential to swim against water currents (Alcaraz and Calbet, 2003). The important role of them is to be a major link in the marine life in between marine microalgae or phytoplankton and fish. Although they can be classified according to their habitat and depth, distribution, size and duration of planktonic life period (Omori and lkeda, 1984), generally, it is considered as there are two types of zooplanktons.

Holoplanktons are those which live permanently in the planktonic form, while meroplanktons are the temporary members in this form. The potential of zooplankton to respond quickly to environment changes and short generation life span, make them important bioindicator of water pollution and all variation occurred in their living environment. Their study is the important part for getting knowledge of the functioning of marine ecosystems (Mees and Jones, 1997).

5.2. Methodology

5.2.1 Estimation of Chlorophyll and Phaeophytin

Estimating Chlorophyll and Phaeophytin was done using known volume of water (500 ml) was filtered through a 0.45μm Millipore membrane filter paper and the pigments retained on the filter paper were extracted in 90% acetone overnight at 50°C. The extinction of the acetone extract was measured using fluorimeter before and after treatment with dilute acid (0.1N HCI).

5.2.2. Phytoplankton sampling and analysis

Phytoplankton samples were collected in the ten prefixed sampling sites using a standard plankton net with a mesh size of 51 μm. Plankton nets are with a square mouth covering an area of 0.900 cm^2 (30 cm square mouth) fitted with a flow meter (Hydrobios). Nets were towed from a moving boat for 10 minutes and the plankton adhering to the net was concentrated in the net bucket. Plankton soup from the net bucket was transferred to a pre-cleaned and rinsed container and preserved with 5% neutralized formaldehyde. The containers were appropriately labelled. The initial and final flow meter reading was noted down for calculating the amount of water filtered to estimate plankton density. As per flow meter reading, a total amount of $165m^3$ of water was filtered by the net. One liter of water was separately collected for density estimation to counter check density estimation obtained by the flow meter reading. Quantitative analysis of phytoplankton (cell count) was carried out using a sedge wick-Rafter counting chamber. One ml of soup added to a Sedgwick counting chamber was observed under an inverted compound microscope. The number of cells present in individual cells of the counting chambers (1/1000) was noted and identified up to a generic level. Several observations were fixed to represent the entire quantity of the soup (generally more than30 times) and the recorded data were used to calculate the density (No/l) using the formula, $N = n \times v/V$ (where N is the total no/l; n is an average number of cells in 1 ml; v is the volume of concentrate; V is the total volume of water filtered). The phytoplankton diversity richness and evenness were past software.

5.3. Phytopigments

The concentration of phytopigments is inversely proportional to the turbidity of the waters and in general, waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.35 -0.68 mg/m^3 with a mean ± SD being 0.51±0.10 mg/m^3 in the Offshore (Table 12), 0.274 to 0.62 mg/m^3 with mean ± SD of 0.41±0.12 mg/m^3 in the Cargo Jetty (Table 13) and 0.31 to 0.71 mg/m^3 with mean ± SD being 0.45±0.11 mg/m^3 in the Phang creek location (Table 14).

Another phytopigment estimated was Phaeophytin, which is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.24-0.42 mg/m^3 with a Mean±SD of 0.32±0.06 mg/m^3 in the Offshore location (Table 12). In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.12- 0.32 mg/m^3 with a Mean±SD of 0.228±0.059 mg/m^3 (Table 13) and in case of the creek location, the concentration of phaeophytin was almost similar when compared to the other two locations and was ranging between 0.24-0.55 mg/m^3 with a Mean±SD of 0.35±0.08 mg/m^3 (Table 14). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 12: Chlorophyll and Phaeophytin concentration observed in the Offshore site

Parameters	1A		1B		1C		1D		1E		1 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.520	0.530	0.660	0.500	0.490	0.460	0.480	0.470	0.680	0.590	0.382	0.350
Phaeophytin	0.250	0.370	0.310	0.280	0.280	0.380	0.310	0.250	0.410	0.420	0.280	0.240

Table 13: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site

Parameters	2A		2B		2C		2D		2E		2 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.520	0.350	0.320	0.280	0.450	0.313	0.341	0.347	0.530	0.274	0.580	0.620
Phaeophytin	0.320	0.280	0.210	0.120	0.280	0.210	0.290	0.200	0.230	0.180	0.260	0.160

Table 14: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site

Parameters	3A		3B		3C		3D		3E		3 Control	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.348	0.580	0.460	0.420	0.560	0.710	0.380	0.310	0.420	0.510	0.430	0.360
Phaeophytin	0.360	0.372	0.32	0.350	0.470	0.550	0.240	0.280	0.370	0.320	0.374	0.280

5.4. Phytoplankton

The study was conducted at 3 sites (or regions) at Kandla Port and near area where dredging activities is going on Creek and the stations are Offshore, Cargo Jetty and Phang Greek.

5.4.1. Offshore

In this site, frequently observed species were *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus wailesii, Ditylum brightwelli, Fragilaria sp, Thalassionema frauenfeldii colony, Thalassionema nitzschioides colonies, Trieres mobiliensis, Odontella sinensis, etc.* whereas less observed species were *Amphiprora sp, Bacillaria paxillifera colonies, Gyrosigma sp, Protoperidinium sp, Rhizosolenia sp etc.* Total 30 Phytoplankton were recorded in this Offshore area. Highest population density was recorded at site 1E-Offshore (431680nos./m^3) and lowest density was recorded at site 1B-Offshore (160000nos./m^3). The maximum number of species observed in site 1Control-Offshore (20 nos.) followed by 1D (18nos.), 1E and 1A (16nos.), 1B(13nos.), 1C-Offshore(12nos.). The population density greatly varied between (160000nos./m^3 to 431680nos./m^3). *Synedra ulna, Fragilaria sp colony, Nitzschia sp, Thalassiosira sp* were recorded which are sometimes considering for pollution indicator species in water. Green algae was also recorded in some location of Offshore which may be indication of freshwater or polluted water mixing with seawater. Some Dinoflagellates were also recorded like *Protoperidinium sp*, Highest population density contributor species was *Coscinodiscus wailesii (range 88000 to 120000*nos./m^3)

5.4.2. Cargo jetty

Total 27 Phytoplankton were recorded in this Cargo Jetty area. The population density greatly varied between 104800 Nos/m^3 to 393440 Nos/m^3. Highest density value recorded at 2control-Cargo Jetty (393440nos./ m^3) and lowest value was at 2C-Cargo Jetty (104800nos./m^3). The lowest number of species noted in the site 2C and 2E-Cargo Jetty (09 nos.) whereas highest in 2A-CargoJetty (15 nos.). In this Cargo Jetty station commonly or frequently observed species were *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus radiatus, Coscinodiscus wailesii, Odontella sinensis, Thalassionema frauenfeldii colony* etc. The rarely found species were Climacosphenia sp, *Chaetoceros sp, Planktoniella blanda, Rhizosolenia imbricata, Triceratium favus etc.* The Dinoflagellates *like Tripos muelleri* was also observed during microscopic analysis that may be indication of water circulation from deep water to upper surface. *Dictyocha sp (Silicoflagellates)* was also recorded.

5.4.3. Phang Creek

The population density of phytoplankton ranged from 64000nos./m^3 to 121120nos./m^3 same way species availability ranged from 11 to 20 nos. Maximum and Minimum value of population density were recorded in site 3Control-Phang Creek (121120nos./m^3) and 3A-Phang Creek (64000 nos./m^3) respectively. Highest number of species recorded in site 3B-Phang Creek (20nos.) and lowest in site 3C-Phang Creek (13nos.). Total recorded phytoplankton was 27 in this creek area. *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus wailesii, Coscinodiscus radiatus, Odontella sinensis Thalassionema frauenfeldii colonies Rhizosolenia sp , Synedra ulna, Thalassionema frauenfeldii colonies, Thalassionema nitzschioides colonies, Thalassiosira sp etc.* were frequently noticed during microscopic work whereas less observed species were Biddulphia sp, Fragilaria sp Gyrosigma sp and some unidentified phytoplankton. Green algae *were also recorded,* which are generally found in fresh water and estuarine area.

Overall view of Phytoplankton showed that a total 40 species of Marine phytoplankton were identified during summer season of the year 2024. Among them,20-Centric diatoms, 15-Pennate diatoms, 2-Dinoflagellates, 1-Green algae and 1-silicoflagellates and some are not identified phytoplankton's was included in unidentified. Some species like *Bacillaria paxillifera colonies, Chaetoceros sp, Climacosphenia sp, Dictyocha sp (Silicoflagellates) Planktoniella blanda, Rhizosolenia gracillima, Trachyneis sp* were rarely recorded during sample analysis. Input of the fresh water indicated by the presence of some common fresh water species like *Green algae*. Presence of *Dinoflagellates (,Tripos muelleri Protoperidinium sp)* indication of bottom water circulation up to surface water layer in some level. *Dictyocha sp* (Silicoflagellates) was also recorded in Cargo Jetty region. Highest phytoplankton density was observed at the site 1E-Offshore (431680nos./m^3) and lowest was observed at site 3A-Phang creek (64000 nos./m^3) (Table 15). Total number of highest species observed at site 1control-Offshore and 3B-Phang creek (20nos.) and lowest in site 2C and 2E-Cargo jetty (09nos.).

The high population density composed by species like Actinocyclus sp, *Coscinodiscus centralis, Coscinodiscus radiates, Coscinodiscus wailesii, Thalassionema frauenfeldii colonies, Thalassionema nitzschioides colonies* (Table 15). This result indicated that genus *Coscinodiscus sp. Actinocyclus sp, Thalassionama sp* were very common with good numbers in all sites. In some sites, least number of species and low density of phytoplankton might be responsible due to some factors like extreme cool weather because of winter season, high pre-predation ratio, marine pollution (anthropogenic pressure), high turbidity, total suspended solids, water current and suddenly changes in environment conditions etc. Diatoms, type of phytoplankton, constitute major part in total phytoplankton composition The individual density of species of sites and all the values of phytoplankton density, list of phytoplankton and others shown in (Table 15).

5.5. Diversity Indices of Phytoplankton

According to Table 16, diversity indices calculation for phytoplankton showed that the Shannon Index ranged from (0.73 to 2.34) indicated low level to moderate level of diversity status. High Shannon Index was recorded at 3Control-Phang creek (2.34) where 18 species were recorded and low at 2E-Cargo Jetty(0.73) where 09 species were recorded. Lowest evenness recorded at site 2A and 2E-Cargo Jetty(0.23)whereas highest was in at 3B-Phang creek (0.65). Dominance_D index ranged from 0.10 to 0.72 whereas higher value in 2E-Cargo Jetty (0.72) and lowest was at in 3B- Phang creek (0.10). Value of Margalef D (0.64 to 1.67) showed more variation in species numbers. (Table 16.).

Table 15. Density of Phytoplankton at different sites of Deendayal Port

Name of Sites	Offshore						Cargo Jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1 control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2 control**	**3A**	**3B**	**3C**	**3D**	**3E**	**3 control**
Genus of Phytoplankton																		
Actinocyclus sp	20000	9600	24000	16000	163200	22400	12000	4000	9600	24000	4000	4000	0	8000	0	3200	14400	8000
Amphiprora sp	0	0	0	0	3200	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacillaria paxillifera colonies	4000	0	0	3200	0	0	0	0	0	800	0	0	0	0	0	0	0	0
Biddulphia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	0	0	480	0
Chaetoceros sp	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	0	0	0
Coscinodiscus centralis	16000	8000	4000	16800	57600	20800	16800	8000	16000	0	8000	8000	4000	12000	9600	16800	10400	14400
Coscinodiscus radiatus	20000	24000	19200	32000	40800	17600	20000	16000	20000	48000	16000	41600	16000	12000	12000	20000	17600	25600
Coscinodiscus sp.	0	0		0	0	0	0	0	0	0	0	0	8000	3200	0	16000	6400	16000
Coscinodiscus wailesii	120000	88000	79200	64000	120000	88000	160000	80000	49600	16000	240000	320000	20000	17600	24800	32160	24000	24000
Climacosphenia sp	0	0	0	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0
Ditylum brightwelli	0	2400	4000	4000	1600	0	2400	0	0	2400	0	2400	0	1600	0	0	0	2400
Dictyocha sp (Silicoflagellates)	0	0	0	0	0	0	2400	0	0	0	0	0	0	0	0	0	0	0
Fragilaria sp	4800	3200	0	4000	16000	12000	0	0	0	0	0	0	0	0	0	800	0	0
Green algae (unidentified)	4000	0	0	0	0	1600	0	3200	0	0	0	0	0	1600	1600	1600	0	800
Gyrosigma sp.	0	800	0	0	0	1600	0	3200	0	0	0	0	1600	1600	0	0	0	800
Navicula sp	0	0	0	0	800	0	0	0	0	0	0	0	0	800	3200	480	1600	0
Nitzschia sp	0	2400	0	800	0	1120	0	0	0	0	0	0	1600	0	0	0	320	640
Odontella sinensis	1600	8000	7200	7200	10400	4800	1600	3200	3200	8000	4000	2400	800	5600	4000	4800	0	960
Pinnularia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	0	0	0	0
Planktoniella blanda	0	0	0	0	0	0	0	0	1600	0	3200	0	0	0	0	0	0	0
Planktoniella sol	4000	2400	0	3200	0	0	2400	0	0	0	0	0	0	0	0	0	0	0

Pleurosigma sp.	640	0	0	0	1600	2400	0	0	0	0	0	0	0	1600	0	1600	800	3200
Protoperidinium sp	0	0	3200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhizosolenia gracillima	0	0	0	0	0	0	0	0	0	3200	0	0	0	0	0	0	0	0
Rhizosolenia imbricata	0	0	0	640	800	0	0	0	800	0	0	0	0	0	0	0	0	0
Rhizosolenia setigera	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0
Rhizosolenia sp	0	2400	0	0	0	1600	0	800	0	800	0	2400	0	0	0	0	0	0
Surirella sp	0	0	0	0	0	800	1600	3200	0	0	0	0	0	320	0	0	320	0
Synedra sp	0	0	1600	3200	0	0	0	4000	0	0	0	0	0	0	4000	320	8000	4000
Synedra ulna	4000	0	0	4000	1600	4000	4000	800	0	0	0	640	2400	3200	2400	2400	5600	320
Thalassionema colonies frauenfeldii	3200	0	0	8000	1600	7200	1920	2400	3200	0	4000	2400	2400	4000	4000	4800	4000	3200
Thalassionema nitzschioides colonies	800	4000	7200	4000	4800	7200	1600	0	0	4000	0	2400	0	4000	0	4800	3200	4800
Thalassiosira aculeata	8000	0	0	0	0	800	0	0	0	0	0	0	0	0	0	1600	0	0
Thalassiosira sp.	8000	0	0	4800	0	10400	800	0	0	0	4000	0	3200	4000	5600	2400	4000	2400
Thalassiosira ferelineta	0	0	3200	0	0	0	0	0	0	0	0	1600	0	0	0	1600	0	4000
Trachyneis sp	0	0	0	0	480	0	0	0	0	0	0	0	0	0	800	0	0	0
Triceratium favus	3200	0	1600	4000	0	2400	2400	2400	0	0	0	2400	0	800	0	1600	0	0
Trieres mobiliensis	0	4800	6400	8000	7200	1280	0	0	0	0	1600	3200	0	1600	1600	2400	0	5600
Tripos muelleri	0	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	4000	0	1600	0	0	0
Density of Phytoplankton (diff. sites wise.)(no/m^3)	222240	160000	160800	187840	431680	208800	230720	131200	104800	108000	284800	393440	64000	86720	75200	119360	101120	121120
Total= 3191840 no/m^3																		
Total No Of Genus/Species=**40**																		

Table 16. Diversity Indices of Phytoplankton at different sites at Kandla Port

	Offshore						Cargo jetty						Phang Creek					
	1A	1B	1C	1D	1E	1-control	2A	2B	2C	2D	2E	2-contrl	3A	3B	3C	3D	3E	3-control
Variables																		
Taxa_S	16	13	12	18	16	20	15	13	9	10	9	13	11	20	13	19	15	18
Individuals (Nos/m^2)	222240	160000	160800	187840	431680	208800	230720	131200	104800	108000	284800	393440	64000	86720	75200	119360	101120	121120
Dominance_D	0.32	0.34	0.29	0.17	0.25	0.22	0.50	0.40	0.29	0.28	0.72	0.67	0.19	0.10	0.17	0.15	0.14	0.13
Shannon Diversity Index (H)	1.76	1.64	1.72	2.24	1.70	2.09	1.25	1.51	1.53	1.59	0.73	0.79	1.95	2.56	2.12	2.28	2.22	2.34
Simpson_1-D	0.68	0.66	0.71	0.83	0.75	0.78	0.50	0.60	0.71	0.72	0.29	0.33	0.81	0.90	0.83	0.85	0.86	0.87
Evenness_e^H/S	0.36	0.39	0.47	0.52	0.34	0.40	0.23	0.35	0.51	0.49	0.23	0.17	0.64	0.65	0.64	0.51	0.62	0.58
Menhinick	0.03	0.03	0.03	0.04	0.02	0.04	0.03	0.04	0.03	0.03	0.02	0.02	0.04	0.07	0.05	0.06	0.05	0.05
Margalef	1.22	1.00	0.92	1.40	1.16	1.55	1.13	1.02	0.69	0.78	0.64	0.93	0.90	1.67	1.07	1.54	1.22	1.45

5.5. Zooplankton

The study was conducted at 3 sites in Kandla Port and nearby areas where dredging activities are going on. The three selected study stations are Offshore, Cargo Jetty and Phang Greek.

5.5.1. Offshore

Acartia sp, Calanoida (unidentified), Euterpina sp (Harpacticoida), Foraminifera (unidentified), Nauplius larva of Copepoda, Ostracoda, *Paracalanus sp* (Calanoida), Sponge Spicules, Zoea larva of Crab etc. were the mostly common zooplankton and throughout observed in all sites of Offshore area. Highest population density was recorded at site 1C-Offshore (125440 nos./100m^3) where number of species was (24 nos.) and lowest density in 1A-Offshore (90080 nos./100m^3) where number of species was recorded (20 nos.). High biomass was observed in the site 1E-Offshore (27.78 ml/100m^3) and low biomass was recorded in site 1D-Offshore (5.95 ml/100m^3). The range of the population density, biomass and number of species were (93120 to 196000 nos./100m^3), (5.95 to 27.78 ml/100m^3) and (20 to 27 nos.) respectively in all sites.

Less observed species were Amphipoda (Crustacea), Arcella sp (Amoebozoa), Centropages sp (Calanoida), Corycaeus sp (Calanoida), Fish larva, Fish egg *Leprotintinnus sp* (Tintinnida), Triloculina sp (Foraminifera) etc in this station. Total 49 zooplankton was recorded in Offshore area adding that more composition of zooplankton by the Phylum Arthropoda (Crustacea), Tintinnids and Foraminifera and Sponge Spicules (Porifera).

5.5.2. Cargo Jetty

The population density of zooplankton varied from 53600 nos./100m^3 to 105920 nos./100m^3. Maximum density was noticed in site 2E-Cargo Jetty (65440nos./100m^3) and minimum was at site 2A-Cargo Jetty (105920nos./100m^3). Maximum number of species (27nos.) found 2A - Cargo Jetty minimum number of species was observed in site 2C-Cargo Jetty (17nos.). Biomass ranged between 7.50 to 122.95 ml/100m^3 where highest biomass noted in site2Control-Cargo Jetty and lowest in 2D-Cargo Jetty. Frequently observed species were *Acartia sp (Calanoida)*, Calanoida (unidentified), *Clausocalanus sp* (Calanoida), Copepoda eggs sacs, *Leprotintinnus sp* (Tintinnida), Ostracoda, Polychaete larvae (Annelids), *Tintinnopsis orientalis* (Tintinnida) Sponge Spicules, Zoea larva of Crab etc. whereas less observed species were Ammonia sp (Foraminifera), *Centropages sp* (Calanoida), Corycaeus sp (Calanoida), Cyphonautes larva (Bryozoan), Euchaeta sp (Calanoida), Mysis larva of Prawn, Harpacticoida (unidentified), *Spiroloculina sp* (Foraminifera),etc. Some Unidentified larval stages were also reported. Total recorded zooplanktons were 47 in Cargo Jetty.

5.5.3. Phang Creek

This Creek area was represented by the zooplankton fauna majority of them were Acartia sp (Calanoida), Calanoida (unidentified), Copepoda eggs sac *Clausocalanus sp* (Calanoida), Foraminifera (unidentified), Veliger larvae of Bivalve, Sponge spicules, *Leprotintinnus sp* (Tintinnida).Very less time or rarely recorded species were, Calcarina sp (Foraminifera), Centropages sp (Calanoida) Cyclopoida (unidentified), Fish larva, Leprotintinnus nordqvistii (Tintinnida), Nauplius larva of Copepoda, *Paracalanus sp* (Calanoida), Tintinnopsis cylindrica (Tintinnida), Zoea larva of Crab. The range of zooplankton biomass was between 17.86 to 74.63 ml/100m^3. Highest Biomass was recorded in site 3A-Phang creek (74.63 ml/100m^3) and lowest in site 3C-Phang creek (17.86 ml/100m^3). Maximum and Minimum species count was at in site 3E-Phang creek (23nos.) and 3D-Phang Creek (15nos.) respectively. Population density was maximum recorded in site 3A-Phang Creek (110080 nos./100m^3) and minimum in site 3D-Phang Creek (57600 nos./100m^3). In site 3D-Phang creek comparatively low density according to other sites may be because of high predator pressure or some environment changes.

Overall assessment of zooplankton showed that the total number of 66 Zooplankton recorded during summer season. Out of these (79) zooplankton, 49 zooplankton recorded in Offshore region, 47 zooplankton at Cargo Jetty and 41 zooplankton in

Phang Creek region. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea), Protozoa (mainly foraminifera and tintinnids), Porifera (sponge spicules). Crustacean zooplankton was the dominant due to the dominance of different larval stages and Copepods which mainly feed phytoplankton. More larval stage of crustacean and other animals observed in samples that indicated reproduction and development season of animals from larval to mature animal.Generally zooplankton population dynamics and studies emphasize is given up to group level rather than to species level because of microscopic size of zooplankton so to the difficulty in identifying the zooplankton as some species are considered as a group or genus level. The most dominant or frequently observed species(all 3 station) were Acartia sp (Calanoida) Calanoida (unidentified), *Clausocalanus sp* (Calanoida), Copepoda eggs sac, Foraminifera (unidentified), Globigerina sp (Foraminifera), Ostracoda, Sponge Spicules, Veliger larvae of Bivalve, Zoea larva of Crab etc. Foraminifera and Ostracoda belonging to the meroplankton were present at all three stations.

Overall range of all three sites Population density, Biomass and Number of species were (53600 to 196000no/100 m^3), (5.95 to 122.95ml/100m^3) and (15 to 27nos) respectively. Average high biomass noted at Cargo Jetty (35.64 ml/100m^3) followed by Phang creek (33.84 ml/100m^3) than Offshore (20.05 ml/100m^3) (Tables 17-19). Highest population density was recorded in site 1E-Offshore (196000 nos/100m^3) and lowest was recorded in site 2C-Cargo Jetty (53600no/100m3). Among all recorded zooplankton, majority dominance occurrence was by the Copepoda, Crustacean larvae, Spong Spicules, Foraminifera (Protozoa), Tintinnids (Protozoa), Zoea larva of Crab..

Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda, Mollusca, Protozoa, Porifera, Foraminifera. The Fish larva and Fish egg (Ichthyoplankton) was also recorded in sites of Offshore. The Zooplankton of Chaetognatha,, Amoebozoa were only represented by the species namely *Sagitta sp (arrow worm), Arcella sp.* respectively. Veliger larva of Bivalve and Heteropods shells include in Phylum Mollusca. The Echinodermata phylum represented by the Ophiopluteus larva and Gastrula larva of Sea star.

In Offshore**,** maximum Occurrence (%) was by the Foraminifera (unidentified) (13.24%) and minimum by the Amphipoda (Crustacea) (0.04%). In Cargo Jetty, maximum Percentage of Occurrence (%) by the Foraminifera (unidentified) (12.42%) and minimum by the Centropages sp (Calanoida) (0.06%). In Phang Creek maximum Occurrence by the Foraminifera(unidentified) (25.49%) and minimum (0.07%) by the Nematoda and some unidentified zooplankton (Tables 17 - 19).

During microscopic sample analysis more number of species varieties of Foraminifera, Sponge spicules, Crustacean larva and Tintinnidswere observed. These all three are very important for paleontological study aspects and also for evolutionary, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Some deep sea species also recorded that is indication of water circulation pattern. Data on zooplankton density, list of zooplankton is shown in Tables (17, 18 and 19).

Plankton identification, both zooplankton and phytoplankton, were done by using relevant identification and taxonomic keys and with standard literatures, monographs and research articles (Kasturirangan, 1963; APHA, 1992; Mitra et al., 2003; Goswami, 2005; Carling et al., 2004; Mandal, 2004; Hussain & Kalaiyarasi, 2013; Guglielmo et al., 2015; Hussain et al., 2016; Sreenivasulu et al., 2017; NIO,1998; NIO,2002) ,etc

5.6. Diversity Indices of Zooplankton

The data in the Table 20 shows diversity indices of zooplankton. *The Shannon*-wiener diversity index (H') fluctuated between 2.19 to 3.03 indicated moderate to quite high range of diversity added indication of healthy body of water with a maximum value in site 1Control-Offshore (3.03) where maximum number of species noted (27 nos.) and minimum value in site 3A-Phang Creek (2.19) where species number was 19. Range of the evenness was 0.47 to 0.83 where lowest and highest recorded in site 3A-Phang creek (0.47) and 1C-Offshore (0.83) respectively. Range of Simpson index was 0.78 to 0.94. The range value of Margalef indices was 1.43 to 2.25 that means high species number variations. (Table 20).

Table 17. Density of Zooplankton at Offshore site of Deendayal Port

Name of Genera/Group	1A	1B	1C	1D	1E	1 Control	Individual total density (no/100m^3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	4000	4000	4000	0	2400	3200	17600	2.33
Ammonia sp (Foraminifera)	3200	0	0	2400	3200	4000	12800	1.69
Amphipoda (Crustacea)	0	320	0	0	0	0	320	0.04
Arcella sp (Amoebozoa)	0	0	0	3200	0	0	3200	0.42
Bolivina sp (Foraminifera)	0	4000	2400	0	0	2400	8800	1.16
Calanoida (unidentified)	0	5600	9600	8000	0	16000	39200	5.19
Centropages sp (Calanoida)	0	3200	0	0	0	0	3200	0.42
Clausocalanus sp (Calanoida)	3200	0	4000	2400	3200	4000	16800	2.22
Copepoda eggs sac	12000	4800	5600	16000	24000	8000	70400	9.32
Corycaeus sp (Calanoida)	0	0	0	0	0	1600	1600	0.21
Cyclopoida (unidentified)	0	4000	12000	0	8000	8000	32000	4.24
Euterpina sp (Harpacticoida)	1600	0	3200	2400	1600	1600	10400	1.38
Fish larva	0	0	0	0	2400	1600	4000	0.53
Fish egg	0	0	0	0	2400	0	2400	0.32
Foraminifera (unidentified)	20000	16000	8000	12000	32000	12000	100000	13.24
Gastrula larva of Echinodermata	480	0	0	0	1600	0	2080	0.28
Globigerina sp (Foraminifera)	5600	0	5600	9600	2400	0	23200	3.07
Globigerinoides sp (Foraminifera)	0	4000	5600	0	0	0	9600	1.27
Heteropoda shells (gastropods)	0	3200	0	0	0	0	3200	0.42
Leprotintinnus simplex (Tintinnida)	0	0	0	1600	0	0	1600	0.21
Leprotintinnus sp (Tintinnida)	0	0	0	2400	0	2400	4800	0.64
Leprotintinnus nordqvistii (Tintinnida)	0	0	0	0	4000	0	4000	0.53
Lucifer sp (small prawn)	1600	0	0	0	0	0	1600	0.21
Microsetella sp (Harpacticoida)	0	0	4000	0	1600	1600	7200	0.95
Mysids (shrimp like)	0	0	3200	0	0	0	3200	0.42
Mysis larva of Prawn	0	2400	0	0	0	0	2400	0.32
Nauplius larva of Copepoda	0	3200	3200	3200	0	2080	11680	1.55
Nauplius larvae of Barnacles	0	0	0	4000	0	2400	6400	0.85
Nauplius larvae of Crustacea	0	0	11200	16000	17600	0	44800	5.93
Oithona sp (Cyclopoida)	0	0	0	0	20000	0	20000	2.65
Ophiopluteus Larva (Echinodermata)	0	0	0	0	0	800	800	0.11
Ostracoda	7200	4000	8000	8000	10400	2400	40000	5.29
Paracalanus sp (Calanoida)	0	0	1600	3200	3200	0	8000	1.06
Parvocalanus sp (Calanoida)	1600	0	3200	2400	4000	3200	14400	1.91
Polychaete larvae (Annelids)	2400	8000	0	4000	7200	3200	24800	3.28
Rotallida (Foraminifera)	0	0	0	0	4000	7200	11200	1.48
Sagitta sp (arrow worm)	1600	0	0	0	0	0	1600	0.21
Spirillina sp (Foraminifera)	800	4000	0	1600	1600	1600	9600	1.27
Spiroloculina sp (Foraminifera)	0	0	0	4000	0	0	4000	0.53
Sponge Spicules	4000	3200	9600	4000	12000	13600	46400	6.14
Subeucalanus sp (Calanoida)	2400	2400	2400	3200	3200	5600	19200	2.54

Tintinnopsis cylindrica (Tintinnida)	0	0	0	1600	0	0	1600	0.21
Tintinnopsis orientalis (Tintinnida)	0	12800	8000	0	10400	6400	37600	4.98
Tintinnopsis radix (Tintinnida)	5600	800	0	0	0	4000	10400	1.38
Tintinnopsis sp (Tintinnida)	8000	0	6400	0	8000	0	22400	2.96
Triloculina sp (Foraminifera)	0	0	640	0	0	7200	7840	1.04
Veliger larvae of Bivalve	0	0	1600	2400	3200	0	7200	0.95
Zoea larva of Crab	3200	3200	2400	3200	2400	4000	18400	2.44
Unidentified larva	1600	0	0	0	0	0	1600	0.21
Total No. Of Genera/Groups=49								
Site-wise Total Density (no/100m^3)	90080	93120	125440	120800	196000	130080	**755520**	**100%**
Biomass (ml/100m^3)	**16.23**	**17.97**	**26.14**	**5.95**	**27.78**	**26.25**		

Table 18: Density of Zooplankton at Cargo Jetty site of Deendayal Port

Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Individual total density (no/100m^3))	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	1600	3200	0	12000	2400	1600	20800	4.19
Ammonia sp (Foraminifera)	4000	0	0	0	0	0	4000	0.81
Arcella sp (Amoebozoa)	1600	0	0	800	0	0	2400	0.48
Calanoida (unidentified)	8000	12000	0	12000	8000	0	40000	8.07
Centropages sp (Calanoida)	0	320	0	0	0	0	320	0.06
Clausocalanus sp (Calanoida)	1600	0	1600	3200	3200	4000	13600	2.74
Copepoda eggs sac	2400	4000	1600	3200	2400	8000	21600	4.36
Corycaeus sp (Calanoida)	0	0	0	0	1600	0	1600	0.32
Cyclopoida (unidentified)	0	4000	8000	0	0	4000	16000	3.23
Cyclops sp (Cyclopoida)	0	0	0	4800	4000	0	8800	1.77
Cyphonautes larva (Bryozoan)	0	0	800	0	0	0	800	0.16
Euchaeta sp (Calanoida)	0	0	0	3200	0	0	3200	0.65
Euterpina sp (Harpacticoida)	1600	0	1600	0	1600	0	4800	0.97
Fish larva	800	0	800	0	0	0	1600	0.32
Foraminifera (unidentified)	32000	0	0	4000	16000	9600	61600	12.42
Globigerina sp (Foraminifera)	6400	3200	4000	0	3200	0	16800	3.39
Harpacticoida (unidentified)	0	0	0	0	1600	0	1600	0.32
Heteropoda shells (gastropods)	2400	0	0	0	0	0	2400	0.48
Hydrocaulus & Hydrotheca(Hydrozoa)	0	1600	0	0	0	0	1600	0.32
Lagena sp (Foraminifera)	0	0	800	0	0	0	800	0.16
Leprotintinnus simplex (Tintinnida)	0	1600	0	0	4000	1600	7200	1.45
Leprotintinnus sp (Tintinnida)	0	3200	1600	1600	2400	1600	10400	2.10
Microsetella sp (Harpacticoida)	0	3200	0	800	0	1600	5600	1.13
Mysis larva of Prawn	0	0	0	0	0	16000	16000	3.23
Nauplius larva of Copepoda	1120	0	4000	2400	4000	0	11520	2.32
Nauplius larvae of Barnacles	2400	0	0	3200	0	0	5600	1.13
Nauplius larvae of Crustacea	0	4800	0	16000	3200	3200	27200	5.49
Nauplius larvae of Cyclopoida	800	0	0	0	0	0	800	0.16
Oithona sp (Cyclopoida)	7200	0	0	4000	4800	3200	19200	3.87
Ophiopluteus Larva (Echinodermata)	0	800	0	640	0	0	1440	0.29
Ostracoda	1600	3200	3200	3200	2400	0	13600	2.74
Paracalanus sp (Calanoida)	1600	2400	4000	3200	1600	0	12800	2.58
Parvocalanus sp (Calanoida)	1600	0	0	0	2400	3200	7200	1.45
Polychaete larvae (Annelids)	4800	4800	4000	1600	2400	4000	21600	4.36
Pontellid nauplius larva (Calanoida)	0	0	1600	0	0	0	1600	0.32
Protozoaea larva (Crustacea)	0	0	0	1600	0	0	1600	0.32
Quinqueloculina sp (Foraminifera)	3200	1600	0	0	1600	0	6400	1.29
Sagitta sp (arrow worm)	800	0	800	0	0	800	2400	0.48
Spiroloculina sp (Foraminifera)	0	0	0	0	0	800	800	0.16
Sponge Spicules	800	4800	3200	3200	0	4000	16000	3.23
Subeucalanus sp (Calanoida)	1600	1600	0	0	2400	0	5600	1.13
Tintinnopsis beroidea (Tintinnida)	0	0	0	0	800	0	800	0.16
Tintinnopsis orientalis (Tintinnida)	9600	12000	12000	2560	8000	0	44160	8.91
Tintinnopsis sp (Tintinnida)	0	0	0	4000	0	0	4000	0.81
Veliger larvae of Bivalve	2400	4000	0	2400	2400	3200	14400	2.90
Zoea larva of Crab	3200	2400	0	2400	0	3200	11200	2.26
Unidentified larva	800	0	0	0	0	1600	2400	0.48
Total No. Of Genera/Groups=47								

Site-wise Total Density (no/100m^3)	105920	78720	53600	96000	86400	75200	**495840**	**100%**
Biomass (ml/100m^3)	**11.54**	**22.22**	**25.25**	**7.50**	**24.39**	**122.95**		

Table 19: Density of Zooplankton at Phang Creek site of Deendayal Port

Name of Genera/Group	3A	3B	3C	3D	3E	3 Control	Total density (no/100m3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	2400	2400	3200	0	2400	2400	12800	2.65
Ammonia sp (Foraminifera)	0	4000	1600	0	3200	3200	12000	2.48
Arcella sp (Amoebozoa)	3200	0	1600	800	800	0	6400	1.32
Bolivina sp (Foraminifera)	1600	0	1600	0	0	0	3200	0.66
Calanoida (unidentified)	4000	0	9600	5600	8000	8000	35200	7.28
Calcarina sp (Foraminifera)	4000	0	0	0	0	0	4000	0.83
Centropages sp (Calanoida)	0	1600	0	0	0	0	1600	0.33
Clausocalanus sp (Calanoida)	800	160	2400	3200	0	4000	10560	2.18
Copepoda eggs sac	4000	4000	0	2400	8000	12000	30400	6.29
Cyclopoida (unidentified)	0	0	4000	1600	0	0	5600	1.16
Euterpina sp (Harpacticoida)	2400	0	0	1600	0	1600	5600	1.16
Fish larva	0	480	0	0	0	0	480	0.10
Foraminifera (unidentified)	48000	15200	12000	16000	22400	9600	123200	25.49
Gastrula larva of Echinodermata	1600	0	0	3200	0	0	4800	0.99
Globigerina sp (Foraminifera)	12000	4000	4800	0	4000	0	24800	5.13
Leprotintinnus simplex (Tintinnida)	0	2400	0	2400	4000	0	8800	1.82
Leprotintinnus sp (Tintinnida)	3200	3200	2400	3200	4000	1600	17600	3.64
Leprotintinnus nordqvistii (Tintinnida)	1600	0	0	0	0	0	1600	0.33
Microsetella sp (Harpacticoida)	0	0	1600	0	3200	1600	6400	1.32
Mysids (shrimp like)	0	8000	4000	0	0	0	12000	2.48
Mysis larva of Prawn	960	2400	0	0	320	0	3680	0.76
Nauplius larva of Copepoda	0	0	0	1600	0	0	1600	0.33
Nauplius larvae of Barnacles	0	0	1600	0	0	0	1600	0.33
Nauplius larvae of Crustacea	0	0	0	4800	4800	1920	11520	2.38
Nematoda	0	0	0	0	0	320	320	0.07
Ostracoda	7200	0	4800	0	1600	4800	18400	3.81
Paracalanus sp (Calanoida)	0	0	0	0	2400	0	2400	0.50
Parvocalanus sp (Calanoida)	0	0	2400	2400	2400	640	7840	1.62
Polychaete larvae (Annelids)	0	800	3200	3200	2400	0	9600	1.99
Prawn larvae (premature stage)	0	5600	0	0	0	0	5600	1.16
Reussella sp (Foraminifera)	0	0	5600	0	1600	0	7200	1.49
Rotallida (Foraminifera)	0	0	0	0	4000	0	4000	0.83
Rosalina sp (Foraminifera)	4000	3200	0	0	8000	0	15200	3.14
Sponge Spicules	4000	3200	3200	5600	12000	12000	40000	8.28
Subeucalanus sp (Calanoida)	0	0	2400	0	0	2400	4800	0.99
Tintinnopsis cylindrica (Tintinnida)	0	0	0	0	800	0	800	0.17
Tintinnopsis orientalis (Tintinnida)	4000	4000	0	0	4800	3200	16000	3.31
Triloculina sp (Foraminifera)	0	1600	0	0	0	0	1600	0.33
Veliger larvae of Bivalve	1120	800	640	0	0	800	3360	0.70
Zoea larva of Crab	0	0	480	0	0	0	480	0.10
Unidentified	0	0	0	0	320	0	320	0.07
Total No. Of Genera/Groups=41								
Site-wise Total Density (no/100m^3)	110080	67040	73120	57600	105440	70080	**169920**	**100%**
Biomass (ml/100m^3)	**74.63**	**26.67**	**17.86**	**43.21**	**22.00**	**18.66**		

Table 20: Diversity indices of Zooplankton at different sites of Deendayal Port

	Offshore						Cargo jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Variables																		
Taxa_S	20	20	24	24	27	27	27	21	17	24	24	19	19	19	21	15	23	17
Individuals (nos. /m^2)	90080	93120	125440	120800	196000	130080	105920	78720	53600	96000	86400	75200	110080	67040	73120	57600	105440	70080
Dominance_D	0.10	0.08	0.06	0.07	0.08	0.06	0.12	0.08	0.11	0.08	0.07	0.10	0.22	0.10	0.08	0.12	0.09	0.11
Shannon Diversity Index(H)	2.62	2.75	3.00	2.90	2.87	3.03	2.69	2.79	2.51	2.85	2.92	2.63	2.19	2.60	2.79	2.41	2.73	2.46
Simpson_1-D	0.90	0.92	0.94	0.93	0.92	0.94	0.88	0.92	0.89	0.92	0.93	0.90	0.78	0.90	0.92	0.88	0.91	0.89
Evenness	0.69	0.78	0.83	0.76	0.65	0.76	0.54	0.77	0.72	0.72	0.77	0.73	0.47	0.71	0.77	0.75	0.67	0.69
Menhinick	0.07	0.07	0.07	0.07	0.06	0.07	0.08	0.07	0.07	0.08	0.08	0.07	0.06	0.07	0.08	0.06	0.07	0.06
Margalef	1.67	1.66	1.96	1.97	2.13	2.21	2.25	1.77	1.47	2.01	2.02	1.60	1.55	1.62	1.79	1.28	1.90	1.43

6.0. References

Airoldi, L., and Beck, M. (2007). Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology: An Annual Review, 45, 345–405.

Alcaraz, M.and Calbet, A. (2003). Zooplankton ecology, in Marine Ecology. Encyclopedia of Life Support Systems (EOLSS), eds C. Duarte and A. Lott Helgueras (Oxford: Developed under the Auspices of the UNESCO, EolssPublishers), 295–318.

APHA (1992). Standard Methods for the Examination of Water and Waste water 18th Ed, American Public Health Association. Awwa, Wpcf, Washington D.C.

Baird, R. and L. Bridgewater, 2017. Standard methods for the examination of water and wastewater. 23rd edition. Washington, D.C.: American Public Health Association.

Barbier Edward, B., Hacker Sally, D., Kennedy, C., Koch, E. W., Stier, A. C., and Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. Ecol. Monogr. 81, 169–193. doi: 10.1890/10-1510.1**.**

Barnes, R D, 1980. Invertebrate Zoology Saunders College, Philadelphia 108pp**.**

Besiktepe, S., Tang, K. W., Mantha, G. (2015). Seasonal variation of abundance and live/dead compositions of copepods in Mersin Bay, northeastern Levantine Sea (eastern Mediterranean). Turk Zool. 39: 494-506. doi:.10.3906/zoo-1405-23.

Bhaskar P. V., Roy R., Gauns M., Shenoy D. M., Rao V. D., Mochemadkar S., 2011. “Identification of non-indigenous phytoplankton species dominated bloom off Goa using inverted microscopy and pigment (HPLC) analysis”, J Earth Syst Sci, pp.1145–1154.

Bhunia, A.B. and Choudhury, A., 1998. Studies on the seasonal abundance and biomass of Crustacean Zooplankton and Chaetognaths in relation to ecological parameter of a tidal Creek (Mooriganga), of Sagar Island (north), Sunderbans, West Bengal. *Indian Journal of. Marine Science 28*, 93-198.

Boyd, S. E., Limpenny, D. S., Rees, H. L., & Cooper, K. M. (2005). The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). *ICES Journal of Marine Science*, *62*(2), 145–162.

Brink, K.H. (1993). The coastal ocean progresses effort. Oceanus, 36, pp. 47-49.

Carling, K. J., Ater, I. M., Pellam, M. R., Bouchard, A. M., Mihue, T. B. (2004). A Guide to the Zooplankton of Lake Champlain. Plattsburgh State University of New York. Scientia Discipulorum. 1: 38-66.

Chakrabarty, M., Banerjee, A., Mukherjee, J., Rakshit, N., Ray, S. (2017) Spatial pattern analysis of zooplankton community of Bakreswar reservoir, India. Energ. Ecol. Environ. 2(3): 193-206. doi:. 10.1007/s40974-017-0057-8.

Chattopadhyay, J., R.R. Sarkar & S. Pal 2003. Dynamics of nutrient–phytoplankton interaction in the presence of viral infection. *BioSystems*, 68: 5–7.

Clark, K R and Warwick, R M 1994. Change in Marine Communities, An Approach to Statistical Analysis and Interpretation Natural Environment Research Council, Plymouth Marine Laboratory, Plymouth, pp144.

Cloern J. E., "Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Fransisco Bay", California. 1996. Rev Geophys, 34(2), pp.127–168, 1996.

Covich, A. P., Palmer, M. A. and T. A. Crowl (1999): The Role of Benthic Invertebrate Species in Freshwater Ecosystems. Bio Science, 49 (2): 119-127.

Davies, O.A., C. C. Tawari and J. F. N. Abowei, 2008. Zooplankton of Elechi Creek, Niger Delta, Nigeria. Environ. Ecol., 26 (4c): 2346 - 2441.

Davis, B. J. 1977. Distribution and temperature adaptation in the teleost fish genus Gibbonsia. Mar. Biol., 42: 315-320.

Day, J H 1967. A monograph on the Polychaeta of Southern Africa Pts I and II, Brit Mus. Nat. Hist, 656, 1-878.

Dekker, R. 1989. The macrozoobenthos of the subtidal western Dutch Wadden Sea. I. 468 Biomass and species richness. Netherlands Journal of Sea Research 23: 57–68.

Desai, S. R, 2008. Subashchandran, MD, Ramachandra TV; Phytoplankton Diversity in Sharavati River Basin, Central Western Ghats. Journal of Sediment and Water Sciences, 2008; 1(1):7- 66.

Descy, J. P, 1993. Ecology of the phytoplankton of river Moselle: Effect of disturbance on community structure and diversity. Hydrobiologia, 249(1-3): 111-116.

Dodson, S. (1992). Predicting crustacean zooplankton species richness. Limnol Oceanogr. 37(4): 848-856.

Dodson, S.I. and Frey, D. G. (2001). Cladocera and other branchiopoda. Ecology and classification of North American Freshwater Invertebrates. Academic Press. London. 850 – 914.

Fauvel, P, 1953 The Fauna of India Including Pakistan, Ceylon, Burma and Malaya Annelida, Polychaeta, Allahabad pp507.

Figueredo, C. C. & A. Giani 2001. Seasonal variation in the diversity and species richness of phytoplankton in a tropical eutrophic reservoir. *Hydrobiologia*, 445: 165-174.

Gajbhiye, S.N. & Abidi, S.A.H. (1993). Zooplankton distribution in the polluted environment around Bombay. Environment Impact on Aquatic & Terrestrial Habitats. pp. 127-142.

Gao, X. and J. Song 2005. Phytoplankton distributions and their relationship with the environment in the Changjiang Estuary, China. *Marine Poll. Bull.*, 50: 327-335.

Garzke, J., Sommer, U., Ismar, S.M.H. (2017). Is the chemical composition of biomass the agent by which ocean acidification influences on zooplankton ecology. Aquat Sci. 79(3): 733-748. doi:. 10.1007/s00027-017-0532-5.

Goswami, S. C. (2005). Zooplankton Methodology collection & identification manual. Published by National Institute of Oceanography, Dona Paula, Goa. Edited by V.K.Dhrgalkar & X.N.Veriecar.

Goswami, S.C and Padmavathi, G. (1996). Zooplankton production, composition and diversity in the coastal water of Goa. *Indian Journal of. Marine Science25,* 91-97.

Gray, J. S. (1997). Marine biodiversity: Patterns, threats and conservation needs. Biodiversity and Conservation, 6, 153–175.

Guglielmo, L., Granata, A., Guglielmo, R. (2015). Class Malacostraca Order Euphausiacea. Revista IDE@- SEA. 86(B): 1-20. ISSN 2386-7183.

GUIDE, (2011). Comprehensive Terrestrial EIA (including Mangroves) for the Proposed Multi-Project SEZ at Kandla. EIA report submitted to Mumbai Regional Centre of National Institute of Oceanography, Dona Paula, Goa.

Hambler, C and Speight, M R 1995. Biodiversity conservation in Britain, science replacing tradition British Wildlife, 6, 137-147yla, P S, S Velvizhi and S Ajmal Khan 1999 A Monograph on the amphipods of Parangipettai coast Annamalai University, India 78.

Harkantra, S. N., A. Nair, Z. A. Ansari and A. H. Parulekar, 1980. Benthos of the shelf region along the West coast of India. *Indian J. Mar. Sci.,* 9: 106-110.

Hussain, S. M., Joy, M. M., Rajkumar, A., Nishath, N. M & Fulmali, S. T. (2016). Distribution of calcareous microfauna (Foraminifera and Ostracoda) from the beach sands of Kovalam, Thiruvananthapur, Kerala, Southwest coast of India.Journal of the Palaeontological Society of India. 61(2). 267-272. ISSN 0522- 9630.

Hussain, S. M., Kalaiyarasi, A. (2013). Distribution of Ostracoda in the Mullipallam Lagoon, near Muthupet, Tamil Nadu, Southeast Coast of India —Implications on Microenvironment. In: Sundaresan J., Sreekesh S.,230 Ramanathan A., Sonnenschein L., Boojh R. (eds) Climate Change and Island and Coastal Vulnerability. Springer, Dordrecht.

Ikeda, T., Kanno, Y., Ozaki, K., Shinada, A., 2001. Metabolic rates of epipelagic marine copepods as a function of body mass and temperature. Mar. Biol. 139, 587–596.

Ingole B, Sivadas S, Goltekar R, Clemente S, Nanajkar M, Sawant R, D'Silva C, Sarkar A, Ansari Z (2006) Ecotoxicological effect of grounded MV River Princess on the intertidal benthic organisms of Goa. Environ. Internat. 32:284-289.

Jagadeesan, L., Jyothibabu, R., Anjusha, A., Arya, P. M., Madhu, N. V., Muraleedharan, K. R., and Sudheesh, K., 2013. Ocean currents structuring the mesozooplankton in the Gulf of Manner and the Palk Bay, southeast coast of India. *Progress in Oceanography*, 110: 27-48.

Jegadeesan, P., 1986. Studies on environmental inventory of the marine zone of Coleroon estuary and inshore waters of Pazhayar, Southeast coast of India. *Ph. D., Thesis*, *Annamalai University*, India.

Jha, D. K., Devi, M. P., Vidyalakshmi, R., Brindha, B., Vinithkumar, N. V., and Kirubagaran, R. (2015). Water quality assessment using water quality index and geographical information system methods in the coastal waters of Andaman Sea, India. Mar. Pollut. Bull. 100, 555–561. doi: 10.1016/j.marpolbul.2015.08.032.

Jickells, T. D. (1998). Nutrient biogeochemistry of the coastal zone. Science 281, 217–222. doi: 10.1126/science.281.5374.217.

Jones, G., and Candy, S. (1981). Effects of dredging on the macrobenthic infauna of Botany Bay. *Marine and Freshwater Research*, *32*(3), 379–398.

Kadam S.S. and L. R. Tiwari, 2012. Zooplankton Composition in Dahanu Creek-West Coast of Ind. Res. J. Rec. Sci., 1(5): 62-65.

Karr, J. R., J D. Allen, and A. C. Benke 2000 River conservation in the United States and Canada. In P. J. Boon, Davies and B. R. Petts, G E (Ed.), Global perspectives on River conservation, pp 3–39 Science, Policy, and Practice. Wiley, New York.

Kasturirangan, L. R (1963). A key for the identification of the more common planktonic Copepoda of Indian coastal waters. Publication No .2. Indian National Committee on Oceanic Research. p. 87.

Krishnamurthy, K. and Santhanam, R. (1975). Ecology of Tintinids (Protozoa: Ciliata) in Porto Novo region. *Indian Journal of. Marine Science 4,* 181-184.

Kumar, A., 1995 Studies of pollution in river Mayurakshi in south Bihar. Indian Journal of Environmental Pollution, 2(1): 21-26.

Levandowsky, M., 1972. An ordination of phytoplankton population in ponds of varying salinity and temperature. *Ecology*, 53(3): 398-407.

Lyla, P S., Velvizhi, S and Ajmal Khan, S 1999. A Monograph on the amphipods of Parangipettai coast Annamalai University, India pp78.

Madin, L.P., Horgan, E.F., and D.K. Steinberg. 2001.Zooplankton at the Bermuda Atlantic Timeseries Study (BATS) station: diel, seasonal and inerannual variation in biomass, 1994-1998. Deep-Sea Research II. 48 (8-9): 2063-2082.

Magurran, A 1991. Ecological Diversity and Its Measurement Princeton University Press, Princeton, pp178.

Mahapatro, D R C., Panigrahy, K and Samal, R N 2011. Macrobenthos of shelf zone off Dhamara estuary, Bay of Bengal. J Oceanog Mar Sci 22, pp 32-42.

Mandal, S.K. (2004). Studies on the Effect of Ship Scrapping Industry Wastes on Marine Phytoplankton at Alang, Gujarat, Ph. D thesis. M. K. Bhavnagar University, Bhavnagar.

Margalef, R 1958. Information theory in ecology. Gen Syst, 3, 36–71.

Marine Biology Organization (MBO), 2007. Zooplankton Retrieved from: http://www.marinebio.com/oceans/zooplankton.Askp. 62k, (Accessed on: September 29, 2006).

Martin G.D, P.A. Nisha, K.K. Balachandran and G.V.M. Gupta (2011). Eutrophication induced changes in benthic community structure of a flow-restricted tropical (Cochin backwaters), India. Environ. Monit. Assess. 176(1-4):427-438.

Maurer, D., Watling, L., Kinner, P., Leathem, W and Wethe, C 1978. Benthic invertebrate assemblages of Delaware Bay. Mar Biol, 45, 65-78.

Maya, M. V., M. A. Soares, R. Agnihotri, A. K. Pratihary, S. Karapurkar, H. Naik & S. W. A. Naqvi 2011. Variations in some environmental characteristics including C and N stable isotopic composition of suspended organic matter in the Mandovi estuary. *Environ. Monit. Assess.,* 175: 501–517.

Mees, J. and Jones, M. B. (1997): The Hyperbenthos. Oceanography and Marine Biology: an Annual Review, 35, 221-255.

Mishra, S., and Panigrahy, R. C. (1999). Zooplankton ecology of the Bahuda estuary (Orissa), east coast of India. *Indian Journal of. Marine Science 28,* 297-301.

Mitra A., Davidson, K. and Flynn, K. J. (2003) The influence of changes in predation rates on marine microbial predator/prey interactions: a modelling study. *Acta Oecol* (Suppl. 1), S359–S367.

Mitra, A., Zaman, S., Sett, S., Raha, AK and Banerjee, AK 2014. Phytoplankton cell volume and diversity in Indian sundarban. Ind J Mar Sci 43, 2 208-215.

Moura, A. N., Bittencourt-Oliveira, M. C & Nascimento, E. C. (2007). Benthic Bacillariophyta of the Paripe River estuary in Pernambuco state, Brazil. Braz. J. Biol. 67(3): 393-401.

Murugan, A., 1989. Ecobiology of Cuddalore, Uppanar backwaters, Southeast coast of India. *Ph.D., Thesis, Annamali Universtiy*, India.

Murugesan, P., 2002. Benthic biodiversity in the marine zone of Vellar estuary (Southeast Coast of India). *Ph. D., Thesis Annamalai University*, India, 359pp.

Nair, VR 2002. Status of flora and fauna of Gulf of Kachchh, India NIO, Goa, pp 1-258.

Newell, R. C., Seiderer, L. J., & Hitchcock, D. R. (1998). The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and Marine Biology: An Annual Review, 36,* 127–178.

NIO, (2002). Status of flora and fauna of Gulf of Kachchh, India. National Institute of Oceanography, Goa.

NIO, 1998. Environmental studies for proposed BPCL jetty and associated facilities at Kandla Part-I Rapid marine EIA, May1998 NIO Mumbai.

NIO. (1980). Technical Report, National Institute of Oceanography, Goa.

Omori, M. and lkeda. T. (1984). Methods in Marine Zooplankton ecology. John Wiley & Sons, New York.

Parasharya D and Patel B. (2014). Spawning aggregation of Melibe viridis Kellart (1858) from Gulf of Kachchh-Western India. International Journal of Scientific and Research Publication, 4(3), ISSN 2250-3153.

Parulekar, A. H., Dhargalkar, V. K., & Singbal, S. Y. S. (1980). Benthic studies in Goa estuaries. Part 3. Annual cycle of macrofaunal distribution, production and trophic relations. *Indian J Mar Sci*.

Pearson, T. H. and Rosenberg, R. (1978): Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. Oceanography and Marine Biology-An Annual Review, 16: 229-311.

Perumal P, Sampathkumar P, Karuppasamy PK (1999) Studies on the bloom-forming species of phytoplankton in the Vellar estuary, southeast coast of India. Ind J Mar Sci 28: 400-403.

Pielou, E C 1966. The measurement of diversity in different types of biological collections. J Theoret Biol 13, 131-144.

Plafkin, J. L., Barber, M. T., Poter, K. D., Gross, S. K. and Highes, R. M. 1989. *Rapid bioassessment protocol for use in streams and rivers for benthic macro invertebrates and fish.* EPA/444/ 4-89/001**.** Office of water regulation and standards. U.S. Environmental Protection Agency, Washingaton DC, USA.

Prabhahar. C., K. Saleshrani & Enbarasan 2011. Studies on the ecology and distribution of phytoplankton biomass in Kadalur coastal zone Tamil Nadu, India. *Curr. Bot.,* **2(3):** 26-30.

Ramakrishna, D A 2003. Manual on identification of schedule molluscs from India 40pp.

Ramakrishna, T C R., Sreeraj, C., Raghunathan, R., Raghuraman, P and Yogesh Kumar, J S 2011. An account of additions to the Icthyofauna of Andaman and Nicobar Islands Records of the Zoological Survey of India, Occasional Paper no 326, 1-140 Published-Director, Zool Surv India.

Rao, K.K and Balasubramanian, T. (1996). Distribution of Foraminifera in the Cochin Estuary. J.mar.biol. Ass. India. 38(1 and 2): 50-57.

Reid, G. K, 1961. Ecology in inland waters and estuaries. New York.375.

Reid, G. K., Wood, R. D. (1976). Ecology of inland waters and estuaries. Toronto, Ontario, D. Van Nostrand Co., pp. 138–146.

Reid, G. K., Wood, R. D. (1976). Ecology of inland waters and estuaries. Toronto, Ontario, D. Van Nostrand Co., pp. 138–146.

Saravanan, K. R., Sivakumar, K., and Choudhury, B. C. (2013). “Important coastal and marine biodiversity areas of India,” in Coastal and Marine Protected Areas in India: Challenges and Way Forward, ENVIS Bulletin: Wildlife & Protected

Areas, Vol. 15, ed. K. Sivakumar (Dehradun: Wildlife Institute of India), 134–188. doi: 10.1007/978-3-642-38200-0_30

Shannon, C E and Wiener, W 1949. The Mathematical theory of Communication Univ of Ilinois Press, Urbana.

Sinha B. and M. R. Islam, 2002. Seasonal variation in zooplankton population of two lentic bodies and Assam State Zoo cum Botanical Garden, Guwahati, Assam, Eco.Environ. Cons., 8: 273-278.

Sivasamy, S.N., 1990. Plankton in relation to coastal pollution at Ennore, Madras coast. Indian J. Marine Sci., 19: 115-119.

Sreenivasulu, G., Jayaraju, N., Raja Reddy, B.C.S., Prasad, T. L., Nagalakshmi, K., Lakshmanna, B. (2017). Foraminiferal research in coastal ecosystems of India during the past decade: A review. Geo ResJ. 13: 38–48.

SubbaRao, N V., Surya Rao, K V and Maitra, S 1991. Marine molluscs State Fauna Series 1, Part 3 Fauna of Orissa. Zool Surv India, Kolkata, 1–175.

Tabassum, A. and Saifullah, S. (2012). Centric Diatoms from the North Arabian Sea Shelf of Pakistan. LAP. BOOK Lambert Academic Publishing. ISBN: 978-3-659-28532-5.

Takai N, Mishima Y, Yorozu A, Hoshika A (2002) Carbon sources for demersal fishes in the western Seto Inlan Sea, Japan, examined by delta 13C and delta 15N
analyses. *Limnol Oceanogr.* 47(3):730-741.

Taylor, B. E. (1998). Analyzing population dynamics of zooplankton. Published by the American Society of Limnology and Oceanography, Inc. Limnol.Oceanogr 33(6, part 1): 1266-1273.

Thakur, B., Chavda, C., & Salvi, H. (2015). Phytoplankton diversity at some selected sites of the Gulf of Kachchh, Gujarat, India. Bulletin of Environmental and Scientific Researcch. 4(4): 7-12. ISSN. 2278-5205.

Thangaraja, G. S., 1984. Ecobiology of the marine zone of the Vellar estuary. *Ph. D. Thesis, Annamalai University, India.*

Thirunavukkarasu, K., Soundarapandian, P., Varadharajan, D., Gunalan, B. (2013). Zooplankton Composition Structure and Community Structure of Kottakudi and Nari Backwaters, South East of Tamilnadu. J. Environ. Anal. Toxicol. 4(1): 200. doi:.10.4172/2161-0525. 1000200.

Tiwari, L.R and Nair, V.R. (1998). Ecology of Phytoplankton from Dharmatar creek, West Coast of India. Indian. J. MarineScience. 27 (3 & 4).

Uptake, A. (1999). Primary production by phytoplankton and microphytobenthos in estuaries. *Estuaries, 29*, 93.

Zohary T, Yacobi YZ, Alster A, Fishbein T, Sh L, Tibor G.(2014). Phytoplankton. In: Zohary T, Sukenik A, BermanT, Nishri A, editors. Lake Kinneret – ecology and management. Dordrecht (Netherlands): Springer; p. 161–190.

Third Season Report

Studies on Dredged Materials for the presence of Contaminants and suggesting suitable disposal options

(As per EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific Condition No. vii)

DPA Work order No. EG/WK/4751/Part (EC&CRZ-1) / 84. Dt. 18.09.2021.

Submitted by

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2024

Project Team

Project Co-Ordinator : Dr. V. Vijay Kumar, Director

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1.	Dr. K. Karthikeyan Assistant Director	Principal Investigator	M.Sc., Ph.D. in Environmental Science; 15 years of experience in Marine Environmental Monitoring and Pollution Assessment studies.
2.	Dr. G. Jayanthi Scientist	Co-Investigator	MSc., MPhil., PhD in Botany; 13 years of Research and teaching experience inclusive of Post-Doctoral experience for 5 years.
3.	Dr. Krushnakant. D. Baxi Scientific Officer	Co-Investigator	Ph.D in Zoology (Marine Biology) with 5 years of experience
4.	Ds. Monika Sharma Sr. Scientific Asst.	Team member	M.Sc. in Environmental Sciences; 7 years of experience in Marine water and sediment analysis
5.	Ms. Dipti Parmar Scientific Assistant	Team member	M.Sc. in Environmental Sciences; 6 years of experience in sediment and water analysis.

Dr. V. Vijay Kumar
Director

CERTIFICATE

This is to state that the **Third Season Report** of the work entitled, **"Studies on Dredged Material for the presence of contaminants"** has been prepared in line with the Work order issued by DPT vide No. EG/WK/4751/Part (EC & CRZ-1)/84. Dt.18.09.2021 as per the EC & CRZ Clearance accorded by the MoEF & CC, GoI dated 19/12/2016, Specific Condition No. vii.

This work order is for a period of Three years from 2021 –2024 for the above-mentioned study.

Authorized Signatory **Institute Seal**

CONTENTS

Deendayal Port Authority, formerly known as Deendayal Port Trust, erstwhile called as Kandla Port Trust is one of the Major Twelve Ports of the Country, holds a prominent position as a significant maritime gateway in India, situated within Gujarat's Kutch district. This stands out as the largest Creek-based port, positioned at the southwestern tip of the Gulf of Kachchh, on India's north-western coastline within the state of Gujarat. Deendayal Port Authority (DPA) serves as a pivotal hub for maritime trade, facilitating the transportation needs of several hinterland states. It boasts excellent connectivity through an extensive rail and road network, functioning as a crucial gateway for the export and import activities of northern and western Indian states, including Jammu & Kashmir, Delhi, Punjab, Himachal Pradesh, Haryana, Rajasthan, Gujarat, as well as parts of Madhya Pradesh, Uttaranchal, and Uttar Pradesh. This port ranks among the largest and most essential ports in the country, playing a vital role in India's international trade and maritime infrastructure. The administration and operations of the port are overseen by the Deendayal Port Trust (DPT), an autonomous entity established under the Major Port Trusts Act of 1963.

The Deendayal Port Trust is entrusted with the comprehensive management, development, and administration of the port. The authority is comprised of a dedicated team of professionals and experts who work diligently to ensure the efficient operation of the port and all related activities. About 35% of the country’s total export takes place through the ports of Gujarat in which the contribution by Deendayal port is considerable. The port handled a total cargo of 105 MMTPA during 2016-17, 110 MMTPA during 2017-18, 115 MMTPA during 2018-19, 122.5 MMTPA during 2019-2020, 117.5 MMTPA during 2020-21 and 137 MMTPA during 2022-23. DPA is the only major Indian port to handle more than 127 MMT cargo throughput, and it has also registered the highest cargo throughput in its history. The port has handled a total of 3151 vessels during FY 2021-22. Over the years, the port has witnessed significant growth and development, becoming a crucial gateway for India's international trade.

Deendayal Port has a strategic location on the west coast of India, offering direct access to the Arabian Sea. It serves as a vital link for India's trade with countries in the Middle East, Africa, Europe, and Asia. The port handles a wide range of cargoes, including petroleum products, chemicals, coal, iron ore, fertilizers, salt, and general cargo.

Further, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. With such capacity, the Port ranks No. 1 among all the major ports in India for 12th Consecutive year. Further, a regular expansion of infrastructure and port facilities is under way to cater future logistic requirements. The port has high commercial importance in the Indian maritime trade as it handled 36.1 million tons (17%) of Cargo out of total Cargo of 213.1 million tons of the maritime Cargo of India during 2015. In addition, regular expansion of infrastructure and port facilities is under way to cater future logistic requirements.

Deendayal Port Authority (DPA) has taken up Development of 7 Integrated facilities, and the Ministry of Environment, Forest and Climate Change (MoEF & CC), has put up some conditions while according Environmental and CRZ clearance. One of the conditions is to carry out the *"Study on Dredged Material for presence of contaminants"* as accorded by the MoEF & CC, GoI dated 19/12/2016 - Specific condition no. vii)" which states that ***"Dredged materials should be analyzed for presence of contaminants and also to decide the disposal options. Monitoring of dredging activities should be conducted and the findings should be shared with the Gujarat SPCB and Regional Office of the Ministry"***.

1.1 Need of the study

Considering the aforementioned condition, DPA has assigned the task of carrying out the study to Gujarat Institute of Desert Ecology (GUIDE), Bhuj. This study will be attempted three times in a year at two specified locations. Further, the study will envisage the evaluation of physico-chemical constituents in the dredged materials in the dumped locations in the study area. GUIDE has been entrusted with the project, which has duration of three years (01.11.2021 – 31.10.2024) as specified in the work order. Accordingly, the study was initiated to evaluate the dredged materials for potential contamination, employing a systematic investigation that encompasses the analysis of physical, chemical, and biological characteristics with special reference to pollutants including heavy metal, Petroleum hydrocarbon etc.

1.2. Scope of the study

a. To monitor the locations where dredged materials are dumped will be conducted.
b. Dredged materials in the area will be analyzed for the presence of contaminants in two different locations.
c. Detailed assessment of the dredged materials for physical, chemical and biological characteristics will be studied.
d. Suggesting suitable disposal options for the dredged material will be made.

1.3. Sampling locations for 2023-24

The study focused on investigating the presence of contaminants in the dredged materials during the year 2023-24. The specific locations for sampling can be found in Table 1 and Plate 1. The selection of these sampling sites was based on information supplied by the Hydraulic and Dredging Division to the Department of Port Administration (DPA), concerning the locations of dumping grounds. These location details were subsequently shared with the Gujarat Institute of Desert Ecology (GUIDE) via an email dated October 24, 2018. Three seasonal studies covering Location 1, Location 2 and Location 3 with the Third season of the study was conducted during 01.08.2024 – 03.08.2024.

Table 1: GPS Co-ordinates of sampling locations

Station	Latitude (N)	Longitude (E)
Location 1 (Offshore)	22° 51' 00" N	70° 10’ 00" E
Location 2 (Cargo jetty)	22°56' 31" N	70 13' 00" E
Location 3 (Phang Creek)	23° 04' 28" N	70°13’ 28" E

1.4. Details of work done during 3rd Quarter (May 2024 – July 2024)

The Third season sampling of the project was conducted in the 3rd Quarter of the project period, *i.e.*, 2023-24. During the sampling, the surface and bottom marine water samples and bottom marine sediment samples were collected from the three designated locations, *i.e.*, Offshore, Cargo Jetty and Creek systems which was pre-designated locations as earmarked by CPWRS was conducted.

After the collection, the samples were preserved using standard protocols and stored in an Ice box and brought to the laboratory within 2-3 hrs of collection Comprehensive analysis was performed on all the samples, both water (36 samples) and sediment (18 samples), to determine various physical, chemical, and biological characteristics. The analysis followed the standard methods prescribed by the Integrated Coastal and Marine Area Management (ICMAM) in 2012. All samples were analysed in triplicates, and the obtained data was compared against the marine water limits specified by the Central Pollution Control Board (CPCB) and other relevant standards.

Plate 1: Map showing locations of proposed sampling (2023-2024)

Chapter 2 Physico-Chemical Characteristics of the Sediment

The sediment samples from the study area were collected for the purpose of characterization employing standard methodology and the analysis of the samples were also performed as per standard protocol and the data of sediment analysis is presented in this Chapter 1. The sediment samples were collected in pre-fixed stations using a Van-Veen type of grab sampler. After collection, the sediment samples were preserved with Rose Bengal and formalin to avoid decomposition of samples and processed for analysis and the samples after collection were brought to the laboratory on the same day of collection and air dried and used for further analysis for the test parameters (Table 2).

Table 2: Physico-chemical and biological characteristics of sediment samples

S. No	Physico-chemical and biological parameters
1	pH (1: 10 suspension)
2	Salinity (ppt)
3	Sand (%)
4	Silt (%)
5	Clay (%)
6	Total organic carbon (%)
7	Phosphorus (mg/kg)
8	Sulphur (mg/kg)
9	Petroleum Hydrocarbon (µg/kg)
10	Cadmium (mg/kg)
11	Lead (mg/kg)
12	Chromium (mg/kg)
13	Copper (mg/kg)
14	Cobalt (mg/kg)
15	Nickel (mg/kg)
16	Zinc (mg/kg)
17	Magnesium (mg/kg)
18	Macrobenthos

2.1. pH and Salinity (1: 10 suspension)

The pH of the sediment suspension is a measure of the activity of H+ ions within the sediment-water system. It indicates whether the sediment is acidic, neutral or alkaline in nature. Since ions are the carrier of electricity, the electrical conductivity (EC) of the sediment-water system rises according to the content of soluble salts. The EC measurement directly corresponds to the concentration of soluble salts in the sediment at any particular temperature. To conduct the analysis, ten grams of the finely sieved sediment was dissolved in 100ml of distilled water to prepare leachate. This leachate was taken for shaking using a rotator shaker for one hour to ensure proper homogenization of the suspension. Following this, the suspension was allowed to settle for two hours, and the supernatant was collected after filtration for the subsequent analysis of pH and salinity using the pH and EC meter (Make: Systronics 361) and Refractometer (Make: Atago) respectively. Each sample was analyzed in triplicates to ensure accuracy, and the mean values were considered for further evaluation.

2.2. Textural analysis (Sand/Silt/Clay)

Sediment samples were collected using Van Veen grab whereas intertidal sediments will be collected using a handheld shovel. After collection, the scooped samples are transferred to polythene bags, labelled and stored under refrigerated conditions. The sediment samples are thawed, oven dried at 40ºC and ground to a fine powder before analyses.

For texture analysis, specified unit of sediment samples were sieved using sieves of different mesh size as per Unified Sediment Classification System (USCS). Cumulative weight retained in each sieve will be calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves. The percent retained will be calculated from the weight retained and the total weight of the sample. The cumulative percent will be calculated by sequentially subtracting percent retained from 100%.

2.3. Total organic carbon

Total organic carbon refers to the carbon content stored within sediment organic matter. It is derived from various sources such as the decomposition of plant and animal residues, root exudates, living and deceased microorganisms, sediment biota etc. To measure total organic carbon in sediment, a process of oxidation is employed using potassium dichromate in the presence of concentrated sulfuric acid. During the analysis, potassium dichromate generates nascent oxygen, which reacts with the carbon present in organic matter, resulting in the production of carbon dioxide (CO2). The excess volume of potassium dichromate is then titrated against a standardized solution of ferrous ammonium sulfate in the presence of phosphoric acid, using Ferroin indicator to detect the initial appearance of unoxidized ferrous iron. This titration allows the determination of the volume of potassium dichromate required to oxidize the organic carbon present in the sample.

2.3.1. Procedure

The determination of the percentage of total organic carbon in sediment involves oxidizing the organic matter within the sediment samples using chromic acid. The excess chromic acid is then estimated by titrating it against ferrous ammonium sulfate, with ferroin serving as an indicator. The step-by-step procedure is outlined as follows:

To begin, 1 gram of sediment sieved to a particle size of 0.5 mm is weighed and transferred into a 500 ml conical flask. Then, 10 ml of 1N $K_2Cr_2O_7$ is added to the flask with pipette followed by gentle swirling to ensure thorough mixing. Next, 20 ml of concentrated H2SO4 is added, and the sediment and reagents are mixed gently. This mixture is allowed to react for 30 minutes on a marble stone to avoid any damage caused by the release of intense heat from the sulfuric acid reaction. Afterward, 200 ml of distilled water is slowly added to the flask, along with 10 ml of concentrated orthophosphoric acid and approximately 0.2 grams of NaF. The sample and reagent mixture is left to stand for 1.5 hours, as the titration endpoint is better observed in a cooled solution. Just before the titration, 1 ml of ferroin indicator is added to the conical flask. The excess $K_2Cr_2O_7$ is then titrated with 0.5 N ferrous ammonium sulfate until the color changes from yellowish green to greenish, and finally to a brownish-red color indicating the endpoint. A blank test without the sediment sample is also performed simultaneously for reference. Through this procedure, the percentage of total organic carbon in the sediment can be accurately determined.

2.4. Total Phosphorus

The determination of total phosphorus in sediment is commonly conducted using Bray's extraction method. This method involves the formation of specific-colored compounds by adding appropriate reagents to the solution, with the intensity of the color being directly proportional to the concentration of phosphorus being estimated. The color intensity is measured spectrophotometrically. In the spectrophotometric analysis, a light source emitting light of a specific wavelength (usually within a band width of 0.1 to 1.0 nm) in the ultraviolet region of the spectrum is used. The photoelectric cells in spectrophotometer measure the light transmitted by the solution allowing for quantitative analysis.

2.4.1. Procedure

To perform the analysis, 50 ml of the Bray's extractant is added to a 100 ml conical flask containing 5 grams of sediment sample. The flask is shaken for 5 minutes and then filtered. Exactly 5 ml of the filtered sediment extract is transferred to a 25 ml measuring flask using a bulb pipette. Subsequently, 5 ml of the molybdate reagent is added using an automatic pipette, followed by dilution to 20 ml with distilled water and shaken well. Furthermore, 1 ml of dilute Stannous Chloride solution is added, and the volume is made up to the 25 ml mark. Thorough shaking is performed to ensure proper mixing. The mixture is then allowed to develop color, and after 10 minutes, readings are taken in the spectrophotometer at a wavelength of 660 nm. Prior to the readings, the instrument is zeroed using a blank prepared similarly but without the sediment.

2.5. Total Sulphur

Total sulphur in the sediment extract was determined using a turbidimetric method with a spectrophotometer. A series of standards containing sulphur at concentrations of 2, 4, 6, 8, and 10 ppm were prepared from a stock solution. Each flask in the series received 25 ml of the respective standard solution, and 2.5 ml of conditioning reagent solution was added. Additionally, 5 ml of extraction solution was added to the mixture. To facilitate the reaction, 0.2-0.3 grams of barium chloride were included and thoroughly mixed. The volume was adjusted to 25 ml with distilled water, and readings were taken at 340 nm using a spectrophotometer.

For the sample analysis, 5 grams of marine sediment were placed in a 100 ml conical flask. To this, 25 ml of a 0.15% $CaCl2$ solution was added and shaken for 30 minutes. The mixture was then filtered through Whatman No. 42 filter paper. Subsequently, 5 ml of the sample aliquot was transferred into a 25 ml volumetric flask. Conditioning reagent (2.5 ml) and 0.2 to 0.3 grams of barium chloride powder were added, followed by making up the volume to 25 ml with distilled water. The flask contents were shaken for 2 minutes, and the absorbance was measured using the same procedure as the standard solutions.

2.6. Petroleum Hydrocarbons

To analyze petroleum hydrocarbons in sediment, the following procedure will be conducted. First, the sediment will undergo reflux with a mixture of KOH and methanol, allowing for the extraction of petroleum hydrocarbons. This reflux process helps release the hydrocarbons from the sediment matrix. Next, the sediment will be subjected to extraction using hexane, which selectively dissolves the hydrocarbons present in the sediment. The excess hexane will be carefully removed, leaving behind a residue containing the concentrated hydrocarbons of interest. To further purify the sample and remove any impurities, a clean-up procedure will be performed using silica gel column chromatography. This column chromatography process helps separate the hydrocarbons from other compounds present in the residue, resulting in a cleaner sample for analysis. Finally, the hydrocarbon content in the sediment will be estimated by measuring fluorescence, following the standard method for petroleum hydrocarbon analysis. This fluorescence measurement allows for quantification and determination of the hydrocarbon levels present in the sediment sample. By following this procedure, accurate analysis of petroleum hydrocarbons in sediment can be achieved.

2.7. Heavy metals

Heavy metals, such as Cadmium (Cd), Lead (Pb), Chromium (Cr), Nickel (Ni), Cobalt (Co), Copper (Cu), Zinc (Zn), Manganese (Mn), and others, are of particular concern in relation to the environment. To release mineral elements from sediment samples, wet oxidation is commonly employed, utilizing oxidizing acids, such as tri/di-acid mixtures.

In the analysis procedure, a sediment sample weighing 1.0 gram is taken in a 100 ml beaker, which is covered with a watch glass. A mixture of Aqua regia (1:3 HNO_3:HCl) in the amount of 12 ml is added to the beaker. The beaker is then subjected to digestion for 3 hours at 100°C on a hot plate using a sand bath. Afterward, the samples are evaporated to near dryness, allowed to cool for 5 minutes, and then 20 ml of 2% nitric acid is added. The beaker is placed on a hot plate for digestion for 15 minutes, after which it is removed from the hot plate and allowed to cool. The mixture is then filtered using Whatman No. 42 mm filter paper. Finally, the volume is adjusted to 50 ml with 2% nitric acid to make up the final solution. The extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis. By following this procedure, the heavy metal content in the sediment can be accurately analyzed using wet oxidation, filtration, and AAS techniques.

2.8. Results

2.8.1. pH (Hydrogen Ion)

When any characteristics study of water or sediment is concerned, pH is considered to be one of the major variable especially in marine sediments as it influences various biogeochemical processes and ecosystem dynamics. These values are influenced by various factors, including the carbon, oxygen, nitrogen, phosphate, silicate, sulphur, iron, and manganese cycles. They are closely associated with processes such as heterotrophic respiration, chemoautotrophic activity, photosynthesis, precipitation, and the dissolution of calcium carbonate in marine water and sediments. In our investigation, we conducted measurements of average pH values at different locations. All three locations show slightly alkaline pH levels in sediments. Offshore has the average pH (8.42 ± 0.12), followed by Cargo Jetty (8.44 ± 0.28) and Phang Creek (8.64±0.12). The differences are minimal, indicating relatively stable and similar pH conditions across all locations. The data on individual values at all the locations and stations are given in Table 3.

2.8.2. Salinity

Salinity of seawater is subject to fluctuations influenced by temperature changes, following diurnal and seasonal cycles that correspond to variations in atmospheric temperature. Salinity levels in marine water and sediment exhibit a wide range, typically spanning from 0 to 36 in most estuaries. Semi-enclosed bays can experience hyper-salinity conditions. In the present study, it was observed that a broader range of salinity concentrations at different stations. Phang Creek shows the average salinity (18.82±3.26 ppt), followed by Cargo Jetty (16.19±7.06 ppt) and Offshore (25.07± 7.22 ppt), respectively. These findings are summarized in Tables 3-5, where all the data is presented.

2.8.3. Sediment Texture

Understanding the sediment texture at different stations provides valuable insights into the habitat characteristics and ecological dynamics of the marine environment. The sediment texture plays a significant role in determining the physical and chemical properties of the marine sediment, influencing the distribution and abundance of benthic organisms at the offshore station. The sediment composition across the three locations such as Offshore, Cargo Jetty, and Phang Creek—shows distinct patterns in the distribution of sand, silt, and clay. In terms of sand content, the Offshore location has the highest percentage at 83.80±20.31%, which indicates a more dynamic, high-energy environment. This could be due to the influence of strong currents or wave action that tends to carry away finer particles, leaving behind coarser sand. Offshore has a lower clay content at 10.80±3.69%, while Phang Creek lies in between with 74.7±9.46%. The silt content is fairly consistent between Offshore and the Cargo Jetty, with 50.6±17.15% and 31.4±20.06%, respectively. Phang Creek, however, shows a notably lower silt percentage at 21.37±6.32%. Clay content is highest in Phang Creek at 63.4±9.46%. Offshore also recorded a lowest clay percentage at 7.00±3.69% and the data of all the field stations are summarized in Tables 3-5.

2.8.4. Total organic Carbon

Total Organic carbon in sediments primarily originates from the decomposition of animals, plants, and anthropogenic sources such as chemical waste, fertilizers, and organic-rich waste. These sources contribute to the enrichment of the marine environment with organic material, which subsequently settles to the bottom sediments from the water column. This pathway leads to an increase in Total Organic Carbon (TOC) values and can have implications for the faunal communities inhabiting the sediments. In our study, during this third season, it was investigated the TOC concentrations at different stations. The mean ± standard deviation (SD) TOC percentages were determined to be Total Organic Carbon which is reported as 1.35±0.08% at the offshore station, 0.73±0.09% at the cargo jetty station, and 0.52±0.06% at the Phang creek station. The TOC concentrations at all stations are presented in Tables 3-5. Understanding the dynamics of organic carbon in marine sediments is vital for assessing the health and ecological integrity of marine environments. It helps in monitoring anthropogenic influences and their potential impacts on the marine ecosystem.

2.8.5. Organic matter

Organic matter serves as the primary reservoir of organic carbon in marine sediments, encompassing the chemical, physical, and biological degradation processes that contribute to the formation of organic material in the marine environment. It consists of a mixture of materials derived from various planktonic and benthic species, forming the ecological foundation for primary producers and consumers in the overlying surface sediment. In our study conducted during the third season, we investigated the levels of organic matter in different locations. The organic matter percentages ranged 2.32±0.13% in the offshore location, 1.26±0.15% at the cargo jetty, and 0.89±0.11% in the Phang creek area and the findings are summarized in the below tables (3-5), which illustrates the variation in organic matter content across the studied locations. Understanding the presence and dynamics of organic matter in marine sediments is crucial for assessing the overall health and ecological functioning of marine ecosystems. Phang Creek shows the highest organic matter suggesting higher inputs of organic material, possibly from terrestrial sources or higher productivity. The Cargo Jetty area shows the lowest organic matter, which might be due to higher energy conditions preventing organic matter accumulation.

2.8.6. Phosphorus and Sulphur

In the present study, the highest concentration of sulphur was recorded at Offshore followed by Cargo Jeety and Phang Creek with average sulphur content at Offshore was (62.61±3.19 mg/kg), followed by Cargo Jetty (44.53±6.57 mg/kg) and Phang creek (41.53±4.49 mg/kg). The concentrations of phosphorus and sulphur at all stations are presented in Tables 3,4 and 5.

On the other hand, Phosphorus (P) is an essential nutrient for life and plays a crucial role in regulating primary productivity within marine systems. It serves as a key element in various biological processes. In marine sediments, phosphorus availability influences primary productivity, affecting the growth and development of marine organisms The Cargo jetty recorded the highest phosphorus content (38.27 mg/kg), followed by Offshore (29.64 mg/kg) and Phang Creek (27.62 mg/kg). This could reflect differences in nutrient inputs or cycling across the locations as Sulphur (S) is involved in dissimilatory sulfate reduction by microbial activity, which is a primary pathway for organic matter mineralization in anoxic sea beds. This process leads to the production of sulfide. Subsequently, chemical or microbial oxidation of the produced sulfide forms a complex network of pathways in the sulfur cycle, resulting in intermediate sulfur species and partial conversion back to sulfate. Phosphorus levels are highest in the offshore and cargo jetty areas. This could indicate different sources of phosphorus, such as upwelling in offshore areas or anthropogenic inputs near the cargo jetty.

The lower levels be due to higher uptake by organisms or different sediment characteristics that don't retain phosphorus as effectively. Phang Creek shows the highest sulphur content with the least variability. This could indicate more reducing conditions in the sediments, possibly due to higher organic matter content and limited oxygen penetration. The lower levels in offshore and cargo jetty areas might reflect more oxidizing conditions due to better water circulation. These elements influence the availability of essential nutrients and can have implications for primary productivity and the overall functioning of marine ecosystems.

2.8.7. Petroleum hydrocarbon (PHC)

Petroleum hydrocarbons in general have low solubility in marine water and tend to adsorb onto particulate matter, leading to their long-term persistence in sediment bottoms. This persistence can have significant negative impacts on benthic aquatic communities within the marine ecosystem. PHCs are a major source of contamination in marine environments, primarily comprising compounds from three classes: alkanes, olefins, and aromatics. In the present study, the levels of PHCs in different locations were measure. Offshore location has recorded the highest average petroleum hydrocarbon content (13.19± 3.61 μg/kg), followed by Phang creek (9.18±3.80 μg/kg) and Cargo jetty site (6.85±3.30 μg/kg). This suggests more anthropogenic oil-related inputs in the nearshore areas.

The presence of petroleum hydrocarbons in marine environments is of great concern due to their potential harmful effects on marine organisms and ecosystems. These contaminants can bioaccumulate in organisms and disrupt their physiological processes, as well as cause long-lasting damage to the benthic communities. The higher levels of petroleum hydrocarbons in Phang Creek and Cargo Jetty compared to the offshore location suggest more significant anthropogenic inputs in these areas.

This could be due to boat traffic, urban runoff, or industrial activities near these locations. The offshore area, being further from these sources, shows lower contamination levels.

2.8.8. Magnesium

In the present study conducted during the third season at Deendayal Port, we determined the concentrations of magnesium at different stations. Phang Creek shows the highest average magnesium content (20991.67±580.01 mg/kg), followed by Offshore (20541.67±698.15mg/kg) and Cargo Jetty (20133.33±787.82 mg/kg).

Highest magnesium content in sediments of Phang Creek could be due to differences in sediment sources, with Phang Creek possibly receiving more magnesium-rich materials from terrestrial sources. The high variability in the Cargo Jetty area suggests a more heterogeneous sediment composition, possibly due to varied inputs from both marine and terrestrial sources. Understanding the distribution and dynamics of magnesium in marine sediments provides valuable insights into the geochemical processes occurring within the sediment column and their impact on the marine ecosystem. Continuous monitoring of magnesium levels is crucial for assessing the health and ecological integrity of marine environments. Dissolved magnesium flux from the overlying ocean into marine sediments is primarily driven by molecular diffusion. This process occurs as pore water magnesium is depleted during the formation of authigenic minerals within the sediment column. Additionally, direct burial of seawater occurs as sediment accumulates on the seafloor, contributing to the input of magnesium into the sediment. Its concentration in sediments can have implications for nutrient availability, sediment mineralogy, and the diverse organisms inhabiting the sediment environment.

2.8.9. Heavy metals

The heavy metal concentration in the sediment samples were examined for the presence of heavy metals from the samples collected from various stations at different locations at Deendayal Port. The analysis of sediment samples from three locations *viz*., offshore, cargo jetty, and Phang Creek revealed varying concentrations of heavy metals. In the offshore samples, Nickel ranged from 31.9 to 43.65 mg/kg (mean 37.21 mg/kg), while the mean concentrations of Chromium was 65.91±29.69, 44.01±7.86 and 54.24±39.08 at Offshore, Cargo jetty and Phang creek locations respectively. The concentration of cobalt was comparatively less when compared the concentration of other metals where mean cobalt concentrations of 5.37±2.78 mg/kg, 4.42±1.32 mg/kg and 4.76±1.48 mg/kg as observed at Offshore, Cargo jetty and Phang creek locations respectively. Manganese was notably high with no major variation in the concentrations in the samples which was observed as 821.50 mg/kg, 817.50 mg/kg and 807.50 mg/kg at Offshore, Cargo jetty and Phang creek locations respectively. The data of all the heavy metal concentrations from all the locations are presented in Tables 3-5.

Table 3: Physico-chemical characteristics of sediment samples collected from Offshore location

S. No	Parameters	1A	1B	1C	1D	1E	Control 1
1	pH (1: 10 suspension)	8.41	8.38	8.23	8.44	8.58	8.48
2	Salinity	23.50	26.50	25.60	30.80	32.10	11.90
3	Petroleum Hydrocarbon	12.21	10.95	BDL	10.82	19.52	12.45
4	Magnesium	20250	21400	19850	20650	19800	21300
5	Sand (%)	32.3	34.7	34.9	33.8	34.9	83.8
	Silt (%)	59.9	56.1	59.7	55.4	56.7	15.8
	Clay (%)	7.8	9.2	5.4	10.8	8.4	0.4
6	Organic matter (%)	2.48	2.43	2.17	2.27	2.37	2.17
7	Total organic carbon	1.44	1.41	1.26	1.32	1.38	1.26
8	Phosphorus	20.43	16.11	16.40	21.87	20.40	29.64
9	Sulphur	61.18	63.55	66.88	65.18	60.66	58.22
10	Nickel	36.65	38.35	35.5	43.65	31.9	BDL
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	9.95	14.9	0.85	14.8	12.4	12.1
13	Chromium	57.05	80.5	49.45	77.1	108.8	22.55
14	Zinc	54.4	60.95	51.45	51.8	57.7	11.65
15	Copper	24.95	35.65	19.6	23.75	31.1	BDL
16	Manganese	815	821.5	764	761	802.5	818.5
17	Cobalt	3.5	7.5	8.7	5.2	6.25	1.05

Table 4: Physico-chemical characteristics of sediment samples collected from Cargo jetty

S. No	Parameters	2A	2B	2C	2D	2E	Control 2
1	pH (1: 10 suspension)	8.79	8.77	8.43	8.13	8.22	8.31
2	Salinity	13.21	11.60	30.30	12.50	13.60	15.90
3	Petroleum Hydrocarbon	BDL	12.25	5.62	3.48	7.24	5.68
4	Magnesium	20600	20200	21050	20550	18950	19450
5	Sand (%)	22.6	22.2	23.5	14.6	18.9	21.7
	Silt (%)	17.0	49.8	63.1	24.4	16.5	17.6
	Clay (%)	60.4	28.0	13.4	61.0	64.6	60.7
6	Organic matter (%)	1.39	1.24	1.44	1.29	1.16	1.03
7	Total organic carbon	0.81	0.72	0.84	0.75	0.66	0.6
8	Phosphorus	33.09	38.27	20.14	17.84	19.85	17.84
9	Sulphur	40.37	44.40	57.29	43.03	38.22	43.85
10	Nickel	9.1	16.35	31.85	9.9	BDL	24.05
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	9.8	17.4	19.9	5.25	17.7	6.75
13	Chromium	42.9	42.6	55.3	37.4	34.8	51.05
14	Zinc	43.9	47.75	57.6	52.25	45.6	74.15
15	Copper	4.95	11.65	20.7	6.65	5.25	19
16	Manganese	770.5	773.5	784	756.5	711.5	817.5
17	Cobalt	6.35	4.3	2.65	5.45	3.55	4.2

Table 5: Physico-chemical characteristics of sediment samples collected from Phang creek

S. No	Parameters	3A	3B	3C	3D	3E	Control 3
1	pH (1: 10 suspension)	8.55	8.70	8.69	8.43	8.71	8.73
2	Salinity	24.60	19.20	19.90	16.40	15.80	17.00
3	Petroleum Hydrocarbon	6.28	4.28	10.28	BDL	11.58	13.48
4	Magnesium	21450	20300	20850	21350	20350	21650
5	Sand (%)	13.3	10.6	10.3	13.4	27.4	16.4
	Silt (%)	27.7	14.7	25.7	12.6	21.7	25.8
	Clay (%)	59.0	74.7	64.0	74.0	50.9	57.8
6	Organic matter (%)	0.98	0.82	0.93	0.72	1.03	0.87
7	Total organic carbon	0.57	0.48	0.54	0.42	0.6	0.51
8	Phosphorus	15.53	27.62	21.87	12.94	20.14	24.74
9	Sulphur	34.96	42.22	44.66	42.44	37.70	47.18
10	Nickel	BDL	2.45	BDL	15.2	14.85	BDL
11	Lead	BDL	BDL	BDL	BDL	BDL	BDL
12	Cadmium	15.35	9.2	10.15	16.6	18	16.85
13	Chromium	69.5	33.75	15.1	124.9	48.65	33.55
14	Zinc	41.7	39.75	47.35	18.9	25.65	23.2
15	Copper	6.55	2.2	6.8	19.35	11.85	7.1
16	Manganese	785.5	774	712	774	807.5	801.5
17	Cobalt	3.3	4.8	3.85	7.25	3.75	5.6

3.1. Introduction

Earth's total volume of water is estimated at 1.386 billion km³, among that, the salty water contributes almost 97.5% and the rest 2.5% contains freshwater. The existence of oceans on the Earth makes appearing it as blue planet from the space. Indian Ocean is the 3rd largest ocean in the world which (with its sub seas) surrounds to India on three sides with average depth of 3,890 meters (12,760 ft). As having at long coastline of almost 8000 km, India has vast marine resources. The Indian ocean's connection is a very large scale, including the Red Sea, East Africa, the Persian Gulf, Southern Arabia, India and Other Indian sub continental countries. This connection network connected people from all the coastal areas of the Indian Ocean and beyond, trading in aromatics, textiles, spices, precious stones, industrial productions, grain and an incredible range of other commodities and substances. Gujarat state of India shows longest coastline compare to other Indian states. Gujarat coastline is famous for various coastal ecosystems and habitats such as estuary, coral reefs, marshes, mangroves, and lagoons, rocky and sandy areas. Gujarat coasts having different coastal ecosystems like mangrove, sandy shores, muddy shores, rocky shores, mixed shores, wet sand shore, coral reefs and intertidal mudflats (Brink, 1993; Parasharya and Patel, 2014). Gujarat state is the only state in India bestowed with two gulfs, Gulf of Kachchh and Gulf of Khambhat. The Kachchh, largest district of the country with an area of 45,652 sq.km. Deendayal Port Authority is (DPT) one among the 12 major ports of the country and it is located in India's western coastal region

3.1.1. Benthos

Benthic animals are considered as the organism which lives in the bottom layer of all types of ecosystems including saline water as well as in freshwater. Benthos is nothing but water bottom communities or the organisms (floral and faunal) live in a benthic region regarding the sediment, rock and other substratum. They include mollusca (gastropods and bivalves), coral, sponges, worms (mostly polychaetes and nematode), crustacean crabs, other crustaceans, echinoderms, oysters etc. They play an important role in conversion of organic detritus from the sedimentary storage into the dissolved nutrients. Their distribution in water bodies can be varies and, on that basis, they can be classified into three types which are Endo-benthos, Epi-benthos (Pearson and Rosenberg, 1978) and Hyper-benthos (Mees and Jones,1997). Benthos could also recognize as one of the best indicators to assess the health and productivity of aquatic ecosystems. The benthic particularly macro benthic communities are an integral part of the coastal biotic components. They can serve as important food resource for the diverse groups of various organisms particularly bottom feeding animals. They are sensitive to wide range of environmental challenges including water movements, pollutants and living spaces (Martin et al., 2011). Their variations to tolerate changes in various environmental factors make them to be considered as an important bio-indicator for monitoring and research of marine environment.

3.2. Methodology

To study the benthic organisms, triplicate samples were collected at each station using Van-Veen grab which covered an area of $0.1m^2$. The wet sediment was sieved with varying mesh sizes (0.5 mm-macrofauna) for segregating the organisms. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution for easy spotting at the time of sorting. The number of organisms in each grab sample was expressed as number/ meter square (No/m^2). All the species were sorted, enumerated and identified to the advanced taxonomic level possible with the consultation of available literature. The works of Fauvel (1953), Day (1967) were referred for polychaetes; Barnes (1980) and Lyla *et al*. (1999) for crustaceans; Subba Rao *et al.* (1991) and Ramakrishna (2003) for molluscs.

Further, the data were treated with univariate statistical methods in PRIMER (Ver. 6.) statistical software (Clarke and Warwick, 1994)

a) Shannon – Wiener index

In the present study, the data were analyzed for diversity index (H’) by following Shannon – Wiener’s formula (1949):

$H' = -\sum^{S} Pi \log 2\ Pi\ldots\ldots \quad i = 1$

which can be rewritten as

$$H' = \frac{3.3219\ (N \log N - \sum ni - \log ni}{N}$$

where, H’= species diversity in bits of information per individual

ni = proportion of the samples belonging to the ith species

(number of individuals of the ith species)

N = total number of individuals in the collection and

$\sum$ = sum

b) Species richness(S) was calculated using the following formula given by Margalef (1958).

c) Margalef index (d)

d = (S-1) / log N

d) Pielou’s evenness index

The equitability (J’) was computed using the following formula of Pielou (1966):

$$J' = \frac{H'}{\log_2 S} \text{ or } \frac{H'}{\text{InS}}$$

Where, J' = evenness; H' = species diversity in bits of information per individual and S = total number of species.

3.3. Results on Species Composition, Population density and Biomass of Macrofauna of selected sites

<u>3.3.1. Species Composition, Population density and Biomass of Macrofauna at selected sites</u>

3.3.1.1. ffshre

In Offshore region of Kandala port, total six sites were selected namely, (1A, 1B, 1C, 1D, 1E and 1- control). A total 6 groups/species(of benthic community) of benthic animals were observed in all stations at Offshore sites and they a Bivalves (Mollusca),Gastropods (Mollusca), Crustacean animals, Polychaeta worms

(Annelida), Saccostrea sp (Bivalvia), *Pirenella cingulata* (gastropoda). All the data(Density and Biomass) expressed in (nos./m^2), (gm/m^2) respectively (Table 6).

Highest population density of benthic organisms was recorded in station 1control-Offshore(1600nos/m^2), whereas lowest in station 1B-Offshore(325nos/m^2). The density range of all stations varied from 325 to 1600nos./m^2. Bivalves and Gastropods were more abundant among all the benthic organisms might be sandy-muddy or rocky substratum in bottom part of Offshore region. Low recorded benthos were Crustacean animals and *Pirenella cingulata* that indicated less part of substratum are muddy and not suitable rock attachement. The highest biomass value (expressed wet weight) of benthic fauna was observed in station 1control-Offshore (17.46gm/m^2) and lowest value was 1B-Offshore(2.19 gm/m^2) (Table 6). Range of the Biomass was 2.19 to 17.46 gm/m^2 . Moderately Biomass values and also density values suggested mixing substratum, less availability of plenty food items and more predator pressure by higher animals. Intermediate association was also one responsible factor for the same. Variation in density and biomass in Offshore region because more influences by the Water Currents, Up welling - Down welling (Churning process of water) movements of water and Nutrients availability and Fluctuation in turbidity of water. Variation in substratum is also a one responsible factor.

3.3.1.2. Cargo Jetty

In Cargo Jetty, frequently observed benthic groups were Crustacean animals and Gastropods less reported benthos were Bivalves, *Pirenella cingulta* and Polychaeta worms. The population density range noted between 50 to 275(nos/m^2) among all the stations (Cargo Jetty-2A, 2B, 2C, 2D, 2E &2-Control) during the study period. Highest and Lowest density were recorded in station 2D- Cargo Jetty(275nos./m^2) and 2C-Cargo Jetty (50nos./m^2) respectively.

Biomass value indicated a highest value in station 2D- Cargo Jetty (4.81gm/m^2) and lowest in 2C- Cargo Jetty (0.36gm/m^2) (Table 6).Average Biomass and Population density value of all station were 2.48gm/m^2, 167nos./m^2 respectively which indicated the low to moderate environment condition of biota, water quality as well as substratum (mostly rocky).

3.3.1.3. Phang creek

Six Stations of Phang creek were selected for the studynamely 3A, 3B, 3C, 3D, 3E and 3-control-Phang Creek.In this Phang Creek benthic organisms were mostly represented byPolychaeta worms (annelids). Only four groups were present namely Polychaeta worms, Bivalve, Crustacean animals, Gastropods whereas *Pirenella cingulata* and *Saccostrea sp* were totally absent. Crustacean animals was only noted in 3D-Phang creek. Polychaeta worms ware more abundant because of suitable muddy environment. The population density was highest in station 3D -Phang Creek (150nos./m^2) and on the other side, lowest density was recorded in 3B-Phang Creek (50nos./m^2).Station 3D-Phang Creek comprises highest wet wt (0.26gm/m^2), whereas low value was recorded in3B & 3control-Phang Creek(0.05 gm/m^2).

Overall result (Offshore, Cargo Jetty and Phang creek) of macrofaunal community showed highest population density in 1control-Offshore (1600nos/m^2) and high biomass was observed (17.46gm/m^2) in 1control-Offshore. Table 6 showed highest population values of Bivalves in 1control- Offshore (800nos/m^2) and same highest value of Gastropoda showed in 1D- Cargo Jetty (475nos/m^2). The lowest value comprised by the *Pirenella cingulata and Saccostrea sp (Bivalves)* including some were totally absent in some sites. Some absent or less frequently observed benthos indicated extreme weather condition (may be suddenly change temperature of running season), more stress condition and unfavourable environment condition for their survival. Bivalves and Gastropods, dominant groups were preferred rocky, sandy or mix substratum, and any other hard substrata**.** Polychaete worms are preferred sandy-muddy substratum or sandy habitat mostly in Phang creek.

Table 6 showed that average population density and biomass higher in Offshore and after Cargo jetty where mostly rocky, sandy or some part covered with muddy area and algal growth providing a unique habitats for benthos. *Low density and biomass was observed in mostly Phang creek area (Table 6 and Figure 1) which indicated* *stressful environment, seasonal effect (rainy time), more anthropogenic activities and also might be some chemical and biological changes in water.* The population density and biomass of benthic community largely affected by the symbiotic and intermediate relation between them or with otherinvertebrates and suitable rocky substratum or coral reef in bottom of sea. Availability of Plankton, as a food source, also affected the benthic animals (Table 6 and Fig. 1 & 2). Extremely mix weather condition (during June and July months) also more affected in Cargo jetty and Phang creek regions of Deendayal port area.

In benthic communities, recorded species at all sites were *Clypeomorus bifasciata, Trochus sp, Radix sp, Donax sp, Turris sp,Marcia sp, Dosinia sp, Donax sp, Anadara sp, Turris sp, Solen, Nereis sp, Saccostrea sp, Optediceros breviculum etc. The percentage of occurrence (Table 6) was revealed highest group present by Gastropoda (72%) then following are Polychaeta worms (56%), Bivalves and Crustacean animals (39%), Placuna sp (33%), Saccostrea sp (17%) and and then others. Detail status of Population density, Group composition and biomass of the benthic community of all selected sites were depicted in (Table 6) and (Figure 1).* Among all the stations, highest percentage composition recorded by Gastropoda (35%) followed by Bivalves (24%), *Saccostrea sp* (16%), Polychaeta worms (13%) and others (Figure.2).

Phytoplankton abundance and their size, zooplankton body composition, patchy distribution of zooplankton, water currents, ebb and flow tides, and water churning process, changing in structure of muddy, rocky and sandy habitats are the main reasons for biomass and density fluctuation in Benthic communities. In Crustacean most commonly observed species are Crabs and attached Barnacles. Main Mollucsa families recorded Trochidae, Cerithidea, Turritellidae, Tellinidae, Donacidae and Bucciniae etc. *Nereis sp* of anneliids was mostly observedin samples. More number of the broken bivalves, debris, plant items , broken gastropods, small pebbles and soil particles are frequently observed during benthic organism’s study.

3.4. Diversity Indices of Benthic Community

Table 7 showed various diversity indices calculation, showed that Shannon Diversity Index ranging from (0.00-1.45) indicated very low diversity. Highest diversity indices was recorded in Station 2D-Cargojetty (1.45) whereas Shannon indices nil (zero) observed in 1A, 2A, 2B, 3B. Comparatively less Shannon indices value very low in Phang creek area number of benthos group/species present between 1 to 3 nos. The evenness values ranged between (0.47 to 1). The highest evenness value (1) is observed in stations Offshore (1A), Cargo jetty (2A and 2B) and Phang creek (3B). Evenness value "1" indicated all organisms occurred in same area or mostly same group. Simpson's Index value ranged between 0.00 to 0.73 indicated to lower to very less moderate diversity. The Margalef value showed range of 0.00 to 0.56 indicated high variation in species/group numbers (Table 7).

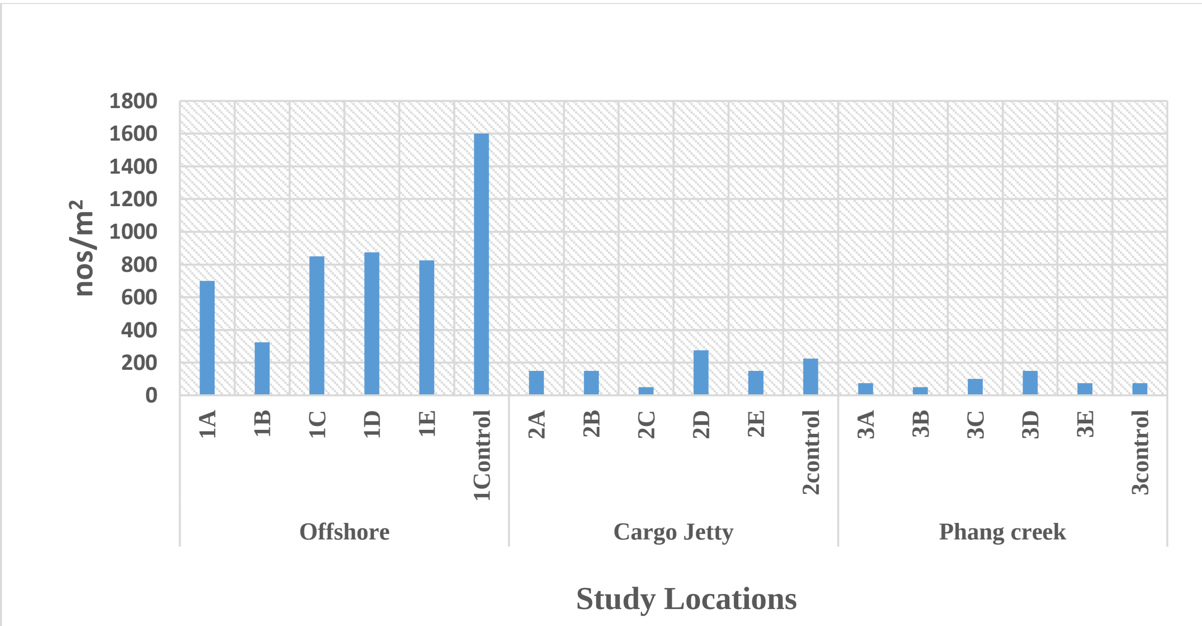


Figure 1. Population density of benthic organisms (nos/m^2)in various sites

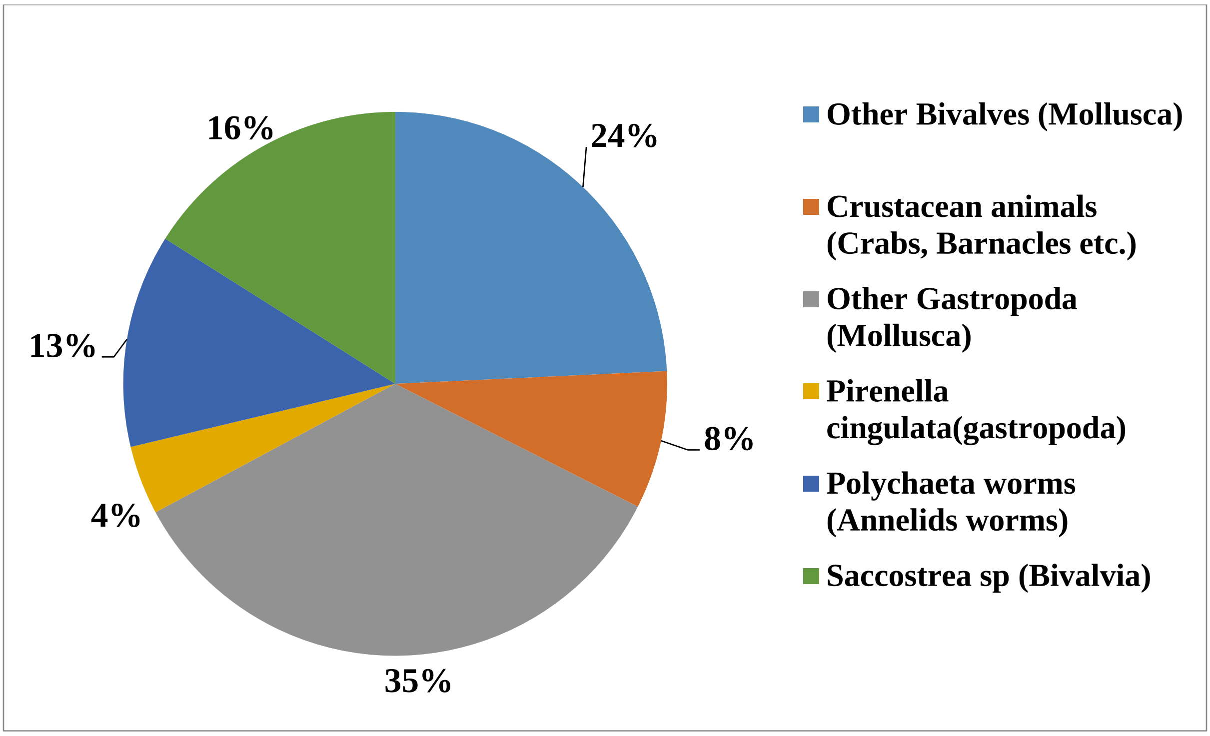


Figure 2. Percentage composition of benthic organisms in various sites.

Table 6. Macrobenthos distribution in different sites of Deendayal Port

Name of Station	Offshore						Cargo Jetty						Phang creek						
	1A	1B	1C	1D	1E	1-Control	2A	2B	2C	2D	2E	2-Control	3A	3B	3C	3D	3E	3-Control	% of Occurrence
Nameof Benthic Groups																			
Other Bivalves (Mollusca)	0	100	0	300	350	800	0	0	25	0	0	0	25	0	0	25	0	0	39
Crustacean animals (Crabs, Mysis etc.)	175	50	0	0	0	0	150	50	25	0	0	50	0	0	0	50	0	0	39
Other Gastropoda (Mollusca)	250	175	175	475	425	250	0	0	0	125	150	175	0	0	50	25	25	25	72
Pirenella cingulata(gastropoda)	0	0	125	0	0	0	0	0	0	150	0	0	0	0	0	0	0	0	11
Polychaeta worms (Marine Annelids)	0	0	300	100	50	0	0	100	0	0	0	0	50	50	50	50	50	50	56
Saccostrea sp (Bivalvia)	275	0	250	0	0	550	0	0	0	0	0	0	0	0	0	0	0	0	17
Total Population Density Nos/m^2	700	325	850	875	825	1600	150	150	50	275	150	225	75	50	100	150	75	75	39
Biomass (wet weight) gm/m^2	6.36	2.19	7.31	14.19	7.23	17.46	2.12	1.75	0.36	4.81	1.16	4.66	0.08	0.05	0.17	0.26	0.15	0.05	

Table 7: Diversity indices of benthic faunal community observed at all the locations during the third season

	Offshore						Cargo Jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3cont**
Variables																		
Taxa_S	1	2	3	5	4	2	1	1	5	5	4	5	3	1	3	3	4	3
Individuals (Nos./m^2)	50	75	200	3225	900	400	50	25	1400	1225	1800	2125	425	50	2300	2225	2250	2800
Dominance_D	1.00	0.56	0.38	0.39	0.41	0.63	1.00	1.00	0.32	0.27	0.33	0.28	0.45	1.00	0.74	0.72	0.67	0.68
Shannon Diversity Index (H)	0.00	0.64	1.04	1.23	1.06	0.56	0.00	0.00	1.27	1.45	1.21	1.41	0.92	0.00	0.49	0.54	0.64	0.56
Simpson_1-D	0.00	0.44	0.63	0.61	0.59	0.38	0.00	0.00	0.68	0.73	0.67	0.72	0.55	0.00	0.26	0.28	0.33	0.32
Evenness_e^H/S	1.00	0.94	0.94	0.69	0.72	0.88	1.00	1.00	0.71	0.85	0.84	0.82	0.84	1.00	0.54	0.57	0.47	0.58
Menhinick	0.14	0.23	0.21	0.09	0.13	0.10	0.14	0.20	0.13	0.14	0.09	0.11	0.15	0.14	0.06	0.06	0.08	0.06
Margalef	0.00	0.23	0.38	0.50	0.44	0.17	0.00	0.00	0.55	0.56	0.40	0.52	0.33	0.00	0.26	0.26	0.39	0.25

Chapter 4 Physico-Chemical Characteristics of Marine Water

4.1. Introduction

In recent decades, there has been a notable deterioration in aquatic ecosystems primarily caused by the presence of a diverse array of organic and inorganic contaminants. Among these pollutants, heavy metals (HMs) and microplastics (MPs) have emerged as significant contributors to this environmental degradation (Frew et al., 2020; Saha et al., 2016). These substances are recognized for their capability to infiltrate and accumulate within the aquatic food chain, making them hazardous pollutants in aquatic environments (Olojo et al., 2005). Of particular concern are heavy metals due to their toxic nature, long-lasting presence, resistance to degradation, the potential for bioaccumulation, and the ability to magnify up the food chain, all of which have raised global alarms (Begum et al., 2013; Cai et al., 2017).

Heavy metal pollution in aquatic ecosystems can be attributed to a variety of sources, including natural factors such as atmospheric deposition and weathering (Ebrahimpour and Mushrifah, 2010; Hamidian et al., 2016) as well as human activities like mining, agricultural runoff, sewage discharge, industrial effluent release, gasoline leaks from fishing vessels, and accidental chemical waste spills (Arulkumar et al., 2017). It is essential to recognize that certain heavy metals, such as copper (Cu), iron (Fe), nickel (Ni), cobalt (Co), zinc (Zn), manganese (Mn), and chromium (Cr), play vital roles in physiological processes and are necessary for the proper biological functioning of organisms in trace amounts. However, exposure to nonessential heavy metals can lead to various health concerns, including renal, cardiovascular, nervous, and bone diseases, as well as immune-related issues (Abadi et al., 2018; Madreseh et al., 2018). It is crucial to acknowledge that all heavy metals become toxic when their concentration exceeds a certain threshold level (Makedonski et al., 2017). In light of these concerns, it is imperative to assess the various characteristics of water in order to determine the extent of pollutant presence in aquatic environments.

4.2. Materials and Methods

In this study, marine water and sediment samples were collected following standard protocols, and their analysis was conducted using established methods for marine water and sediment analysis as prescribed by APHA (2012), NIO manual (1982), and ICMAM Manual (2012). For general analysis, surface water samples were collected using a clean polyethylene bucket, while water samples from the bottom were collected using a weighted Niskin sampler. Water samples at a depth of 1 meter below the surface were collected using a 1-liter glass bottle sampler. Parameters such as pH, temperature, and salinity were measured on-site using handheld meters and verified in the laboratory.

The collected water samples were stored under refrigerated conditions until further analysis of other parameters. According to the standard protocol, fixatives and preservatives were added to the samples for specific parameters. For example, Winkler A&B solution was immediately added to measure dissolved oxygen, concentrated H2SO4 was used to bring the pH below 2 for chemical oxygen demand analysis, and nitric acid was used for the preservation of heavy metals. Formalin was added to marine water samples for planktonic analysis. In general, all water and sediment samples were stored in sterile polythene bottles and Ziplock bags and kept in an icebox to maintain suitable conditions until they were transported to the laboratory. The parameters to be analyzed (Table 8) and the methods used for the sample analysis are described below.

Table 8: Physico-chemical and biological characteristics of marine water samples

S. No	Physico-chemical and Biological parameters
1	pH
2	Salinity (ppt)
3	Total Dissolved Solids (mg/L)
4	Turbidity (NTU)
5	Dissolved Oxygen (mg/L)
6	Bio-Chemical Oxygen Demand (mg/L)
7	Chemical Oxygen Demand (mg/L)
8	Phenolic compound (µg/L)
9	Petroleum Hydrocarbons (µg/L)
10	Oil and grease (mg/L)
11	Cadmium (mg/L)
12	Lead (mg/L)
13	Chromium (mg/L)
14	Copper (mg/L)
15	Cobalt (mg/L)
16	Nickel (mg/L)
17	Zinc (mg/L)
18	Magnesium (mg/L)
19	Chlorophyll (mg/m^3)
20	Phaeophytin (mg/m^3)
21	Phytoplankton Phytoplankton cell counts (no/L) Total Genera (no.) Major Genera
22	Zooplankton Biomass (ml/100m^3) Population (no/100m^3) Total Group (no.) and Major Groups

4.2.1. pH, Temperature and Salinity

pH and temperature measurements were conducted using a Thermo Fisher pH/EC/Temperature meter. Prior to use, the instrument was calibrated with standard buffers. For pH determination, an appropriate volume of the sample was titrated against silver nitrate (20 g/l), with potassium chromate serving as an indicator. The chlorinity of the sample was estimated, and salinity values were derived using a specific formula.

4.2.2. Total Dissolved Solids (TDS)

To confirm the readings obtained from the handheld meter, the samples underwent a gravimetric procedure. Approximately 100 ml of the water sample was taken in a beaker and filtered. The filtered sample was then completely dried in a hot air oven at 105°C. The TDS values were calculated by measuring the difference between the initial and final weight of the dried sample.

4.2.3. Turbidity

For turbidity measurement, a sample tube (Nephelometric cuvette) was filled with distilled water and inserted into the sample holder. The lid of the sample compartment was closed, and the meter reading was adjusted to zero by manipulating the 'SET ZERO' knob. The sample tube containing the 40 NTU standard solution was then placed in the tube, and the meter reading was set to 100. Similar measurements were carried out for other standard solutions. To determine the turbidity of the marine water sample, the sample tube was filled with the water sample, and the corresponding reading was recorded.

4.2.4. Dissolved Oxygen (DO)

To determine the Dissolved Oxygen (DO) levels in a water sample obtained from a marine environment, the following procedure was employed. Collect sea water sample, ensuring that the sampling container is clean and free from any potential contaminants that may affect the accuracy of the results. Subsequently, transfer the water sample into a Winkler's bottle or a suitable container, taking care to eliminate any trapped air bubbles. It is crucial to completely fill the bottle to minimize any headspace that could potentially alter the DO readings. Next, add the appropriate volumes of Winkler's reagents, such as manganese sulfate and alkali-iodide-azide, to the water sample as per the specific instructions of the Winkler's method. Gently and thoroughly mix the contents of the bottle to ensure uniform distribution of the reagents without introducing any air bubbles. Allow the bottle to stand undisturbed for a designated incubation period, typically around 30 minutes, to enable the necessary reactions to occur. After the incubation period, perform a titration using a standardized sodium thiosulfate ($Na_2S_2O_3$) solution until a faint yellow color appears, indicating the complete consumption of dissolved oxygen in the sample. Record the volume of sodium thiosulfate solution used for titration, which represents the amount of dissolved oxygen present in the water sample. To account for any dissolved oxygen in the reagents, it is essential to conduct the same procedure with blank samples that do not contain the water sample. This allows for an accurate calculation of the DO levels in the original water sample. Finally, employ the appropriate formula provided by Winkler's method to calculate the DO concentration in the water sample.

4.2.5. Biochemical Oxygen Demand (BOD)

To determine the Biochemical Oxygen Demand (BOD), the following procedure was employed using the direct unseeded method. Collect representative sea water sample from the desired location, ensuring the sampling container is clean and uncontaminated. Fill a BOD bottle with the water sample, leaving minimal headspace to prevent air contact that could affect BOD measurements. It's important to completely fill the bottle to minimize air bubbles. Record the initial Dissolved Oxygen (DO) level in the water sample using a dissolved oxygen meter or appropriate measurement method. Seal the BOD bottle tightly with the stopper to prevent air exchange. Incubate the sealed BOD bottle in a controlled environment, such as a BOD incubator, at a specified temperature (typically 20°C), for a designated incubation period, usually around 5 days. Throughout the incubation period, keep the BOD bottle in darkness to minimize the impact of photosynthetic activity. After the incubation period, measure the final DO level in the water sample using the same method or instrument as the initial measurement. Calculate the BOD by subtracting the final DO level from the initial DO level, accounting for any necessary dilution or blank corrections. This difference represents the amount of oxygen consumed by the organic matter in the water sample during the incubation period.

4.2.6. Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) test is a widely used method for quantifying the levels of organic and inorganic pollutants in water samples. The first step involves collecting representative water samples from the target site, ensuring proper labeling and record-keeping. Subsequently, these samples are placed into digestion vials or tubes, to which digestion reagents, typically potassium dichromate and sulfuric acid, are added. This step initiates the oxidation of organic matter in the sample. The sealed vials or tubes are then subjected to high-temperature heating, typically around 150-160°C, for a predetermined period, usually around 2 hours. This heating process breaks down complex organic compounds into simpler forms. After digestion, the samples are allowed to cool to room temperature. To determine the COD concentration, a colorimetric measurement is taken. A suitable reagent is added to the digested samples, reacting with any residual potassium dichromate, and generating a color change proportional to the COD concentration. This color intensity is measured using a colorimeter or spectrophotometer, and the results are calibrated using known COD standards. The final calculations yield the COD value, typically expressed in milligrams of oxygen per liter (mg/L) of the sample.

4.2.7. Phenolic compounds

To analyze phenolic compounds in water, the following procedure was followed. A 500 ml water sample containing phenols was treated with 4-aminoantipyrine, which converted the phenols into an orange-colored antipyrine complex. This complex was then extracted using 25 ml of chloroform. The absorbance of the extracted complex was measured at 460 nm using phenol as a standard for comparison. This measurement allowed for the quantification of phenolic compounds present in the water sample.

4.2.8. Petroleum Hydrocarbons (PHc)

The analysis of Petroleum Hydrocarbons (PHc) in a water sample involved the following protocol. One liter seawater sample was extracted using organic solvent, hexane. The mixture was then separated into an organic layer and an aqueous layer. The organic layer, containing the petroleum hydrocarbons, was isolated. To remove any remaining water, the organic layer was dried using anhydrous sulphate. The volume of the organic layer was subsequently reduced to 10 ml at a temperature of 30°C under low pressure. The fluorescence of the extracted organic compound was measured at 360 nm (with excitation at 310 nm) using Saudi Arabian crude residue as a standard. This residue was obtained by evaporating the lighter fractions of crude oil at 120°C. By comparing the fluorescence intensity of the extract with that of the standard, the concentration of petroleum hydrocarbons in the water sample could be determined.

4.2.9. Oil and Grease

To determine the content of Oil and Grease in a sample, the following procedure was followed. Approximately 500 ml of the sample was transferred to a separating funnel, and the sample bottle was rinsed with 30 ml of trichlorotrifluoroethane. The rinsing solvent was then added to the separating funnel. Next, 5 ml of 1:1 hydrochloric acid (HCl) was added to the mixture, and the contents were vigorously shaken for about 2 minutes. If a soluble emulsion was formed, the sample container was shaken for an additional 5 to 10 minutes. After shaking, the layers in the separating funnel were allowed to separate, and the lower layer (organic layer) was discarded.

The solvent layer was drained through a funnel containing a filter paper moistened with solvent, and it was collected in a clean distillation flask that had been pre-weighed. The solvent was then distilled from the flask using a water bath set at 70°C. The resulting residue was carefully transferred into a clean, pre-weighed, and dried beaker, using the minimum amount of solvent necessary. The beaker was placed on a water bath at 70°C for 15 minutes to evaporate off all the solvent. After the evaporation process, the beaker was cooled in a desiccator for 30 minutes to reach a consistent temperature, and its weight was then measured.

4.2.10. Heavy metals

Heavy metals are a significant concern, especially in coastal environments, since it is biomagnifying from lower organisms to higher organisms through water and sediment. Common heavy metals of concern include Cadmium (Cd), Lead (Pb), Chromium (Cr), Copper (Cu), Cobalt (Co), Nickel (Ni), Zinc (Zn), Magnesium (Mg) and Manganese (Mn). To release mineral elements from sediment and analyze them, a wet oxidation process is typically employed using oxidizing acids, such as a mixture of Tri / Di-acids. The procedure begins by weighing 0.5 grams of the sediment sample and placing it in a 100 ml beaker, which is covered with a watch glass. Then, 12 ml of Aqua regia (a mixture of 1 part HNO3 and 3 parts HCl) is added to the beaker. The beaker is placed in a digestion apparatus and heated at 100°C for 3 hours on a hot plate using a sand bath. The sample is evaporated until it is nearly dry, and then allowed to cool for 5 minutes. Next, 20 ml of 2% nitric acid is added to the cooled sample in the beaker, and the mixture is further digested on the hot plate for 15 minutes. After digestion, the beaker is removed from the hot plate and allowed to cool. The sample is then filtered using a Whatman No. 42 mm filter paper to remove any solid particles. To make up the final volume, the filtrate is diluted with 2% nitric acid to a total volume of 50 ml. The resulting extracted sample is then aspirated into an Atomic Absorption Spectrometer (AAS) for analysis of the heavy metal concentrations.

4.3. Results

In this third season study conducted in the present year, we closely monitored three distinct locations: Offshore, Cargo Jetty, and Phang Creek. A comprehensive analysis of physico-chemical characteristics in marine water samples was conducted at each of these sites. The collected data is thoughtfully presented in Tables 9-11. These findings serve as a significant source of information regarding the precise physico-chemical conditions prevailing at each of these locations. Consequently, they play a pivotal role in enhancing the comprehension of the environmental factors that exert influence on the quality of marine water in these specific areas. The description of the data in each station is detailed as below.

4.3.1. Location 1 - Offshore location

The offshore water samples exhibited moderate levels of salinity (35.86 ± 1.47 ppt) and total dissolved solids (44788.17 ± 5796.20 mg/L). The water was relatively warm (29.21 ± 0.13°C) with a slightly alkaline pH (7.41 ± 0.10). Turbidity was notable (96.32 ± 18.88 NTU), which could be due to suspended particles or plankton. Dissolved oxygen levels (6.01 ± 0.63 mg/L) were adequate for marine life but the lowest BOD (2.27 ± 0.28 mg/L), suggesting less biodegradable organic matter. However, it shows the highest levels of COD (33.83 ± 6.00 mg/L). The presence of petroleum hydrocarbons (24.99 ± 8.56 µg/L) indicating potential anthropogenic inputs from marine activities and phenolic compounds (6.70 ± 1.77 µg/L) suggests some level of anthropogenic influence. Nutrient indicators like chlorophyll (0.59 ± 0.09 mg/m^3) and phaeophytin (0.32 ± 0.08 µg/L) were present in low concentrations. The mean value of Oil and Grease exhibited 5.93 ± 2.23 mg/L. The heavy metals concentration of Nickel was seen only in control site with 3.02 µg/L. Whereas Manganese showed 2.11 µg/L in 1C site. Chromium and zinc showed Below Detectable Limit (BDL) with 0.36 ± 0.22 µg/L and 0.17 ± 0.16 µg/L. The concentration of heavy metals observed for Magnesium is 4727.92 ± 102.01 mg/L (Table 9). Overall, the offshore waters showed signs of moderate anthropogenic impact but maintained conditions generally suitable for marine life.

4.3.2. Location 2 – Cargo Jetty

At the Cargo Jetty location, the recorded data shows that the mean value of temperature was 29.44 ± 0.17°C, and the mean value of pH was observed as 7.77 ± 0.03. The average salinity of the seawater was 36.75 ± 1.53 ppt reflecting the salt content, while the Total Dissolved Solids (TDS), which indicates the presence of various anions and cations, had an average value of 44,517.00 ± 6,516.71 mg/L. Turbidity values were notably high, averaging 289.14 ± 76.54 NTU. The Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) showed mean values of 6.33

± 0.50 mg/L and 1.17 ± 0.72 mg/L respectively (as shown in Table 10). The average Chemical Oxygen Demand (COD) value was determined to be 30.00 ± 5.53 mg/L. The concentrations of Phenolic compounds showed a mean concentration of 6.43 ± 1.93 μg/L. Petroleum hydrocarbons were present with a mean concentration of 17.06 ± 6.88 μg/L, and the mean concentration of oil and grease in the marine water samples was 7.80 ± 2.09 mg/L, which falls below the acceptable limit of 10 mg/L according to GPCB norms. In terms of heavy metals, magnesium showed the highest concentration at 4,757.50 ± 63.08 mg/L. Whereas Lead (0.19 ± 0.15 mg/L), nickel (1.29 ± 1.02 mg/L) and manganese (0.19 ± 0.15 mg/L) was present in the sampling point 2C and 2D. While cobalt was detected at 0.135 mg/L in a single sample at 2C. Other detected metals included chromium (1.15 ± 0.25 mg/L, cadmium (1.62 ± 1.07 mg/L), zinc (0.34 ± 0.14 mg/L). Notably, copper showed Below Detection Limit (BDL) values across all sampling points in Station 2 as given in Table 10.

4.3.3. Location 3 - Phang Creek

At the Phang Creek location near the port, all the samples were subjected for analysis for various characteristics (Table 11). The mean temperature recorded as 29.37 ± 0.14°C and pH values averaging 7.94 ± 0.03. The average salinity of the seawater was measured at 38.11 ± 2.98 ppt, while the TDS showed an average value of 43,467.33 ± 6,176.51 mg/L which indicates the presence of various anions and cations. Turbidity values averaged 248.95 ± 46.94 NTU. The average value of water quality parameters revealed Dissolved Oxygen levels of 5.73 ± 0.18 mg/L, Biochemical Oxygen Demand of 2.41 ± 0.22 mg/L, and Chemical Oxygen Demand of 30.50 ± 6.45 mg/L. Phenolic compounds were present with 24.81 ± 2.88 μg/L, while mean value of petroleum hydrocarbons showed concentrations of 16.54 ± 5.99 μg/L, and oil and grease levels were recorded at 6.33 ± 1.29 mg/L. The heavy metal analysis revealed significant magnesium presence at 4,713.75 ± 84.59 mg/L, with chromium showing concentrations of 1.97 ± 0.18 mg/L. Other detected metals included nickel at 1.58 ± 0.86 mg/L, cadmium at 1.22 ± 1.00 mg/L, and zinc at 0.30 ± 0.11 mg/L. The Lead (0.345 mg/L) were detected only at control sampling point, whereas cobalt (0.03 mg/L) were detected at single sampling point 3E. Both copper and manganese consistently remained Below Detection Limit (BDL) at this location.

Table 9: Physico-chemical characteristics of the marine water from sampling location 1 (Offshore)

S. No	Parameters	1A		1B		1C		1D		1E		Control 1	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1.	Temperature (^{0}C)	29.3	29.1	29.3	29.2	29.3	29.0	29.3	29.2	29.3	29.1	29.4	29.0
2.	pH	7.22	7.21	7.40	7.38	7.44	7.43	7.48	7.45	7.50	7.49	7.45	7.42
3.	Salinity (ppt)	35.18	34.75	36.90	36.04	36.04	37.33	36.90	33.46	33.89	35.18	36.04	38.61
4.	Total Dissolved Solids (mg/L)	46259	49478	40953	53420	48775	40325	49195	40245	32569	43647	49842	42750
5.	Turbidity (NTU)	81.6	84.5	86.2	80.5	84.4	75.2	93.6	93.5	132.2	123.3	120.3	100.5
6.	Dissolved Oxygen(mg/L)	6.1	5.8	5.5	5.5	5.3	5.1	6	5.8	7.1	6.6	6.8	6.5
7.	Bio-Chemical Oxygen Demand (mg/L)	2.20	1.50	2.60	2.30	2.20	2.30	2.20	2.20	2.50	2.40	2.30	2.50
8.	Chemical Oxygen Demand (mg/L)	42.00	38.00	36.00	32.00	40.00	34.00	42.00	28.00	26.00	24.00	32.00	32.00
9.	Phenolic Compounds (µg/L)	6.80	3.70	9.60	5.70	6.50	7.10	5.20	8.30	9.10	5.40	5.20	7.80
10.	Petroleum Hydrocarbons (µg/L)	25.25	12.86	13.58	20.58	32.58	28.52	40.58	32.85	20.89	25.42	30.89	15.87
11.	Oil and grease (mg/L)	5.2	3.6	4.8	6.0	3.6	4.4	10.8	9.2	7.6	6.0	5.6	4.4
12.	Magnesium (mg/L)	4800	4815	4815	4865	4830	4695	4645	4595	4650	4775	4555	4695
13.	Nickel (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	3.02	BDL
14.	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
15.	Cadmium (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
16.	Chromium (mg/L)	0.14	BDL	0.24	0.08	0.28	0.28	0.57	0.75	0.51	0.21	0.27	0.63
17.	Zinc (mg/L)	0.02	BDL	0.045	BDL	BDL	BDL	0.06	0.17	0.295	BDL	0.425	BDL
18.	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19.	Manganese (mg/L)	BDL	BDL	BDL	BDL	2.11	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20.	Cobalt (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit.

Table 10: Physico-chemical characteristics of the marine water from sampling location 2 (Cargo Jetty)

S. No	Parameters	2A		2B		2C		2D		2E		Control 2	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1.	Temperature (^{0}C)	29.3	29.1	29.5	29.3	29.5	29.4	29.7	29.5	29.5	29.3	29.6	29.6
2.	pH	7.77	7.75	7.78	7.78	7.81	7.79	7.77	7.76	7.78	7.79	7.73	7.7
3.	Salinity (ppt)	36.47	39.47	35.18	38.61	34.75	36.04	37.32	36.47	36.04	38.18	37.75	34.75
4.	Total Dissolved Solids (mg/L)	47920	48323	42634	46611	52769	57974	41006	37746	35442	38480	42722	42577
5.	Turbidity (NTU)	320	335	320	334	357	334	282.8	317	145.2	190.7	168	366
6.	Dissolved Oxygen(mg/L)	6.5	6.4	6.6	6.5	6.5	5.9	5.9	5.5	7.1	7.1	6.2	5.8
7.	Bio-Chemical Oxygen Demand (mg/L)	1.9	1.5	0.6	0.4	1.2	0.4	0.9	0.4	2.6	2	0.9	1.2
8.	Chemical Oxygen Demand (mg/L)	28	22	36	28	32	26	40	28	36	32	22	30
9.	Phenolic Compounds (µg/L)	6.1	6.8	4	5.7	6.2	5.1	6	4.5	7.6	7	11.6	6.6
10.	Petroleum Hydrocarbons (µg/L)	18.50	12.50	23.85	20.78	15.28	9.87	11.58	13.58	25.68	30.85	12.87	9.42
11.	Oil and grease (mg/L)	9.6	9.6	6	10	10	9.6	7.6	7.6	3.6	6.8	8	5.2
12.	Magnesium (mg/L)	4670	4800	4745	4840	4790	4760	4635	4770	4815	4805	4775	4685
13.	Nickel (mg/L)	BDL	BDL	BDL	BDL	2.005	BDL	0.565	BDL	BDL	BDL	BDL	BDL
14.	Lead (mg/L)	BDL	BDL	BDL	BDL	0.29	0.255	0.02	BDL	BDL	BDL	BDL	BDL
15.	Cadmium (mg/L)	BDL	BDL	2.9	BDL	0.275	2.485	1.37	BDL	1.075	BDL	BDL	BDL
16.	Chromium (mg/L)	1.115	0.85	0.89	0.805	0.985	1.245	1.425	1.11	1.22	1.055	1.615	1.45
17.	Zinc (mg/L)	BDL	BDL	0.235	BDL	0.465	0.52	0.37	BDL	0.225	BDL	0.395	0.14
18.	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19.	Manganese (mg/L)	BDL	BDL	BDL	BDL	0.29	0.255	0.02	BDL	BDL	BDL	BDL	BDL
20.	Cobalt (mg/L)	BDL	BDL	BDL	BDL	0.135	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit

Table 11. Physico-chemical characteristics of the marine water from sampling location 3 (Phang Creek)

S. No	Parameters	3A		3B		3C		3D		3E		Control 3	
		SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
1.	Temperature (^{0}C)	29.5	29.2	29.5	29.3	29.4	29.5	29.5	29.1	29.4	29.3	29.5	29.2
2.	pH	7.92	7.93	7.9	7.9	7.98	7.96	7.98	7.99	7.93	7.95	7.91	7.94
3.	Salinity (ppt)	36.9	36.9	34.75	37.75	37.32	43.76	36.47	38.18	39.47	37.75	34.32	43.76
4.	Total Dissolved Solids (mg/L)	30332	36506	43126	41006	53783	47623	43605	45653	50187	43362	40155	46270
5.	Turbidity (NTU)	274.5	300	272	324	238	302	219	259	179.1	186.7	213.1	220
6.	Dissolved Oxygen(mg/L)	5.7	5.5	5.7	5.6	6.1	5.7	6	5.7	5.7	5.7	5.8	5.5
7.	Bio-Chemical Oxygen Demand (mg/L)	2.5	2.3	2.9	2.4	2.3	2.1	2.7	2.4	2.2	2.2	2.5	2.4
8.	Chemical Oxygen Demand (mg/L)	42	38.0	36	34	32	28	24	20	32	24	30	26
9.	Phenolic Compounds (µg/L)	22.8	22	24.1	25.4	19.3	27.2	30.2	25.1	25.2	24	28.3	24.1
10.	Petroleum Hydrocarbons (µg/L)	22.20	18.50	12.50	9.50	13.58	10.58	22.42	19.52	12.35	BDL	28.20	12.58
11.	Oil and grease (mg/L)	8.4	6.0	5.6	7.6	5.6	7.2	7.6	4.4	5.6	7.6	4.8	5.6
12.	Magnesium (mg/L)	4675	4865	4590	4585	4740	4660	4760	4685	4665	4795	4770	4775
13.	Nickel (mg/L)	1.855	1.47	1.74	0.85	1.595	0.75	1.49	0.11	2.79	0.925	3.005	2.37
14.	Lead (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.345	BDL
15.	Cadmium (mg/L)	BDL	0.76	2.875	BDL	0.27	BDL	0.825	BDL	BDL	1.375	BDL	BDL
16.	Chromium (mg/L)	1.955	1.535	2.005	2.21	2.055	2.08	2.08	1.89	1.835	1.97	2.18	1.87
17.	Zinc (mg/L)	0.315	0.19	0.195	0.345	0.465	0.27	0.38	0.2	0.26	0.195	0.535	0.235
18.	Copper (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
19.	Manganese (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
20.	Cobalt (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL	BDL	BDL

Note: BDL denotes Below Detection Limit

Chapter 5 Biological Characteristics of Marine Water

5.1. Introduction for Plankton

Plankton is defined as all those living organisms which are suspended and drifting in water. Phytoplanktons are the primary producers in marine ecosystems and form the basis of the food web. The animal portion of plankton is known as Zooplankton, which are pelagic animals and unable to maintain their position by swimming against the physical movement of water. Size is very important to understanding about the classification of both zooplankton and phytoplankton. Based on size, various categories of plankton are smallest one Picoplankton (0.2-2 µm), Nanoplankton (2-20 µm), Microplankton (20-200 µm), Mesoplankton (200 µm-2 mm), Macroplankton (2-20 mm) and Megaplakton(> 20 mm) . The planktonic communities encompass of aquatic organisms which drift passively and also have limited mobility to move contrary of the water mass. Plankton are divided in two parts which are phytoplankton and zooplankton (Brink. 1993).The tiny flora or plants are called as Phytoplankton, and weak swimming tiny fauna or animals are called as Zooplankton. Phytoplankton are the primary producers in marine ecosystems and form the basis of the food web. Zooplankton are pelagic animals play a role in the food chain in aquatic ecosystem to provide a food resource to various organisms. Major phytoplankton in sea water is Diatoms (Tiwari and Nair, 1998; Thakur et al, 2015), Cocolithophores, Sillicoflagellates, Blue green algae (Cyanobacteria) and Dinoflagellates. Zooplankton comprises the second level in the food chain and includes Tintinnids, Foramonifers, Radiolarians, Amphipoda, Copepoda, Calanoida, Chaetognaths, larvae of benthic invertebrates and fish larvae etc. (Gajbhiye and Abidi, 1993; Thirunavukkarosu, 2013; Chakrabarty et al. 2017). Interspecific competition among the Zooplankton; Inter-relationship for prey and predator between zooplankton and their mostly predator animals; Grazing ratio of primary-secondary consumers; Suspension of sediment; Fluctuation in Phytoplankton abundance; Waves, Currents and Tidal turbulence effect; Fluctuation in Chlorophyll a and Nutrients; Input of Organic and other Pollution creating sources; Fish potential ratio; Monsoon effect; Suddenly changes in atmosphere; Peak time of every seasons and it's effect; Vertical migration of Zooplankton; Food selection pattern of predator; Collection time and number of collected samples, mixing of water column, high surface action, Seasonal up welling and down welling process in water column

5.1.1. Phytoplankton

Phytoplankton are single celled marine algae with great difference in shape, size and form, either use flagella for movement in water or just drift with currents (Zohari et al, 2014). These photosynthetic organisms need sunlight for photosynthesis. Diatoms dominate the phytoplankton biomass in highly productive areas of the ocean. The diatoms are one of the most important phytoplankton as a primary producer of marine ecosystem. They are estimated to produce 20-25 % of the world total net primary production (Werner, 1977).

With trapping carbon in the process of photosynthesis, they can control the atmospheric carbon dioxide and help in combating the global climate change. With this, they have significant role in the management of nutrients cycles in the ocean systems. Their role as primary producers in aquatic ecosystem, in the process of nutrients cycling in the ocean systems, also in calcification, silicification, nitrogen-fixing,etc. made them important marine component for marine life study. Their sensitiveness for various anthropogenic activities in the marine environment such as Eutrophication, introduction of invasive species, overfishing etc, make them one of the best indicators to analyse these activities.

5.1.2. Zooplankton

The faunal species particularly microscopic fauna, living inside the water bodies are known as zooplankton. Zooplankton is tiny-small animals found in all water bodies particularly the pelagic and littoral zone in the ocean. They are classified by size and or by development stages. Zooplankton community is composed of both primary consumers (which eat phytoplankton) and secodanry (which feed on the other zooplankton). Crustaceans zooplankton are Arthropods whose body is covered with chitinous exoskeleton for protection. Nearly all fish depend on zooplankton for food in both larval stages and entire life period (Madin et al., 2001). They are attractive, various and plentiful group of faunal species which can swim or generally drift with water currents but have no potential to swim against water currents (Alcaraz and Calbet, 2003). The important role of them is to be a major link in the marine life in between marine microalgae or phytoplankton and fish. Although they can be classified according to their habitat and depth, distribution, size and duration of planktonic life period (Omori and lkeda, 1984), generally, it is considered as there are two types of zooplanktons. Holoplanktons are those which live permanently in the planktonic form, while meroplanktons are the temporary members in this form. The potential of zooplankton to respond quickly to environment changes and short generation life span, make them important bioindicator of water pollution and all variation occurred in their living environment. Their study is the important part for getting knowledge of the functioning of marine ecosystems (Mees and Jones, 1997).

5.2. Methodology

5.2.1 Estimation of Chlorophyll and Phaeophytin

Estimating Chlorophyll and Phaeophytin was done using known volume of water (500 ml) was filtered through a 0.45μm Millipore membrane filter paper and the pigments retained on the filter paper were extracted in 90% acetone overnight at 50°C. The extinction of the acetone extract was measured using fluorimeter before and after treatment with dilute acid (0.1N HCI).

5.2.2. Phytoplankton sampling and analysis

Phytoplankton samples were collected in the ten prefixed sampling sites using a standard plankton net with a mesh size of 51 μm. Plankton nets are with a square mouth covering an area of 0.900 cm^2 (30 cm square mouth) fitted with a flow meter (Hydrobios). Nets were towed from a moving boat for 10 minutes and the plankton adhering to the net was concentrated in the net bucket. Plankton soup from the net bucket was transferred to a pre-cleaned and rinsed container and preserved with 5%

neutralized formaldehyde. The containers were appropriately labelled. The initial and final flow meter reading was noted down for calculating the amount of water filtered to estimate plankton density. As per flow meter reading, a total amount of 165m^3 of water was filtered by the net. One liter of water was separately collected for density estimation to counter check density estimation obtained by the flow meter reading. Quantitative analysis of phytoplankton (cell count) was carried out using a sedge wick-Rafter counting chamber. One ml of soup added to a Sedgwick counting chamber was observed under an inverted compound microscope. The number of cells present in individual cells of the counting chambers (1/1000) was noted and identified up to a generic level. Several observations were fixed to represent the entire quantity of the soup (generally more than30 times) and the recorded data were used to calculate the density (No/l) using the formula, N = n×v/V (where N is the total no/l; n is an average number of cells in 1 ml; v is the volume of concentrate; V is the total volume of water filtered). The phytoplankton diversity richness and evenness were past software.

5.3. Phytopigments

The concentration of phytopigments is inversely proportional to the turbidity of the waters and in general, waters owing to the high turbidity restricts sunlight penetration essential for nutrient uptake by phytoplankton and thus inhibiting primary production. The concentration of chlorophyll pigment in the water samples ranged from 0.48 -0.74 mg/m^3 with a mean ± SD being 0.59±0.09 mg/m^3 in the Offshore (Table 12), 0.48 to 0.77 mg/m^3 with mean ± SD of 0.59±0.09 mg/m^3 in the Cargo Jetty (Table 13) and 0.43 to 0.99 mg/m^3 with mean ± SD being 0.707±0.159 mg/m^3 in the Phang creek location (Table 14).

Another phytopigment estimated was Phaeophytin, which is one of the breakdown products of Chlorophyll was also estimated in the water samples collected from all the three locations and the concentration of Phaeophytin in the marine water samples were in the concentrations such as 0.25-0.48 mg/m^3 with a Mean±SD of 0.32±0.08 mg/m^3 in the Offshore location (Table 12). In case of Cargo Jetty location, the concentration of the secondary pigment was in the range of 0.22- 0.44 mg/m^3 with a Mean±SD of 0.32±0.088 mg/m^3 (Table 13) and in case of the creek location, the concentration of phaeophytin was almost similar when compared to the other two locations and was ranging between 0.23-0.77 mg/m^3 with a Mean±SD of 0.46±0.16 mg/m^3 (Table 14). An optimum ration of Chlorophyll to Phaeophytin of above 1.5 as expected for natural estuarine and coastal waters.

Table 12: Chlorophyll and Phaeophytin concentration observed in the Offshore site

Parameters	**1A**		**1B**		**1C**		**1D**		**1E**		**1 Control**	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.650	0.580	0.580	0.480	0.670	0.480	0.640	0.620	0.740	0.520	0.670	0.480
Phaeophytin	0.320	0.280	0.250	0.280	0.250	0.320	0.480	0.320	0.340	0.280	0.460	0.260

Table 13: Chlorophyll and Phaeophytin concentration observed in the Cargo Jetty site

Parameters	**2A**		**2B**		**2C**		**2D**		**2E**		**2 Control**	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.770	0.650	0.640	0.520	0.580	0.480	0.620	0.560	0.520	0.700	0.480	0.650
Phaeophytin	0.440	0.420	0.230	0.310	0.250	0.260	0.230	0.420	0.320	0.350	0.220	0.440

Table 14: Chlorophyll and Phaeophytin concentration observed in the Phang Creek site

Parameters	**3A**		**3B**		**3C**		**3D**		**3E**		**3 Control**	
	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW	SW	BW
Chlorophyll	0.430	0.610	0.580	0.840	0.810	0.990	0.820	0.630	0.570	0.650	0.680	0.870
Phaeophytin	0.390	0.400	0.64	0.460	0.740	0.770	0.320	0.230	0.420	0.490	0.350	0.410

5.4. Phytoplankton

The study was conducted at 3 sites (or regions) at Deendayal Port and near area where dredging activities is going on Creek and the stations are Offshore, Cargo Jetty and Phang Greek.

5.4.1. Offshore

In this site, frequently observed species were *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus wailesii, Coscinodiscus rediatus, Ditylum brightwelli, Thalassionema frauenfeldii colony, Thalassionema nitzschioides colonies, Odontella sinensis, etc.* whereas less observed species were *Amphiprora sp*, Green algae, *Navicula sp, Bacillaria paxillifera colonies, Gyrosigma sp, Protoperidinium sp etc.* Total 23 Phytoplankton were recorded in this Offshore area. Highest population density was recorded at site 1control-Offshore (36000nos./m^3) and lowest density was recorded at site 1C-Offshore (19840nos./m^3). The maximum number of species observed in site 1E and 1A-Offshore (13 nos.) followed by 1control (12nos.), 1B and 1C (11nos.), 1D(09nos.). The population density greatly varied between (19840nos./m^3 to 36000nos./m^3). *Synedra ulna, Navicula sp, Green algae Thalassiosira sp* were recorded which are sometimes considering for pollution indicator species in water. Green algae was also recorded in some location of Offshore which may be indication of freshwater or polluted water mixing with seawater. Some Dinoflagellates were also recorded like *Protoperidinium sp.* Highest population density contributor species was *Coscinodiscus wailesii* (range 5120 to 12000nos./m^3)

5.4.2. Cargo jetty

Total 24 Phytoplankton were recorded in this Cargo Jetty area. The population density greatly varied between 27040 nos/m^3 to 38240 nos/m^3.Highest density recorded at 2control-Cargo Jetty (38240nos./ m^3) and lowest value was at 2A and 2C-Cargo Jetty (27040nos./m^3). The lowest number of species noted in the site 2D-Cargo Jetty(09 nos.) whereas highest in 2control-CargoJetty (20nos.). In this Cargo Jetty station commonly or frequently observed species were *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus radiatus, Coscinodiscus wailesii, Odontella sinensis, Thalassiosira sp* etc. The rarely found species were Green algae, *Protoperidinium sp, Thalassiosira aculeata, Triceratium favus etc.* The Dinoflagellates like *Protoperidinium sp* was also observed during microscopic analysis that may be indication of water circulation from deep water to upper surface. *Silicoflagellates* were also recorded which are normally found in deep sea.

5.4.3. Phang Creek

The population density of phytoplankton ranged from 36800nos./m^3 to 86080nos./m^3 same way species availability ranged from 13 to 21 nos. Maximum and Minimum value of population density were recorded in site 3Control-Phang Creek (86080nos./m^3) and 3B-Phang Creek (36800 nos./m^3) respectively. Highest number of species recorded in site 3control-Phang Creek (21nos.) and lowest in site 3B and 3C-Phang Creek (13nos.). Total recorded phytoplankton was 29 in this creek area. *Actinocyclus sp, Coscinodiscus centralis, Coscinodiscus wailesii, Coscinodiscus radiatus, Odontella sinensis Thalassionema frauenfeldii coloniesRhizosolenia sp , Synedra ulna, Thalassionema frauenfeldii colonies,Thalassionema nitzschioides colonies, Thalassiosira sp etc.* were frequently noticed during microscopic work whereas less observed species were *Biddulphia sp, Pinnularia sp, Trieres mobiliensis Thalassiosira aculeata* and some unidentified phytoplanktons. Green algae *were also recorded*, which are generally found in fresh water and estuarine area.

Overall view of Phytoplankton showed that a total 37 species of Marine phytoplankton were identified during summer season of the year 2024. Among them,14-Centric diatoms, 18-Pennate diatoms, 2-Dinoflagellates, 2-Green algae and 1-silicoflagellates and some are not identified phytoplankton's was included in unidentified. Some species like Biddulphia sp ,*Bacillaria paxillifera colonies, Dictyocha sp (Silicoflagellates) Protoperidinium sp Trachyneis sp , Tripos muelleri* were rarely recorded during sample analysis. Input of the fresh water indicated by the presence of some common fresh water species like *Green algae* and *Oocystis sp.*

Presence of *Dinoflagellates (Tripos Muelleri Protoperidinium sp)* indication of bottom water circulation up to surface water layer in some level. *Dictyocha sp* (Silicoflagellates) was also recorded in Phang creek region. Highest phytoplankton density was observed at the site 3control-Phang creek (86080nos./m^3) and lowest was observed at site 1C-Offshore (19840 nos./m^3) (Table 15). Total number of highest species observed at site 3control-Phang creek (21nos.) and lowest in site 1D-Offshore and 2D-Cargo jetty (09nos.).

The high population density composed by species like Actinocyclus sp, *Coscinodiscus centralis, Coscinodiscus radiates, Coscinodiscus wailesii, Thalassionema frauenfeldii colonies, Thalassionema nitzschioides colonies, Thalassiosira sp* (Table 15). This result indicated that genus *Coscinodiscus sp. Actinocyclus sp, Thalassionama sp* were very common with good numbers in all sites. In some sites, least number of species and low density of phytoplankton might be responsible due to some factors like extreme cool or hot weather because of rainy season, mixing of water, high pre-predation ratio, marine pollution (anthropogenic pressure), high turbidity, total suspended solids, water current and suddenly changes in environment conditions etc. Diatoms, type of phytoplankton, constitute major part in total phytoplankton composition The individual density of species of sites viz. has been depicted in Table 15.

5.5. Diversity Indices of Phytoplankton

According to Table 16, diversity indices calculation for phytoplankton showed that the Shannon Index ranged from (1.79 to 2.54) indicated low level to moderate level of diversity range. High Shannon Index was recorded at 3A-Phang creek (2.34) where 17 species were recorded and low at 2D-Cargo Jetty(0.73) where 09 species were recorded. Lowest evenness recorded at site 2B-Cargo Jetty(0.59) whereas highest was in at 1control-Offshore (0.81). Dominance_D index ranged from 0.09 to 0.21 where higher value in 2D-Cargo Jetty (0.21) and lowest was at in 2control-Cargo jetty (0.09). Value of Margalef D (0.76 to 1.80) showed more to moderate variation in species numbers as shown in Table 16.

Table 15. Density of Phytoplankton at different sites of Deendayal Port

Name of Sites	Offshore						Cargo Jetty						Phang Creek					
	1A	1B	1C	1D	1E	1 control	2A	2B	2C	2D	2E	2 control	3A	3B	3C	3D	3E	3 control
Genus of Phytoplankton																		
Actinocyclus sp	2400	800	1120	2400	2400	4000	4000	640	3200	1600	4000	1600	0	4000	3200	4800	7200	10400
Amphiprora sp	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacillaria paxillifera colonies	0	0	0	0	0	1600	0	0	0	0	0	0	0	0	0	0	0	0
Biddulphia sp	0	0	0	0	0	0	0	0	0	0	0	0	1600	480	0	0	800	0
Campylodiscus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640
Coscinodiscus centralis	2400	2080	1600	2400	7200	2400	3200	8000	3840	9600	3200	3200	7200	4160	7200	10400	5600	12000
Coscinodiscus radiatus	5600	3360	4320	4800	4800	4800	1920	7200	6400	11200	8800	3200	9600	9600	10400	11200	10400	14400
Coscinodiscus sp.	1440	1920	0	0	0	0	0	0	0	0	0	0	0	1760	0	2080	0	0
Coscinodiscus wailesii	7200	8000	5120	12000	6400	9600	8000	9600	3360	7200	8800	8800	1760	2080	4800	1920	20000	19200
Ditylum brightwelli	800	1600	1600	2400	1600	2400	0	800	800	320	1600	3200	1600	0	0	0	0	800
Dictyocha sp (Silicoflagellates)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640
Diploneis sp	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0	0
Green algae (unidentified)	800	640	0	0	0	0	0	0	1600	0	0	800	0	0	0	480	0	960
Gyrosigma sp.	0	0	0	0	800	1600	0	0	0	0	0	640	1600	0	2400	2400	0	800
Navicula sp	0	0	480	1600	0	0	0	0	0	0	800	0	800	0	480	2400	1600	
Nitzschia sp	0	0	0	0	0	0	0	0	0	0	0	0	1600	0	0	0	0	1600
Odontella sinensis	1600	2400	0	2400	2400	0	0	2400	800	0	320	1600	3200	4000	2400	3200	0	1600
Oocystis sp	0	0	0	0	800	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia sp	0	0	0	0	0	0	480	0	0	1600	0	0	800	0	1600	0	0	1600
Planktoniella sol	0	0	0	0	1600	2400	0	0	0	0	0	1600	0	0	0	0	3200	0
Pleurosigma sp.	480	0	0	0	0	0	1600	0	1440	0	0	0	0	480	0	2400	800	800
Pleurosigma angulatum	0	0	0	0	0	0	0	0	0	0	0	1600	0	0	0	0	0	0
Protoperidinium sp	0	0	640	0	0	0	0	0	800	0	0	0	0	0	0	0	0	0
Silicoflagellates	0	0	0	0	0	0	320	0	0	0	0	800	0	0	0	0	0	0
Surirella sp	0	0	0	0	0	0	0	0	0	0	0	1600	1600	0	1600	0	800	2400
Synedra sp	0	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0	4000
Synedra ulna	1600	1920	1440	1600	0	1600	0	640	0	1600	2400	0	2400	3200	800	640	4000	800

Thalassionema frauenfeldii colonies	0	1760	2080	2400	2400	2400	3200	2400	0	0	1600	1600	2400	3200	2400	3200	3200	4800
Thalassionema nitzschioides colonies	0	0	0	0	0	0	0	0	0	0	0	1600	0	0	0	2400	0	0
Thalassiosira eccentrica	0	0	0	0	0	0	0	0	0	0	0	800	1600	0	0	0	0	0
Thalassiosira aculeata	0	0	0	0	0	0	320	800	0	0	0	800	0	800	0	800	0	1600
Thalassiosira sp.	1120	1600	1120	0	1600	1600	1600	2400	800	1600	1600	2400	2400	2400	4000	4000	10400	4800
Trachyneis sp	0	0	0	0	0	0	0	320	800	0	0	0	0	0	0	0	0	0
Triceratium favus	800	0	0	0	1600	0	0	0	1600	2400	0	800	1600	640	4000	0	0	1600
Trieres mobiliensis	0	0	0	0	0	1600	2400	320	1600	0	1600	800	0	0	0	1600	960	640
Tripos muelleri	0	0	0	0	0	0	0	0	0	0	0	0	800	0	0	0	0	0
Unidentified	0	0	320	0	0	0	0	0	0	0	0	0	0	0	0	0	320	0
Density of Phytoplankton (diff. sites wise.)(no/m^3)	27040	26080	19840	32000	34400	36000	27040	35520	27040	37120	34720	38240	42560	36800	45280	53920	69280	86080
Total= 708960 no/m^3																		
Total No Of Genus/Species=**37**																		

Table 16. Diversity Indices of Phytoplankton at different sites at Deendayal Port

	Offshore						Cargo jetty						Phang Creek					
Variables	**1A**	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Taxa_S	13	11	11	9	13	12	11	12	13	9	11	20	17	13	13	16	14	21
Individuals (Nos/m^2)	27040	26080	19840	32000	34400	36000	27040	35520	27040	37120	34720	38240	42560	36800	45280	53920	69280	86080
Dominance_D	0.14	0.15	0.15	0.20	0.12	0.13	0.16	0.18	0.12	0.21	0.16	0.09	0.11	0.13	0.12	0.11	0.15	0.12
Shannon Diversity Index (H)	2.22	2.15	2.11	1.92	2.31	2.28	2.06	1.96	2.31	1.79	2.05	2.70	2.54	2.26	2.31	2.45	2.14	2.43
Simpson_1-D	0.86	0.85	0.85	0.80	0.88	0.87	0.84	0.82	0.88	0.79	0.84	0.91	0.89	0.87	0.88	0.89	0.85	0.88
Evenness_e^H/S	0.71	0.78	0.75	0.76	0.77	0.81	0.71	0.59	0.77	0.67	0.70	0.74	0.74	0.73	0.77	0.72	0.61	0.54
Menhinick	0.08	0.07	0.08	0.05	0.07	0.06	0.07	0.06	0.08	0.05	0.06	0.10	0.08	0.07	0.06	0.07	0.05	0.07
Margalef	1.18	0.98	1.01	0.77	1.15	1.05	0.98	1.05	1.18	0.76	0.96	1.80	1.50	1.14	1.12	1.38	1.17	1.76

5.5. Zooplankton

The study was conducted at 3 sites in Deendayal Port and nearby areas where dredging activities are going on. The three selected study stations are Offshore, Cargo Jetty and Phang Greek.

5.5.1. Offshore

Acartia sp, Calanoida (unidentified), Copepoda eggs sac, Egg capsules of Littorinids, Polychaete larvae (Annelids), Zoea larva of Crab, Foraminifera (unidentified), Nauplius larva of Copepoda, Sponge Spicules, Zoea larva of Crab etc. were the mostly common zooplankton and throughout observed in all sites of Offshore area. Highest population density was recorded at site 1D-Offshore (48000 nos./100m^3) where number of species was (24 nos.) and lowest density in 1A-Offshore (26560nos./100m^3) where number of species was recorded (18nos.). High biomass was observed in the site 1A-Offshore (66.67 ml/100m^3) and low biomass was recorded in site 1E-Offshore (13.51 ml/100m^3). The range of the population density, biomass and number of species were (26560 to 48000 nos./100m^3), (13.51 to 66.67 ml/100m^3) and (16 to 25 nos.) respectively in all sites.

Less observed species were Animal Development stage, Arcella sp (Amoebozoa), Dynamena pumila colony (Hydroid), Gastropoda shells, Spirillina sp (Foraminifera) etc. in this station. Total 44 zooplankton was recorded in Offshore area adding that more composition of zooplankton by the Phylum Arthropoda(Crustacea), Foraminifera and Sponge Spicules (Porifera).

5.5.2. Cargo Jetty

The population density of zooplankton varied from 26560 nos./100m^3 to 77760 nos./100m^3. Maximum density was noticed in site 2C-Cargo Jetty (77760nos./100m^3) and minimum was at site 2A-Cargo Jetty (26560nos./100m^3). Maximum number of species (28nos.) found 2control - Cargo Jetty minimum number of species was observed in site 2A-Cargo Jetty (15nos.). Biomass ranged between 16.67 to 31.82 ml/100m^3 where highest biomass noted in site2D-Cargo Jetty and lowest in 2B-Cargo Jetty.

Frequently observed species were *Acartia sp (Calanoida), Ammonia sp (Foraminifera), Bolivina sp (Foraminifera), Egg capsules of Littorinids* Calanoida (unidentified), Foraminifera (unidentified), Globigerina sp (Foraminifera), Ostracoda, Polychaete larvae (Annelids), Sponge Spicules, Zoea larva of Crab etc. whereas less observed species were Egg (unidentified), Gastropoda shells, Leprotintinnus nordqvistii (Tintinnida), Sagitta sp (arrow worm), *Subeucalanus sp* (Calanoida), *Triloculina sp* (Foraminifera) etc. Some Unidentified larval stages were also reported.Total recorded zooplanktons were 44 in Cargo Jetty.

5.5.3. Phang Creek

This Creek area was represented by the zooplankton fauna majority of them were Calanoida (unidentified), *Clausocalanus sp* (Calanoida), Copepoda eggs sacs, Foraminifera (unidentified), Gastrula larva of Echinodermata, Globigerina sp (Foraminifera), Ostracoda , Sponge spicules, *Leprotintinnus sp* (Tintinnida). Very less time or rarely recorded species were Egg (unidentified) , Euterpina sp (Harpacticoida), Fish larva, Globigerinoides sp (Foraminifera), *Leprotintinnus nordqvistii* (Tintinnida), *Nonion sp* (Foraminifera), Sagitta sp (arrow worm), *Tintinnopsis orientalis* (Tintinnida).

The range of zooplankton biomass was between 20.71 to 40.98 ml/100m^3. Highest Biomass was recorded in site 3A-Phang creek (40.98 ml/100m^3) and lowest in site 3B-Phang creek (20.71 ml/100m^3). Maximum and Minimum species count was at in site 3E-Phang creek (26nos.) and 3A-Phang Creek (18nos.) respectively. Population density was maximum recorded in site 3C-Phang Creek (88480 nos./100m^3) and minimum in site 3B-Phang Creek (53600 nos./100m^3). In site 3B-Phang creek comparatively low density according to other sites may be because of high predator pressure or some environment changes.

Overall assessment of zooplankton showed that the total number of 64 Zooplankton recorded during this season. Out of these (64) zooplankton, 44 zooplankton recorded in Offshore region, 44 zooplankton at Cargo Jetty and 48 zooplankton in Phang Creek region. The recorded zooplankton of all 3 stations mainly representing Phylum Arthropoda (Crustacea), Protozoa (mainly foraminifera and tintinnids), Porifera (sponge spicules). Crustacean zooplankton was the dominant due to the dominance of different larval stages and Copepods which mainly feed phytoplankton. More larval stage of crustacean and other animals observed in samples that indicated reproduction and development season of animals from larval to mature animal. Generally zooplankton population dynamics and studies emphasize is given up to group level rather than to species level because of microscopic size of zooplankton so to the difficulty in identifying the zooplankton as some species are considered as a groupor genus level. The most dominant or frequently observed species(all 3 station) were Acartia sp (Calanoida) Calanoida (unidentified), *Clausocalanus sp* (Calanoida), Copepoda eggs sac, Foraminifera (unidentified), Leprotintinnus sp (Tintinnida), Ostracoda, Polychaete larvae (Annelids) Globigerina sp (Foraminifera), Ostracoda, Sponge Spicules, Zoea larva of Crab etc. Foraminifera and Ostracoda belonging to the meroplankton were present at all three stations.

Overall range of all three sites Population density, Biomass and Number of species were (26560 to 88480no/100 m^3), (13.51 to 66.67ml/100m^3) and (15 to 26nos) respectively. Average high biomass noted at Offshore (35.65 ml/100m^3) followed by Phang creek (30.15 ml/100m^3) than Cargo Jetty (22.70 ml/100m^3) (Tables 17-19). Highest population density was recorded in site 3C-Phang creek (88480 nos/100m^3) and lowest was recorded in site 2A-Cargo Jetty and 1A-Offshore (26560no/100m3). Among all recorded zooplankton, majority dominance occurrence was by the Copepoda, Crustacean larvae, Spong Spicules, Foraminifera (Protozoa), Ostracoda, Tintinnids (Protozoa), Zoea larva of Crab. Jelly fish (Hydrozoa: Cnidaria) was also recorded in Offshore and Phang creek region.

Maximum zooplankton faunal composition was dominated by the Phylum Arthropoda, Mollusca, Protozoa, Porifera, Foraminifera. The Fish larva and Fish

(Ichthyoplankton) was also recorded in some sites of Offshore and Cargo jetty. The Zooplankton of Chaetognatha,, Amoebozoa were only represented by the species namely *Sagitta sp (arrow worm), Arcella sp.* respectively. Veliger larva of Bivalve and Heteropods shells include in Phylum Mollusca. The Echinodermata phylum represented by the Ophiopluteus larva and Gastrula larva of Sea star.

In Offshore**,** maximum Occurrence (%) was by the Zoea larva of Crab (9.04%) and minimum by the Dynamena pumila colony (Hydroid) and Nematoda (0.14%). In Cargo Jetty, maximum Percentage of Occurrence (%) by the Foraminifera (unidentified) (16.4%) and minimum by the *Brachionus sp* (Rotifera) (0.09%). In Phang Creek maximum. Occurrence by the Foraminifera (unidentified) (16.65%) and minimum (0.08%) by the Egg (unidentified) and some unidentified zooplankton (Table 17 - 19).

During microscopic sample analysis more number of species varieties of Foraminifera, Sponge spicules, Crustacean larva, Copepoda and Tintinnids were observed. These all three are very important for paleontological study aspects and also for evolutionary, ecological and environmental rebuilding. Some species of Ostracoda, Foraminifera and Sponge spicules are considered in microfossils materials. Some deep sea species also recorded that is indication of water circulation pattern. Data on zooplankton density, list of zooplankton is shown in Tables (17-19).

Plankton identification, both zooplankton and phytoplankton, were done by using relevant identification and taxonomic keys and with standard literatures, monographs and research articles.(Kasturirangan, 1963; APHA, 1992; Mitra et al., 2003;Goswami, 2005; Carling et al.,2004; Mandal, 2004; Hussain & Kalaiyarasi, 2013; Guglielmo et al., 2015; Hussain et al., 2016; Sreenivasulu et al., 2017; NIO,1998; NIO,2002) ,etc

5.6. Diversity Indices of Zooplankton

Table 20 shows *diversity indices of zooplankton. The* Shannon-wiener diversity index (H') fluctuated between 2.39 to 3.17 indicated moderate to quite high range of diversity added indication of healthy body of water with a maximum value in site 3A-

Phang creek (2.39) where number of species noted (28 nos.) and minimum value in site 3A-Phang Creek (2.19) where species number was 18nos.Range of the evenness was 0.60 to 0.92 where lowest and highest recorded in site 3A and 3D-Phang creek (0.60) and 1A-Offshore (0.92) respectively. Range of Simpson index was 0.84 to 0.95. The range value of Margalef indices was 1.37 to 2.25 that means high species number variations. (Table 20).

Table 17.Density of Zooplankton at Offshore site of Deendayal Port

Name of Genera/Group	1A	1B	1C	1D	1E	1 Control	Individual total density (no/100m^3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	0	1600	0	1600	640	0	3840	1.74
Animal Development stage	0	0	0	0	3200	0	3200	1.45
Ammonia sp (Foraminifera)	800	960	0	0	0	1600	3360	1.52
Arcella sp (Amoebozoa)	0	0	1600	0	0	0	1600	0.72
Brachionus sp (Rotifera)	0	0	0	0	0	1600	1600	0.72
Calanoida (unidentified)	1600	4800	1600	4000	4000	1600	17600	7.96
Clausocalanus sp (Calanoida)	2400	0	0	2400	0	0	4800	2.17
Copepoda eggs sac	960	1920	800	2400	800	480	7360	3.33
Corycaeus sp (Calanoida)	0	800	0	480	0	0	1280	0.58
Cyclopoida (unidentified)	0	3520	960	0	0	0	4480	2.03
Cyclops sp (Cyclopoida)	0	0	0	0	2400	0	2400	1.09
Dynamena pumila colony (Hydroid)	0	0	0	320	0	0	320	0.14
Egg capsules of Littorinids	1600	1280	800	4000	0	3200	10880	4.92
Euterpina sp (Harpacticoida)	0	1600	0	800	0	800	3200	1.45
Fish larva	0	0	0	800	0	800	1600	0.72
Foraminifera (unidentified)	1600	1600	0	4800	2720	5600	16320	7.38
Gastropoda shells	0	0	0	1600	0	0	1600	0.72
Globigerina sp (Foraminifera)	0	960	0	2400	0	0	3360	1.52
Harpacticoida (unidentified)	0	1600	0	0	0	0	1600	0.72
Heteropoda shells (gastropods)	640	960	0	0	0	800	2400	1.09
Jelly fish (Hydrozoa: Cnidaria)	3200	1600	0	1120	4000	0	9920	4.49
Leprotintinnus sp (Tintinnida)	0	2400	0	2400	800	0	5600	2.53
Microsetella sp (Harpacticoida)	320	1600	1600	0	0	0	3520	1.59
Mysis larva of Prawn	1600	0	800	0	0	0	2400	1.09
Nauplius larva of Copepoda	1600	0	1600	1600	1600	800	7200	3.26
Nauplius larvae of Barnacles	1600	800	0	0	1600	0	4000	1.81
Nauplius larvae of Crustacea	0	0	4000	3200	1600	0	8800	3.98
Nematoda	0	0	0	0	0	320	320	0.14
Oithona sp (Cyclopoida)	1600	0	0	0	0	3200	4800	2.17
Ophiopluteus Larva (Echinodermata)	0	1120	0	0	800	1600	3520	1.59
Ostracoda	0	800	480	1600	0	2400	5280	2.39
Paracalanus sp (Calanoida)	0	1600	1600	800	0	0	4000	1.81
Parvocalanus sp (Calanoida)	0	800	1600	0	1600	0	4000	1.81
Polychaete larvae (Annelids)	1440	1600	4000	1600	2400	3200	14240	6.44
Sagitta sp (arrow worm)	1120	640	0	0	0	0	1760	0.80

Spirillina sp (Foraminifera)	0	0	0	0	0	1600	1600	0.72
Spiroloculina sp (Foraminifera)	0	0	0	0	0	480	480	0.22
Sponge Spicules	0	1600	4000	1280	0	3200	10080	4.56
Subeucalanus sp (Calanoida)	0	0	0	0	1600	0	1600	0.72
Thermocyclops sp (Cyclopoida)	1280	0	1600	0	1600	0	4480	2.03
Tintinnopsisorientalis (Tintinnida)	0	0	0	1600	800	1600	4000	1.81
Veliger larvae of Bivalve	0	1120	0	800	0	1600	3520	1.59
Zoea larva of Crab	1600	5600	5600	5600	1600	0	20000	9.04
Unidentified larva	1600	0	0	800	0	800	3200	1.45
Total No. Of Genera/Groups=44								
Site-wise Total Density (no/100m^3)	26560	42880	32640	48000	33760	37280	**221120**	**100%**
Biomass (ml/100m^3)	**66.67**	**37.04**	**16.30**	**23.26**	**13.51**	**57.14**		

Table 18. Density of Zooplankton at Cargo Jetty site of Deendayal Port

Name of Genera/Group	2A	2B	2C	2D	2E	2 Control	Individual total density (no/100m^3))	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	0	800	800	800	0	1600	4000	1.16
Ammonia sp (Foraminifera)	960	2400	0	2400	8800	2400	16960	4.93
Brachionus sp (Rotifera)	0	320	0	0	0	0	320	0.09
Bolivina sp (Foraminifera)	640	800	1600	800	2400	1600	7840	2.28
Calanoida (unidentified)	1120	800	0	1600	1600	1120	6240	1.81
Calcarina sp (Foraminifera)	0	0	800	1600	0	0	2400	0.70
Clausocalanus sp (Calanoida)	800	2400	4000	0	1600	1600	10400	3.02
Copepoda eggs sac	0	0	0	2400	2400	1600	6400	1.86
Cyclops sp (Cyclopoida)	0	1600	800	0	0	0	2400	0.70
Cyphonautes larva (Bryozoan)	800	0	800	0	0	0	1600	0.46
Egg capsules of Littorinids	0	4000	4000	0	5600	2400	16000	4.65
Egg (unidentified)	0	0	0	800	0	0	800	0.23
Euterpina sp (Harpacticoida)	0	0	800	800	0	1600	3200	0.93
Fish (small)	0	0	0	0	800	0	800	0.23
Foraminifera (unidentified)	4000	4000	16000	11200	12800	7200	55200	16.04
Gastrula larva of Echinodermata	640	0	480	0	800	0	1920	0.56
Gastropoda shells	0	0	800	0	0	0	800	0.23
Globigerina sp (Foraminifera)	2400	4000	4000	1600	3200	0	15200	4.42
Globigerinoides sp (Foraminifera)	0	1600	0	3200	2400	1600	8800	2.56
Harpacticoida (unidentified)	0	800	0	800	0	0	1600	0.46
Heteropoda shells (gastropods)	1600	4000	2400	0	0	800	8800	2.56
Leprotintinnus sp (Tintinnida)	3200	4800	4800	8800	8000	3200	32800	9.53
Leprotintinnus nordqvistii (Tintinnida)	0	0	0	0	0	800	800	0.23
Microsetella sp (Harpacticoida)	0	1600	0	800	0	0	2400	0.70
Nauplius larva of Copepoda	0	1600	2400	800	0	2400	7200	2.09
Nauplius larvae of Crustacea	0	0	0	0	2080	1600	3680	1.07
Nonion sp (Foraminifera)	800	1600	0	0	0	1600	4000	1.16
Ostracoda	1600	1600	5760	4000	640	2400	16000	4.65
Paracalanus sp (Calanoida)	1600	0	0	0	1600	1600	4800	1.39
Parvocalanus sp (Calanoida)	0	0	4000	3200	0	1600	8800	2.56
Polychaete larvae (Annelids)	1600	1600	2080	3200	800	1600	10880	3.16
Reussella sp	0	0	0	1600	1600	0	3200	0.93

(Foraminifera)								
Rotallida (Foraminifera)	0	0	11200	0	1600	800	13600	3.95
Sagitta sp (arrow worm)	0	800	0	0	0	800	1600	0.46
Spirillina sp (Foraminifera)	0	0	1760	1600	800	1600	5760	1.67
Spiroloculina sp (Foraminifera)	0	0	1920	2400	0	1600	5920	1.72
Sponge Spicules	4800	4800	4160	8000	6400	4000	32160	9.34
Subeucalanus sp (Calanoida)	0	0	0	0	0	480	480	0.14
Tintinnopsis orientalis (Tintinnida)	0	1600	0	0	1600	1600	4800	1.39
Tintinnopsis sp (Tintinnida)	0	1600	0	0	800	0	2400	0.70
Triloculina sp (Foraminifera)	0	1600	800	0	0	0	2400	0.70
Veliger larvae of Bivalve	0	0	1600	800	1600	0	4000	1.16
Zoea larva of Crab	0	2400	0	0	0	1600	4000	1.16
Unidentified	0	0	0	800	0	0	800	0.23
Total No. Of Genera/Groups=44								
Site-wise Total Density (no/100m^3)	26560	53120	77760	64000	69920	52800	**344160**	**100%**
Biomass (ml/100m^3)	**18.38**	**16.67**	**20.62**	**31.82**	**21.55**	**27.17**		

Table 19. Density of Zooplankton at Phang Creek site of Deendayal Port

Name of Genera/Group	3A	3B	3C	3D	3E	3 Control	Total density (no/100m3)	% of Occurrence (Site-wise)
Acartia sp (Calanoida)	0	1600	1600	0	1600	0	4800	1.15
Ammonia sp (Foraminifera)	0	4000	2400	0	5600	800	12800	3.06
Arcella sp (Amoebozoa)	0	0	4000	1600	1600	800	8000	1.91
Bolivina sp (Foraminifera)	1600	1600	1600	0	0	1600	6400	1.53
Calanoida (unidentified)	3200	1920	2400	6400	4000	4800	22720	5.43
Clausocalanus sp (Calanoida)	0	1600	1600	800	0	800	4800	1.15
Copepoda eggs sac	800	1600	0	0	2400	1600	6400	1.53
Cyclops sp (Cyclopoida)	1600	0	1440	1120	1600	0	5760	1.38
Egg capsules of Littorinids	3200	1440	0	5600	1600	2400	14240	3.41
Egg (unidentified)	0	0	0	320	0	0	320	0.08
Euterpina sp (Harpacticoida)	0	0	800	800	0	0	1600	0.38
Favella sp (Tintinnida)	0	0	0	0	640	0	640	0.15
Fish larva	0	0	0	0	800	0	800	0.19
Foraminifera (unidentified)	20800	9600	17600	12800	4000	4800	69600	16.65
Gastrula larva of Echinodermata	1600	1600	1600	0	2400	1600	8800	2.10
Globigerina sp (Foraminifera)	2400	2400	3200	0	6400	3200	17600	4.21
Globigerinoides sp (Foraminifera)	0	0	4000	0	0	4800	8800	2.10
Harpacticoida (unidentified)	0	1600	0	2400	0	0	4000	0.96
Heteropoda shells (gastropods)	0	1600	3200	0	0	0	4800	1.15
Hydrocaulus & Hydrotheca(Hydrozoa)	0	0	640	0	800	0	1440	0.34
Jelly fish (Hydrozoa: Cnidaria)	800	0	0	320	0	0	1120	0.27
Lagena sp (Foraminifera)	1600	0	0	0	0	0	1600	0.38
Leprotintinnus sp (Tintinnida)	4000	10400	8800	10400	12000	11200	56800	13.59
Leprotintinnus nordqvistii (Tintinnida)	0	0	0	0	0	640	640	0.15
Microsetella sp (Harpacticoida)	0	0	0	0	800	1600	2400	0.57
Nauplius larva of Copepoda	0	0	0	1600	1600	1600	4800	1.15
Nauplius larvae of Barnacles	0	0	0	0	1600	0	1600	0.38
Nauplius larvae of Crustacea	0	0	0	2240	8000	4000	14240	3.41
Nonion sp (Foraminifera)	0	0	0	1600	0	0	1600	0.38
Ophiopluteus Larva (Echinodermata)	0	0	0	1600	800	0	2400	0.57
Ostracoda	2400	0	9600	8800	2400	9600	32800	7.85
Paracalanus sp (Calanoida)	1600	1440	3200	800	800	0	7840	1.88
Parvocalanus sp (Calanoida)	0	0	1600	0	0	800	2400	0.57
Polychaete larvae	2400	800	0	2400	1600	1600	8800	2.10

(Annelids)								
Quinqueloculina sp (Foraminifera)	0	0	3200	640	0	0	3840	0.92
Reussella sp (Foraminifera)	0	800	0	0	0	0	800	0.19
Rotallida (Foraminifera)	0	2400	3200	0	2400	0	8000	1.91
Rosalina sp (Foraminifera)	800	0	0	0	0	0	800	0.19
Sagitta sp (arrow worm)	0	0	0	800	800	0	1600	0.38
Spirillina sp (Foraminifera)	1600	0	0	0	0	1120	2720	0.65
Spiroloculina sp (Foraminifera)	0	0	1600	0	0	0	1600	0.38
Sponge Spicules	4800	4000	8000	7200	6400	8800	39200	9.38
Tintinnopsis cylindrica (Tintinnida)	0	0	0	0	0	800	800	0.19
Tintinnopsis orientalis (Tintinnida)	0	0	1600	0	0	0	1600	0.38
Tintinnopsis sp (Tintinnida)	0	0	0	1120	0	1600	2720	0.65
Triloculina sp (Foraminifera)	0	1600	0	0	0	0	1600	0.38
Veliger larvae of Bivalve	2400	1600	1600	0	1440	1600	8640	2.07
Unidentified larva	0	0	0	800	0	0	800	0.19
Total No. Of Genera/Groups=48								
Site-wise Total Density (no/100m^3)	57600	53600	88480	72160	74080	72160	**418080**	**100%**
Biomass (ml/100m^3)	**40.98**	**20.71**	**23.53**	**39.06**	**23.36**	**33.33**		

Table 20. Diversity indices ofZooplankton at different sites of Deendayal Port

	Offshore						Cargo jetty						Phang Creek					
	1A	**1B**	**1C**	**1D**	**1E**	**1-control**	**2A**	**2B**	**2C**	**2D**	**2E**	**2-contrl**	**3A**	**3B**	**3C**	**3D**	**3E**	**3-control**
Variables																		
Taxa_S	18	25	16	24	18	21	15	25	24	24	23	28	18	20	24	23	26	24
Individuals (nos. /m^2)	26560	42880	32640	48000	33760	37280	26560	53120	77760	64000	69920	52800	57600	53600	88480	72160	74080	72160
Dominance_D	0.07	0.06	0.09	0.06	0.07	0.07	0.10	0.06	0.09	0.09	0.09	0.05	0.16	0.10	0.08	0.10	0.07	0.08
Shannon Diversity Index(H)	2.80	3.03	2.55	2.96	2.75	2.82	2.49	3.04	2.75	2.78	2.74	3.17	2.39	2.67	2.81	2.63	2.90	2.80
Simpson_1-D	0.93	0.94	0.91	0.94	0.93	0.93	0.90	0.94	0.91	0.91	0.91	0.95	0.84	0.90	0.92	0.90	0.93	0.92
Evenness	0.92	0.83	0.80	0.80	0.87	0.80	0.81	0.83	0.65	0.67	0.67	0.85	0.60	0.73	0.69	0.60	0.70	0.68
Menhinick	0.11	0.12	0.09	0.11	0.10	0.11	0.09	0.11	0.09	0.09	0.09	0.12	0.08	0.09	0.08	0.09	0.10	0.09
Margalef	1.67	2.25	1.44	2.13	1.63	1.90	1.37	2.21	2.04	2.08	1.97	2.48	1.55	1.75	2.02	1.97	2.23	2.06

6.0. References

Airoldi, L., and Beck, M. (2007). Loss, status and trends for coastal marine habitats of Europe. Oceanography and Marine Biology: An Annual Review, 45, 345–405.

Alcaraz, M.and Calbet, A. (2003). Zooplankton ecology, in Marine Ecology. Encyclopedia of Life Support Systems (EOLSS), eds C. Duarte and A. Lott Helgueras (Oxford: Developed under the Auspices of the UNESCO, EolssPublishers), 295–318.

APHA (1992). Standard Methods for the Examination of Water and Waste water 18th Ed, American Public Health Association. Awwa, Wpcf, Washington D.C.

Baird, R. and L. Bridgewater, 2017. Standard methods for the examination of water and wastewater. 23rd edition. Washington, D.C.: American Public Health Association.

Barbier Edward, B., Hacker Sally, D., Kennedy, C., Koch, E. W., Stier, A. C., and Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. Ecol. Monogr. 81, 169–193. doi: 10.1890/10-1510.1**.**

Barnes, R D, 1980. Invertebrate Zoology Saunders College, Philadelphia 108pp**.**

Besiktepe, S., Tang, K. W., Mantha, G. (2015). Seasonal variation of abundance and live/dead compositions of copepods in Mersin Bay, northeastern Levantine Sea (eastern Mediterranean). Turk Zool. 39: 494-506. doi:.10.3906/zoo-1405-23.

Bhaskar P. V., Roy R., Gauns M., Shenoy D. M., Rao V. D., Mochemadkar S., 2011. “Identification of non-indigenous phytoplankton species dominated bloom off Goa using inverted microscopy and pigment (HPLC) analysis”, J Earth Syst Sci, pp.1145–1154.

Bhunia, A.B. and Choudhury, A., 1998. Studies on the seasonal abundance and biomass of Crustacean Zooplankton and Chaetognaths in relation to ecological parameter of a tidal Creek (Mooriganga), of Sagar Island (north), Sunderbans, West Bengal. *Indian Journal of. Marine Science 28*, 93-198.

Boyd, S. E., Limpenny, D. S., Rees, H. L., & Cooper, K. M. (2005). The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). *ICES Journal of Marine Science*, *62*(2), 145–162.

Brink, K.H. (1993). The coastal ocean progresses effort. Oceanus, 36, pp. 47-49.

Carling, K. J., Ater, I. M., Pellam, M. R., Bouchard, A. M., Mihue, T. B. (2004). A Guide to the Zooplankton of Lake Champlain. Plattsburgh State University of New York. Scientia Discipulorum. 1: 38-66.

Chakrabarty, M., Banerjee, A., Mukherjee, J., Rakshit, N., Ray, S. (2017) Spatial pattern analysis of zooplankton community of Bakreswar reservoir, India. Energ. Ecol. Environ. 2(3): 193-206. doi:. 10.1007/s40974-017-0057-8.

Chattopadhyay, J., R.R. Sarkar & S. Pal 2003. Dynamics of nutrient–phytoplankton interaction in the presence of viral infection. *BioSystems*, 68: 5–7.

Clark, K R and Warwick, R M 1994. Change in Marine Communities, An Approach to Statistical Analysis and Interpretation Natural Environment Research Council, Plymouth Marine Laboratory, Plymouth, pp144.

Cloern J. E., “Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Fransisco Bay”, California. 1996. Rev Geophys, 34(2), pp.127–168, 1996.

Covich, A. P., Palmer, M. A. and T. A. Crowl (1999): The Role of Benthic Invertebrate Species in Freshwater Ecosystems. Bio Science, 49 (2): 119-127.

Davies, O.A., C. C. Tawari and J. F. N. Abowei, 2008. Zooplankton of Elechi Creek, Niger Delta, Nigeria. Environ. Ecol., 26 (4c): 2346 - 2441.

Davis, B. J. 1977. Distribution and temperature adaptation in the teleost fish genus Gibbonsia. Mar. Biol., 42: 315-320.

Day, J H 1967. A monograph on the Polychaeta of Southern Africa Pts I and II, Brit Mus. Nat. Hist, 656, 1-878.

Dekker, R. 1989. The macrozoobenthos of the subtidal western Dutch Wadden Sea. I. 468 Biomass and species richness. Netherlands Journal of Sea Research 23: 57–68.

Desai, S. R, 2008. Subashchandran, MD, Ramachandra TV; Phytoplankton Diversity in Sharavati River Basin, Central Western Ghats. Journal of Sediment and Water Sciences, 2008; 1(1):7- 66.

Descy, J. P, 1993. Ecology of the phytoplankton of river Moselle: Effect of disturbance on community structure and diversity. Hydrobiologia, 249(1-3): 111-116.

Dodson, S. (1992). Predicting crustacean zooplankton species richness. Limnol Oceanogr. 37(4): 848-856.

Dodson, S.I. and Frey, D. G. (2001). Cladocera and other branchiopoda. Ecology and classification of North American Freshwater Invertebrates. Academic Press. London. 850 – 914.

Fauvel, P, 1953 The Fauna of India Including Pakistan, Ceylon, Burma and Malaya Annelida, Polychaeta, Allahabad pp507.

Figueredo, C. C. & A. Giani 2001. Seasonal variation in the diversity and species richness of phytoplankton in a tropical eutrophic reservoir. *Hydrobiologia*, 445: 165-174.

Gajbhiye, S.N. & Abidi, S.A.H. (1993). Zooplankton distribution in the polluted environment around Bombay. Environment Impact on Aquatic & Terrestrial Habitats. pp. 127-142.

Gao, X. and J. Song 2005. Phytoplankton distributions and their relationship with the environment in the Changjiang Estuary, China. *Marine Poll. Bull.*, 50: 327-335.

Garzke, J., Sommer, U., Ismar, S.M.H. (2017). Is the chemical composition of biomass the agent by which ocean acidification influences on zooplankton ecology. Aquat Sci. 79(3): 733-748. doi:. 10.1007/s00027-017-0532-5.

Goswami, S. C. (2005). Zooplankton Methodology collection & identification manual. Published by National Institute of Oceanography, Dona Paula, Goa. Edited by V.K.Dhrgalkar & X.N.Veriecar.

Goswami, S.C and Padmavathi, G. (1996). Zooplankton production, composition and diversity in the coastal water of Goa. *Indian Journal of. Marine Science25,* 91-97.

Gray, J. S. (1997). Marine biodiversity: Patterns, threats and conservation needs. Biodiversity and Conservation, 6, 153–175.

Guglielmo, L., Granata, A., Guglielmo, R. (2015). Class Malacostraca Order Euphausiacea. Revista IDE@- SEA. 86(B): 1-20. ISSN 2386-7183.

GUIDE, (2011). Comprehensive Terrestrial EIA (including Mangroves) for the Proposed Multi-Project SEZ at Kandla. EIA report submitted to Mumbai Regional Centre of National Institute of Oceanography, Dona Paula, Goa.

Hambler, C and Speight, M R 1995. Biodiversity conservation in Britain, science replacing tradition British Wildlife, 6, 137-147yla, P S, S Velvizhi and S Ajmal Khan 1999 A Monograph on the amphipods of Parangipettai coast Annamalai University, India 78.

Harkantra, S. N., A. Nair, Z. A. Ansari and A. H. Parulekar, 1980. Benthos of the shelf region along the West coast of India. *Indian J. Mar. Sci.,* 9: 106-110.

Hussain, S. M., Joy, M. M., Rajkumar, A., Nishath, N. M & Fulmali, S. T. (2016). Distribution of calcareous microfauna (Foraminifera and Ostracoda) from the beach sands of Kovalam, Thiruvananthapur, Kerala, Southwest coast of India.Journal of the Palaeontological Society of India. 61(2). 267-272. ISSN 0522- 9630.

Hussain, S. M., Kalaiyarasi, A. (2013). Distribution of Ostracoda in the Mullipallam Lagoon, near Muthupet, Tamil Nadu, Southeast Coast of India —Implications on Microenvironment. In: Sundaresan J., Sreekesh S.,230 Ramanathan A., Sonnenschein L., Boojh R. (eds) Climate Change and Island and Coastal Vulnerability. Springer, Dordrecht.

Ikeda, T., Kanno, Y., Ozaki, K., Shinada, A., 2001. Metabolic rates of epipelagic marine copepods as a function of body mass and temperature. Mar. Biol. 139, 587–596.

Ingole B, Sivadas S, Goltekar R, Clemente S, Nanajkar M, Sawant R, D'Silva C, Sarkar A, Ansari Z (2006) Ecotoxicological effect of grounded MV River Princess on the intertidal benthic organisms of Goa. Environ. Internat. 32:284-289.

Jagadeesan, L., Jyothibabu, R., Anjusha, A., Arya, P. M., Madhu, N. V., Muraleedharan, K. R., and Sudheesh, K., 2013. Ocean currents structuring the mesozooplankton in the Gulf of Manner and the Palk Bay, southeast coast of India. *Progress in Oceanography*, 110: 27-48.

Jegadeesan, P., 1986. Studies on environmental inventory of the marine zone of Coleroon estuary and inshore waters of Pazhayar, Southeast coast of India. *Ph. D., Thesis*, *Annamalai University*, India.

Jha, D. K., Devi, M. P., Vidyalakshmi, R., Brindha, B., Vinithkumar, N. V., and Kirubagaran, R. (2015). Water quality assessment using water quality index and geographical information system methods in the coastal waters of Andaman Sea, India. Mar. Pollut. Bull. 100, 555–561. doi: 10.1016/j.marpolbul.2015.08.032.

Jickells, T. D. (1998). Nutrient biogeochemistry of the coastal zone. Science 281, 217–222. doi: 10.1126/science.281.5374.217.

Jones, G., and Candy, S. (1981). Effects of dredging on the macrobenthic infauna of Botany Bay. *Marine and Freshwater Research*, *32*(3), 379–398.

Kadam S.S. and L. R. Tiwari, 2012. Zooplankton Composition in Dahanu Creek-West Coast of Ind. Res. J. Rec. Sci., 1(5): 62-65.

Karr, J. R., J D. Allen, and A. C. Benke 2000 River conservation in the United States and Canada. In P. J. Boon, Davies and B. R. Petts, G E (Ed.), Global perspectives on River conservation, pp 3–39 Science, Policy, and Practice. Wiley, New York.

Kasturirangan, L. R (1963). A key for the identification of the more common planktonic Copepoda of Indian coastal waters. Publication No .2. Indian National Committee on Oceanic Research. p. 87.

Krishnamurthy, K. and Santhanam, R. (1975). Ecology of Tintinids (Protozoa: Ciliata) in Porto Novo region. *Indian Journal of. Marine Science 4*, 181-184.

Kumar, A., 1995 Studies of pollution in river Mayurakshi in south Bihar. Indian Journal of Environmental Pollution, 2(1): 21-26.

Levandowsky, M., 1972. An ordination of phytoplankton population in ponds of varying salinity and temperature. *Ecology*, 53(3): 398-407.

Lyla, P S., Velvizhi, S and Ajmal Khan, S 1999. A Monograph on the amphipods of Parangipettai coast Annamalai University, India pp78.

Madin, L.P., Horgan, E.F., and D.K. Steinberg. 2001.Zooplankton at the Bermuda Atlantic Timeseries Study (BATS) station: diel, seasonal and inerannual variation in biomass, 1994-1998. Deep-Sea Research II. 48 (8-9): 2063-2082.

Magurran, A 1991. Ecological Diversity and Its Measurement Princeton University Press, Princeton, pp178.

Mahapatro, D R C., Panigrahy, K and Samal, R N 2011. Macrobenthos of shelf zone off Dhamara estuary, Bay of Bengal. J Oceanog Mar Sci 22, pp 32-42.

Mandal, S.K. (2004). Studies on the Effect of Ship Scrapping Industry Wastes on Marine Phytoplankton at Alang, Gujarat, Ph. D thesis. M. K. Bhavnagar University, Bhavnagar.

Margalef, R 1958. Information theory in ecology. Gen Syst, 3, 36–71.

Marine Biology Organization (MBO), 2007. Zooplankton Retrieved from: http://www.marinebio.com/oceans/zooplankton.Askp. 62k, (Accessed on: September 29, 2006).

Martin G.D, P.A. Nisha, K.K. Balachandran and G.V.M. Gupta (2011). Eutrophication induced changes in benthic community structure of a flow-restricted tropical (Cochin backwaters), India. Environ. Monit. Assess. 176(1-4):427-438.

Maurer, D., Watling, L., Kinner, P., Leathem, W and Wethe, C 1978. Benthic invertebrate assemblages of Delaware Bay. Mar Biol, 45, 65-78.

Maya, M. V., M. A. Soares, R. Agnihotri, A. K. Pratihary, S. Karapurkar, H. Naik & S. W. A. Naqvi 2011. Variations in some environmental characteristics including C and N stable isotopic composition of suspended organic matter in the Mandovi estuary. *Environ. Monit. Assess.,* 175: 501–517.

Mees, J. and Jones, M. B. (1997): The Hyperbenthos. Oceanography and Marine Biology: an Annual Review, 35, 221-255.

Mishra, S., and Panigrahy, R. C. (1999). Zooplankton ecology of the Bahuda estuary (Orissa), east coast of India. *Indian Journal of. Marine Science 28,* 297-301.

Mitra A., Davidson, K. and Flynn, K. J. (2003) The influence of changes in predation rates on marine microbial predator/prey interactions: a modelling study. *Acta Oecol* (Suppl. 1), S359–S367.

Mitra, A., Zaman, S., Sett, S., Raha, AK and Banerjee, AK 2014. Phytoplankton cell volume and diversity in Indian sundarban. Ind J Mar Sci 43, 2 208-215.

Moura, A. N., Bittencourt-Oliveira, M. C & Nascimento, E. C. (2007). Benthic Bacillariophyta of the Paripe River estuary in Pernambuco state, Brazil. Braz. J. Biol. 67(3): 393-401.

Murugan, A., 1989. Ecobiology of Cuddalore, Uppanar backwaters, Southeast coast of India. *Ph.D., Thesis, Annamali Universtiy*, India.

Murugesan, P., 2002. Benthic biodiversity in the marine zone of Vellar estuary (Southeast Coast of India). *Ph. D., Thesis Annamalai University*, India, 359pp.

Nair, VR 2002. Status of flora and fauna of Gulf of Kachchh, India NIO, Goa, pp 1-258.

Newell, R. C., Seiderer, L. J., & Hitchcock, D. R. (1998). The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and Marine Biology: An Annual Review*, *36*, 127–178.

NIO, (2002). Status of flora and fauna of Gulf of Kachchh, India. National Institute of Oceanography, Goa.

NIO, 1998. Environmental studies for proposed BPCL jetty and associated facilities at Kandla Part-I Rapid marine EIA, May1998 NIO Mumbai.

NIO. (1980). Technical Report, National Institute of Oceanography, Goa.

Omori, M. and lkeda. T. (1984). Methods in Marine Zooplankton ecology. John Wiley & Sons, New York.

Parasharya D and Patel B. (2014). Spawning aggregation of Melibe viridis Kellart (1858) from Gulf of Kachchh-Western India. International Journal of Scientific and Research Publication, 4(3), ISSN 2250-3153.

Parulekar, A. H., Dhargalkar, V. K., & Singbal, S. Y. S. (1980). Benthic studies in Goa estuaries. Part 3. Annual cycle of macrofaunal distribution, production and trophic relations. *Indian J Mar Sci*.

Pearson, T. H. and Rosenberg, R. (1978): Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. Oceanography and Marine Biology-An Annual Review, 16: 229-311.

Perumal P, Sampathkumar P, Karuppasamy PK (1999) Studies on the bloom-forming species of phytoplankton in the Vellar estuary, southeast coast of India. Ind J Mar Sci 28: 400-403.

Pielou, E C 1966. The measurement of diversity in different types of biological collections. J Theoret Biol 13, 131-144.

Plafkin, J. L., Barber, M. T., Poter, K. D., Gross, S. K. and Highes, R. M. 1989. *Rapid bioassessment protocol for use in streams and rivers for benthic macro invertebrates and fish.* EPA/444/ 4-89/001**.** Office of water regulation and standards. U.S. Environmental Protection Agency, Washingaton DC, USA.

Prabhahar. C., K. Saleshrani & Enbarasan 2011. Studies on the ecology and distribution of phytoplankton biomass in Kadalur coastal zone Tamil Nadu, India. *Curr. Bot.,* **2(3):** 26-30.

Ramakrishna, D A 2003. Manual on identification of schedule molluscs from India 40pp.

Ramakrishna, T C R., Sreeraj, C., Raghunathan, R., Raghuraman, P and Yogesh Kumar, J S 2011. An account of additions to the Icthyofauna of Andaman and Nicobar Islands Records of the Zoological Survey of India, Occasional Paper no 326, 1-140 Published-Director, Zool Surv India.

Rao, K.K and Balasubramanian, T. (1996). Distribution of Foraminifera in the Cochin Estuary. J.mar.biol. Ass. India. 38(1 and 2): 50-57.

Reid, G. K, 1961. Ecology in inland waters and estuaries. New York.375.

Reid, G. K., Wood, R. D. (1976). Ecology of inland waters and estuaries. Toronto, Ontario, D. Van Nostrand Co., pp. 138–146.

Reid, G. K., Wood, R. D. (1976). Ecology of inland waters and estuaries. Toronto, Ontario, D. Van Nostrand Co., pp. 138–146.

Saravanan, K. R., Sivakumar, K., and Choudhury, B. C. (2013). “Important coastal and marine biodiversity areas of India,” in Coastal and Marine Protected Areas in India: Challenges and Way Forward, ENVIS Bulletin: Wildlife & Protected

Areas, Vol. 15, ed. K. Sivakumar (Dehradun: Wildlife Institute of India), 134–188. doi: 10.1007/978-3-642-38200-0_30

Shannon, C E and Wiener, W 1949. The Mathematical theory of Communication Univ of Ilinois Press, Urbana.

Sinha B. and M. R. Islam, 2002. Seasonal variation in zooplankton population of two lentic bodies and Assam State Zoo cum Botanical Garden, Guwahati, Assam, Eco.Environ. Cons., 8: 273-278.

Sivasamy, S.N., 1990. Plankton in relation to coastal pollution at Ennore, Madras coast. Indian J. Marine Sci., 19: 115-119.

Sreenivasulu, G., Jayaraju, N., Raja Reddy, B.C.S., Prasad, T. L., Nagalakshmi, K., Lakshmanna, B. (2017). Foraminiferal research in coastal ecosystems of India during the past decade: A review. Geo ResJ. 13: 38–48.

SubbaRao, N V., Surya Rao, K V and Maitra, S 1991. Marine molluscs State Fauna Series 1, Part 3 Fauna of Orissa. Zool Surv India, Kolkata, 1–175.

Tabassum, A. and Saifullah, S. (2012). Centric Diatoms from the North Arabian Sea Shelf of Pakistan. LAP. BOOK Lambert Academic Publishing. ISBN: 978-3-659-28532-5.

Takai N, Mishima Y, Yorozu A, Hoshika A (2002) Carbon sources for demersal fishes in the western Seto Inlan Sea, Japan, examined by delta 13C and delta 15N
analyses. *Limnol Oceanogr.* 47(3):730-741.

Taylor, B. E. (1998). Analyzing population dynamics of zooplankton. Published by the American Society of Limnology and Oceanography, Inc. Limnol.Oceanogr 33(6, part 1): 1266-1273.

Thakur, B., Chavda, C., & Salvi, H. (2015). Phytoplankton diversity at some selected sites of the Gulf of Kachchh, Gujarat, India. Bulletin of Environmental and Scientific Researcch. 4(4): 7-12. ISSN. 2278-5205.

Thangaraja, G. S., 1984. Ecobiology of the marine zone of the Vellar estuary. *Ph. D. Thesis, Annamalai University, India.*

Thirunavukkarasu, K., Soundarapandian, P., Varadharajan, D., Gunalan, B. (2013). Zooplankton Composition Structure and Community Structure of Kottakudi and Nari Backwaters, South East of Tamilnadu. J. Environ. Anal. Toxicol. 4(1): 200. doi:.10.4172/2161-0525. 1000200.

Tiwari, L.R and Nair, V.R. (1998). Ecology of Phytoplankton from Dharmatar creek, West Coast of India. Indian. J. MarineScience. 27 (3 & 4).

Uptake, A. (1999). Primary production by phytoplankton and microphytobenthos in estuaries. *Estuaries, 29*, 93.

Zohary T, Yacobi YZ, Alster A, Fishbein T, Sh L, Tibor G.(2014). Phytoplankton. In: Zohary T, Sukenik A, BermanT, Nishri A, editors. Lake Kinneret – ecology and management. Dordrecht (Netherlands): Springer; p. 161–190.

ANNEXURE C
Detail of CSR Activity

YEAR WISE ACTUAL WORK COSTING OF CSR WORKS APPROVED BY BOARD

1) CSR Works executed during the year 2011 – 2012 and year 2012 – 2014. (Upto Dec'21)

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	(a).Road from Dr. Baba Saheb Ambedkar Circle to N.H. 8-A (Via Ganesh Nagar).	Rs.482.65 Lakhs
	(b)Road from S.T. Bus Stand (N.H. 8 – A) to Sunderpuri Cross Road Via Collector Road.	
	(C)Road from N.H. 8 –A Railway Crossing to Maninagar (Along Rly Track).	
	(d)Road from Khanna Market Road (Collector Road) to Green Palace Hotel.	
2.	Construction of Internal Roads at "Shri Ram" Harijan Co-op. Housing Society Ltd. (Nr. Kidana).	
3.	(a)Construction of Cremation Ground and kabrastan with other facilities at Vadinar.	Rs 19.44 (Lakhs)
4.	(b)Providing Cement Concrete internal roads in village Vadinar Stage –I.	Rs 16.16 (Lakhs)
	(a)Approach Road provided for developing the Tourism at village Veera near Harsidhi Mata Temple where lot of tourists & Pilgrims visit.	Rs. 4.65 (Lakhs)
	(b)Water Tank along with R.O. provided near by developing Tourism area.	Rs. 30,000 (Thousand)
	(c)Creating facility of flooring and steps surrounding the lake to stop the soil erosion and attract the tourists, at Village Veera.	Rs. 4.80 (Lakhs)
	Total Rs	**528 Lakhs**

2) CSR Works for the year 2014-2015.

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	Construction of Community Hall-cum school at Maheshwari Nagar, G'dham	Rs 51.90 Lacs
2.	Renovation of "Muktidham" at Kandla	Rs 10.65 Lacs
3.	Sunderpuri-1 valmiki community hall	Rs 5.00 Lacs
	Sunderpuri-2 valmiki community hall	Rs 5.00 Lacs
	Ganeshnagar Community Hall	Rs 10.00 Lacs
	JagjivanMaheshwari community hall	Rs 10.00 Lacs
	Various works of Road of Sapanagar	Rs 99.19 Lac
4.	Construction of compound wall in the Dam of Jogninar village	Rs 14.48 lacs
5.	In addition above 30 Lakhs as committed in Public Hearing meeting held on 18/12/2013 an amount Rs 30 Lakhs shall also be contributed for the CSR works to be carry out at villages Tuna, Vandi , Rampar, Veera etc.	Rs 30.00 Lacs
	Total Rs.	**Rs 236.22 Lacs**

3) **CSR Works for the year 2015-2016.**

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	Construction of toilets for Girls / Ladies at Khari Rohar village	**Rs. 3.00 Lakhs**
2.	Construction of Toilets for Girls manatMathak Primary School, Mathak Village	**Rs. 3.00 Lakhs**
	Total	**Rs.6.00 Lakhs**

4) **CSR Works for the year 2016-2017.**

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	RCC Community Hall at Harshidhi Mata Temple, Veera village, AnjarTaluka	Rs.19.00 Lakhs
2.	Fabricated Community Hall at Sanghad village, AnjarTaluka	Rs.21.00 Lakhs
3.	CSR Works for Shri MaheshwariMeghvadSamaj, Gandhidham at Grave Yard , Behind Redison Hotel.	Rs.8.00 Lakhs
4.	CSR works for ShirDhanrajMatiyadevMuktiDham, Sector-14 , Rotary Nagar, Gandhidham	Rs. 30.50 Lakhs
5.	CSR works for NirvasitHarijan Co-operative Housing Society, Gandhidham.(Health Cum Education Centre)	Rs. 41.00 Lakhs
6.	CSR works for Shri Rotary Nagar Primary school, Gandhidham.	Rs. 2.80 Lakhs
7.	CSR works at NU -4 , NU-10(B) Sapnanagar& Saktinagar, Golden Jublee Park, at Gandhidham	Rs. 18.00 Lakhs
	Total	**Rs 140.30 Lakhs**

5) **CSR Works for the year 2017-2018.**

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	CSR works at Shri Ganesh Nagar Govt High School, Gandhidham	38.30
2.	Grant Financial contribution for facility of Army cantonment for 50 air coolers at Kutch Border Area.	15.00
3.	CSR works at Tuna & Vandi villages (providing drainage lines under Swachh Bharat Abhiyan)	39.80
4.	CSR works for S.H.N Academy English School (Managed by Indian Institute of Sindhology –Bharati Sindhu Vidyapeeth), Adipur	40.00
5.	Construction of Internal Road at Bhaktinagar Society, Kidana	
	Total	**148.10**

6) **CSR Works for the year 2018-19**

Sr. no	**Name of work**	**Actual cost (Rs in Lakhs)**
1.	CSR work to Donate 100 Nos of Computers to Daughters of Martyred Soldiers in the country under the "BETI BACHAO BETI PADHAO" program by Atharva Foundation, Mumbai	Rs 24.00 Lakhs
2.	CSR work to Donate ONE (40 Seater) School Bus for Deaf Children Students for the Institute of Mata Lachmi Rotary Society, Adipur	Rs 18.00 Lakhs
3.	CSR work to Providing One R.O Plant with Cooler at Panchyat Prathmik Sala, Galpadar Village for the ANARDE Foundation, Kandla & Gandhidham Center.	Rs 1.50 Lakhs
4.	CSR work for Providing Drainage Line at Meghpar Borichi village, Anjar Taluka	Rs 25.00 Lakhs
5.	CSR work for Construction of Health Centre at Kidana Village	Rs 13.00 Lakhs
6.	CSR work to provide 4 Nos. of Big Dust Bin for Mithi Rohar Juth Gram Panchayat	Rs 3.40 Lakhs
7.	CSR work for Renovation & construction of shed at Charan Samaj, Gandhidham –Adipur.	Rs 10.00 Lakhs
8.	CSR Work for Renovation/Repairing of Ceiling of School Building at A. P Vidhyalay, Kandla	Rs 10.00 Lakhs
9.	CSR work for Construction of Over Head Tank & Providing 10 Nos of Computers (for students) of Navjivan Viklang Sevashray, Bhachau, Kutch	Rs 9.50 Lakhs
10.	CSR work to Provide Books & Tuition fees for Educational facilities to weaker section children of ValmikiSamaj, Kutch	Rs 2.00 lakhs
11.	CSR work to provide Water Purifier & Cooler for the ST. Joseph's Hospital, Gandhidham	Rs 1.50 Lakhs
12.	CSR work for Construction of Second Floor (Phase – I) for Training Centre of "GarbhSanskran Kendra" "Samarth Bharat Abhiyan" of Kutch KalyanSangh, Gandhidham	Rs 37.00 Lakhs
	Total cost	**Rs 154.90 Lakhs**

7) CSR Works for the year 2019-20

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR activities for Providing Drainage line at Nani Nagalpar village.	3.00
2.	CSR activities for Development of ANGANWADI Building at School no- 12 at Ward no 3 & 6 at Anjar.	7.00
3.	CSR activities for Improving the facilities of Garden at Sapna Nagar(NU-4) & (NU-10 B),Gandhidham.	18.00
4.	CSR activities for development of School premises of Shri Guru Nanak Edu. Society, Gim.	30.00
5.	CSR activities for the improvement of the facilities at St JOSEPH Hospital &Shantisadan at Gandhidham	20.00
6.	Consideration of Expenditure for running of St Ann's High School at Vadinar of last five years 2014 to 2019 under CSR.	825.00
7.	CSR activities for development of school premises of Shri Adipur Group Kanya Sala no-1 at Adipur	6.50
8.	CSR activities for development of school premises of ShriJagjivan Nagar PanchyatPrathmiksala, Gandhidham	16.50
9.	CSR activities for development of school premises of Ganeshnagar Government high school, Gandhidham	9.00
10.	CSR activities for improving greenery, increase carbon sequestration and beat Pollution at Kandla, DPA reg.	352.32
11.	CSR activities for providing infrastructures facilities at "Bhiratna Sarmas Kanya Chhatralaya" under the Trust of SamajNav- Nirman at Mirjapur highway, Ta Bhuj.	46.50
	Total cost	**1333.82**

8) CSR Works for the year 2020-21

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR Proposal for earmarking of 15% Funds for National Marintime Heritage Complex, Lothal, Gujarat (NMHC) from allocated CSR Fund of Rs 3.46 Cr	51.90
	Total	**51.90**

9) CSR Works for the year 2021-22

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR Activities for providing Water supply pipe line for drinking water facilities for poor people & Fishermen at VANDI Village.	20
2.	CSR activities for providing facilities in Girls Hostel of Kasturba Gandhi Balika Vidhyalay, Gandhidham. Cost for Construction of compound wall, entrance gate, girls toilets)	30
3.	CSR works for Construction of Auditorium Hall at RSETI (Rural Self Employment Training Institute) at Bhujodi-Bhuj.	16
4.	CSR works for the providing of SOLAR POWER SYSTEM and other facilities for 0the JEEV SEVA SAMITI at Gandhidham.	9.3
5.	CSR Activities for providing HD projector for KANYA MAHA VIDYALAYA, Adipur	1.5
6.	CSR works for Construction of New Building for Setting up of skill development centre at Rajkot (Sewa Gujarat).	250
7.	CSR Works for Ladies Environment Action Foundation (LEAF) Trust for providing infrastructure to the primary school at Gandhinagar District	46.5
8.	CSR works lor Providing of Furniture for the School "Shri Galpadar Panchayat Prathmic Kumar group Sala" at Galpadar village,Taluka:Gim	5
	Total Cost	**378.3**

10) CSR Works for the year 2022-23

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR work for providing One Bore hole with construction one room along with Motor pump at Village MOTI NAGALPAR, Anjar.	18
2.	CSR work for Construction of Shamashan bhoomi (Crematorium) at Gandhidham.	49.5
3.	CSR work for providing metallic sheet DOME in Community Hall at Old Sunderpuri for Shri Juni Sundarpuri Maheshwari Samaj at Gandhidham.	15
4.	CSR Activities for construction of Samajwadi at village: Rampar,Taluka:Anjar.	15
5.	Financial assistance under CSR for providing basic facilities at Gandhidham GSRTC bus station.	25
6.	CSR Activities for construction of School Building for physically disabled, deaf & mute children, Shri & Shrimati Chhaganlal Shyamjibhai Virani Behera Munga Shala Trust, Virani Deaf School at Rajkot.	5
7.	CSR work for construction of new Administrative staff block for the Maitri Maha Vidhyalaya, Adipur.	64.65
8.	Financial support under CSR for providing 60 seater school bus for "Aadhaar Sankul", Manav Seva Trust,Gandhidham.	25
9.	CSR work for extension of Night shelter cum old age home for “DADA BHAGWANDAS ADVANI TRUST” Adipur.	78
10.	Financial assistance under CSR for Rooftop Solar System & Afforestation under clean energy & sustainable development in 10 villages around DPA	63.72
	Total Cost	**358.87**

11) **CSR Works for the year 2023-24 till September**

Sr. no	Name of work	Actual cost (Rs in Lakhs)
1.	CSR works for Shree Kachchh Mahila Kalyan Kendra, Bhuj-Kutch	55
2.	CSR Activities for Installation of 125 no. Sanitary Pad Vending Machines at Women Hostels,NGOs etc, in Kutch District	15
3.	CSR Fund for Vadinar Village & surrounding	128.54
4.	CSR Activities for Girls Hostel at Kasturba Gandhi Balika Vidhyalaya At Shinay, Taluka:Gim.	33.25
5.	CSR request for Allotment of fund for construction of Community hall at Adipur for Maheshwari Meghval Samaj.	25
6.	CSR Request for requirement of funds for renovation work in Sector-7, Gandhidham (Aryasamaj Gandhidham)	30
7.	CSR Request for providing"Antim Yatra Bus" & Mortuary Cabinet Morgue" for Adipur-Gandhidham from CSR Funds,	25
8.	CSR Request for creation of a Children park at Gandhidham Military Station, Gandhidham	15
9.	CSR Request for construction of Toilet block units for Girls & Boys NAV JIVAN VIKLANG SEVA SHREY Bhachau	3.04
10.	CSR Request for laying Synthetic Athletic track in Galpadar and to Provide One E-Kart facility for Conveyance of youths at BSF Campus, Gandhidham	75
11.	CSR request for submitted by AAS, Indore for solid waste Management at Gandhidham & Kandla.	49.93
12.	CSR request from Trikamsaheb Manav Seva Trust at Madhapar Near Bhuj for grant for Construction of Community Hall, Compound Wall etc.	40
13.	CSR Request for construction of Dome shaped shed at Rampar Village Prathmik Shala,Rampar	24
14.	CSR Fund for development of School premises of Shri Guru Nanak Education	4.5
15.	CSR Request for conducting Awareness campaigns on T.B. Prevention & treatment, Mumbai	60
16.	CSR Request for fund under CSR for Railway Institute, Gandhidham, Western	5
17.	CSR Proposal project for Sanitary Pad Making Machine for School Girls, Anjar	12.39
18	CSR Funds for Building Construction of girl's hostel (Kanya Chhatralay) @Luni,Akhil Kutch Ganesh Sevak Sarvajanik Trust-Luni	₹ 50.00
19	CSR request for amenities for Devlopment of sports facilities Through CSR Funds, Navy Head Quarter Porbandar,NAVYat Navy Head Quarter, Porbandar	₹ 47.18
20	CSR request for financial support under CSR for '' Organizing Programs on Skill Development'',Gandhidham Collegiate Board, Adipur	₹ 98.76
21	CSR fund for construction work for Community hall(samajvadi for cause of human services).Kidana,Kutch Andhra Seva Trust, Gandhidham	₹ 20.00
22	CSR funds for Karam Educational Complex@mirapar,Bhuj,Akhil Kutch MAheshwari Vikas Seva Sangh, Bhuj(Karam Sankul EDU)	₹ 50.00
23	CSR fund for vadinar village & surrounging for prathmik shala,Vadinar prathmik shala managed by dist. Panchayat	₹ 28.47
24	CSR fund for repairing of construction for school,Shree vadinar vadi school vadinar	₹ 16.04
25	CSR Project proposal for Outdoor flooring and laundry Construction for mentally Disturbed women, St. Joseph's Hospital Trust-Gandhidham ,St, Joseph's Hospital trust-Gandhidham	₹ 29.16
26	CSR request for creation of Bio Diversity Miyawaki Forest at Gandhidham Military Station, Gandhidham	₹ 57.64

27	CSR Funds request for the Construction of Hall/Dome for Indoor games at Gandhidham,Shri kutch Deshiya Saraswat Brahmin mahasthan trust-Gandhidham.	₹ 20.00
28	CSR Request for repairing of School shed, R.O. Plant, School Colour Work at Ganeshnagar Panchayat Prathmik kumar shala At Gandhidham-Kutch.,Shri Ganeshnagar Panchayat Prathmik Kumar Shala Gandhidham	₹ 8.00
29	CSR request for livelihoods Development of rural women at Kutch Area, ,BAIF Institute for Sustainble Livelihoods and development, pune	₹ 8.71
30	Improvement of village pond at Kidana, Taluka: Gandhidham.,Deputy collector & sub divisional magistrate office , anjar	₹ 72.90
31	CSR request for construction of Gym and Indoor Badminton Court as well as Synthetic Tennis Court,Anjar	₹ 77.90
32	Sanik Kaleyan Board bhuj and Jamnagar	₹ 44.00
33	NMHC Projects	₹ 605.80
	Total Cost	**Rs.1835.21 Lakh**

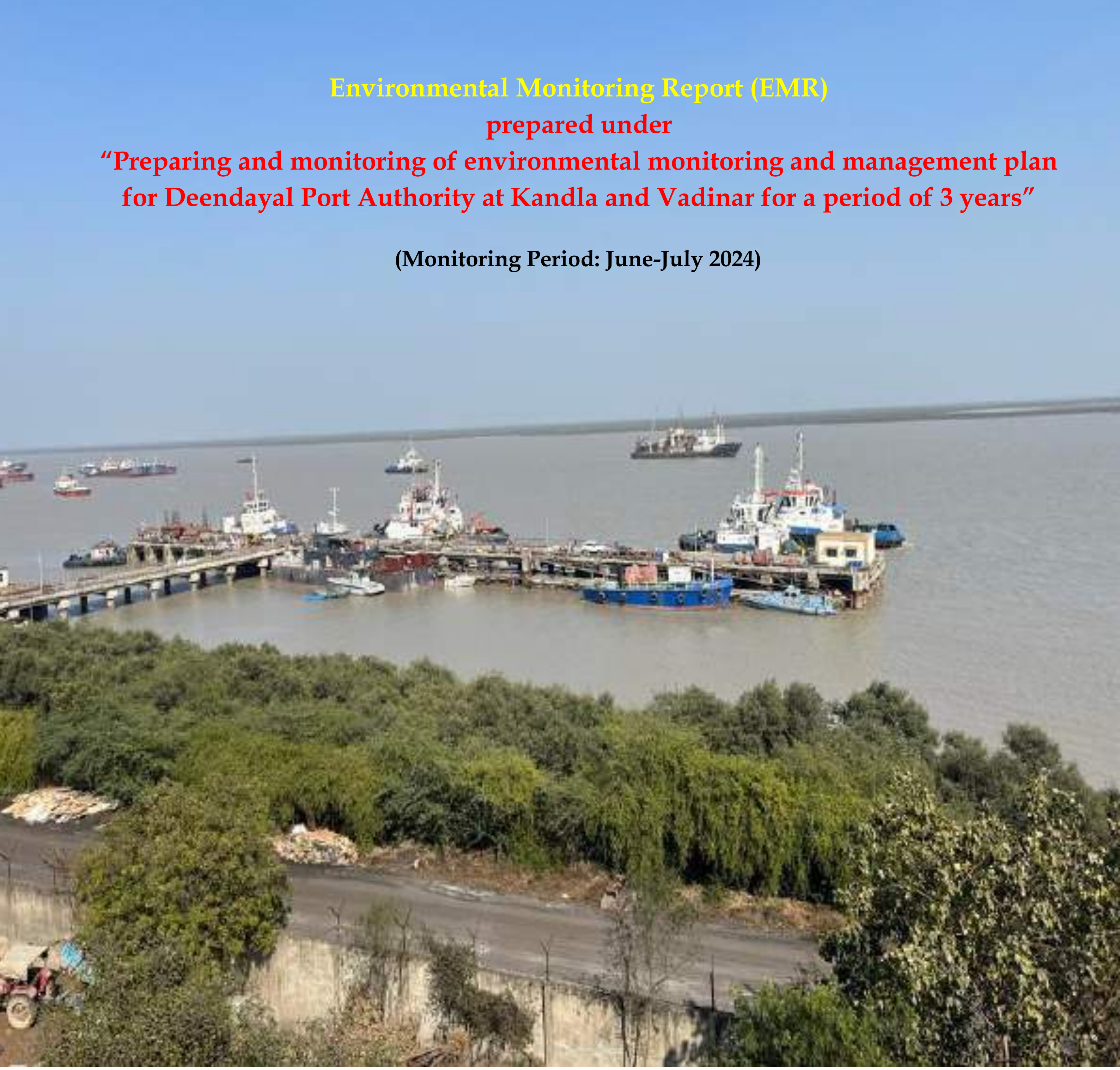
ANNEXURE D
Monitoring Report

Environmental Monitoring Report (EMR)

prepared under

"Preparing and monitoring of environmental monitoring and management plan for Deendayal Port Authority at Kandla and Vadinar for a period of 3 years"

(Monitoring Period: June-July 2024)



Document Ref No.: GEMI/DPA/782(2)(3)/2024-25/121

Submitted to:

Deendayal Port Authority (DPA), Kandla

Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

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

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About this Document

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

- **Name of the Report:** *Environment Monitoring Report (June-July 2024)*
- **Date of Issue:** 10/09/2024
- **Version:** 1.0
- **Report Ref.:** GEMI/DPA/782(2)(3)/2024-25/121

Table of Contents

List of Tables

List of Maps

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

1.2 Green Ports Initiative

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

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

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

1.3 Importance of EMP

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

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

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

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

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

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

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

1.4 Objectives and scope of the Study

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

The scope of work includes not limited to following:

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

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

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

CHAPTER 2: METHODOLOGY

2.1 Study Area

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

a. Kandla

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

- **Climatic conditions of Kandla**

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

b. Vadinar

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

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

- **Climatic conditions of Vadinar**

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

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

Map 1: Locations of Kandla and Vadinar Port

Map 2: Locations of Kandla Port

Map 3: Locations of Vadinar Port

2.2 Environmental Monitoring at Kandla and Vadinar

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

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

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

Methodology adopted for the study

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

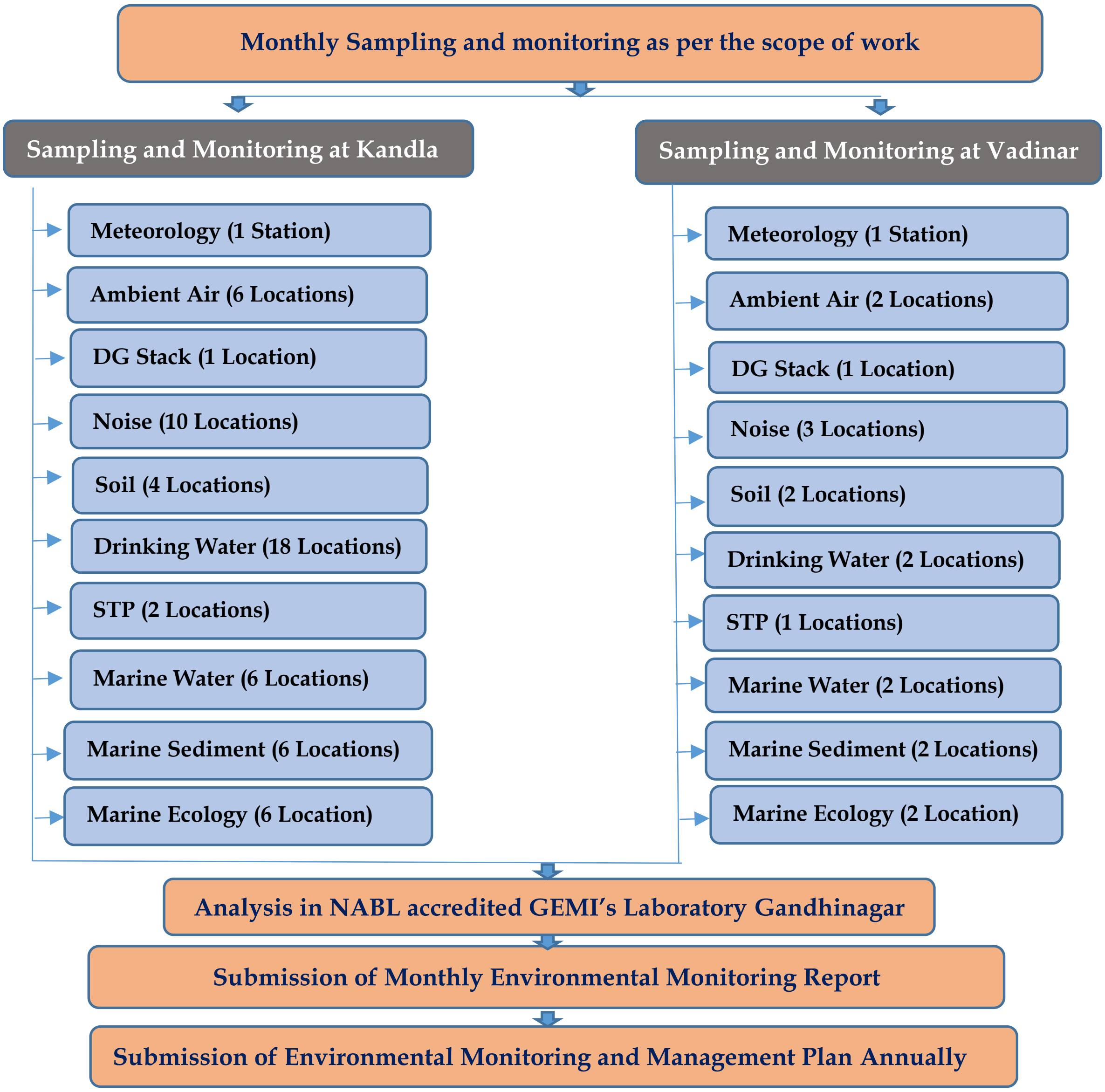


Figure 1: Methodology flow chart

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

CHAPTER 3: METEOROLOGY MONITORING

3.1 Meteorology Monitoring

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

Table 1: Details of Automatic Weather Station

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

Methodology

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

Table 2: Automatic Weather Monitoring Station details

Sr. No.	Details of Meteorological Data	Unit of Measurement	Instrument	Frequency
1.	Wind Direction	degree	Automatic Weather Monitoring Station (Envirotech WM280)	Hourly Average
2.	Wind Speed	Km/hr		
3.	Rainfall	mm/hr		
4.	Relative Humidity	% RH		
5.	Temperature	°C		
6.	Solar Radiation	W/m²		

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

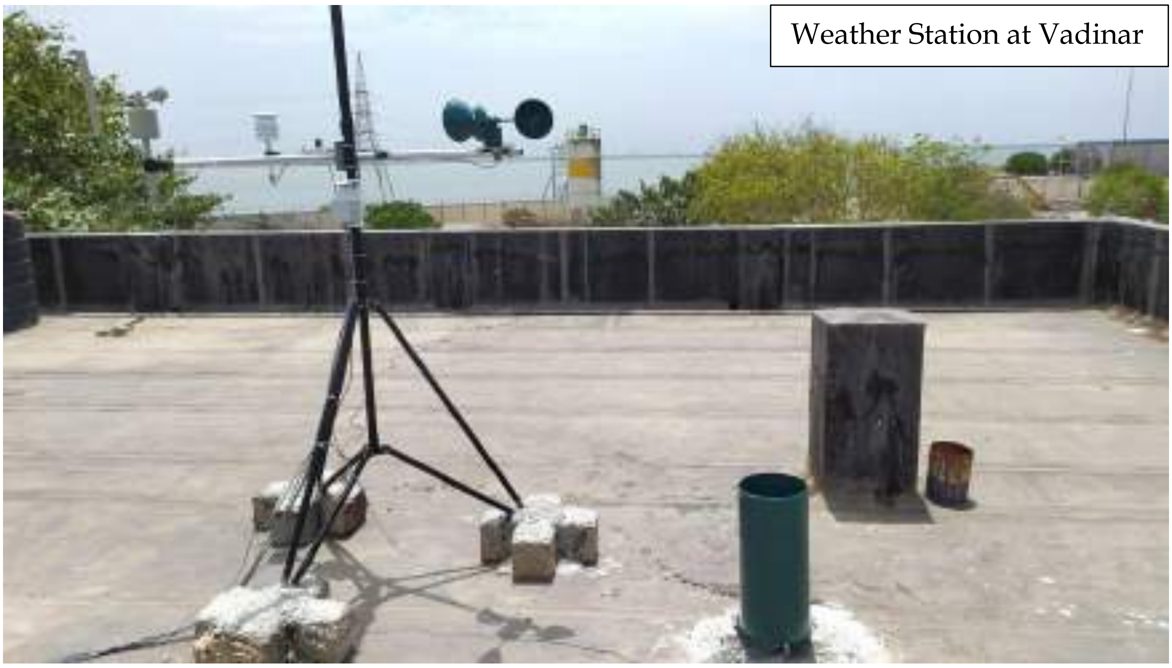


Figure 2: Photographs of Automatic Weather Monitoring Station at Kandla and Vadinar

3.2 Results and discussion

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

Table 3: Meteorological data for Kandla and Vadinar

Details of Micro-meteorological data at Kandla Observatory												
Monitoring Period	Wind Speed (Km/h)			Temperature (°C)			Relative humidity (%)			Solar Radiation (W/m²)	Wind Direction (°)	Rainfall (mm)
Stat.	Mean	Max.	Min	Mean	Max	Min	Mean	Max	Min			
March-April, 2024	3.24	86	1.3	32.24	41.4	26.2	73.15	89.8	43.8	67.97	From West-South-West	3.96
Details of Micro-meteorological data at Vadinar Observatory												
Monitoring Period	Wind Speed (Km/h)			Temperature (°C)			Relative humidity (%)			Solar Radiation (W/m²)	Wind Direction (°)	Rainfall (mm)
Stat.	Mean	Max.	Min	Mean	Max	Min	Mean	Max.	Min			
March-April, 2024	9.69	139.4	3.98	30.13	36	24.4	77.43	91.5	55.3	71.63	From South-West	0.43

3.3 Data Interpretation and Conclusion

- **Temperature**

a. **Kandla:** The ambient temperature for the monitoring period varies between the range of 26.2 – 41.4°C for Kandla, with average temperature of 32.24°C.

b. **Vadinar:** The ambient temperature for the monitoring period varies between the range of 24.4 -36°C for Vadinar, with average temperature of 30.13°C.

- **Relative Humidity**

a. **Kandla**: The Relative Humidity recorded between the range of 43.8 – 89.8%, with average Humidity of 73.15%.

b. **Vadinar:** During the study period, the Relative Humidity varies between 55.3 - 91.5%, with average Humidity of 77.43%.

- **Rainfall**

a. **Kandla:** 3.96 rainfall was observed at Kandla.

b. **Vadinar:** 0.43 rainfall was observed at Vadinar.

- **Wind Speed**

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

c. **Kandla:** Wind speed recorded ranges between 1.3 – 86, with average Wind Speed of 3.24 Km/hr.

a. **Vadinar:** During the monitoring period, the Wind speed recorded ranges between 3.98 – 139.4, with average Wind Speed of 9.69 Km/hr.

- **Solar Radiation:**

a. **Kandla:** The average Solar Radiation for the monitoring period was recorded as 67.97 W/m^2.

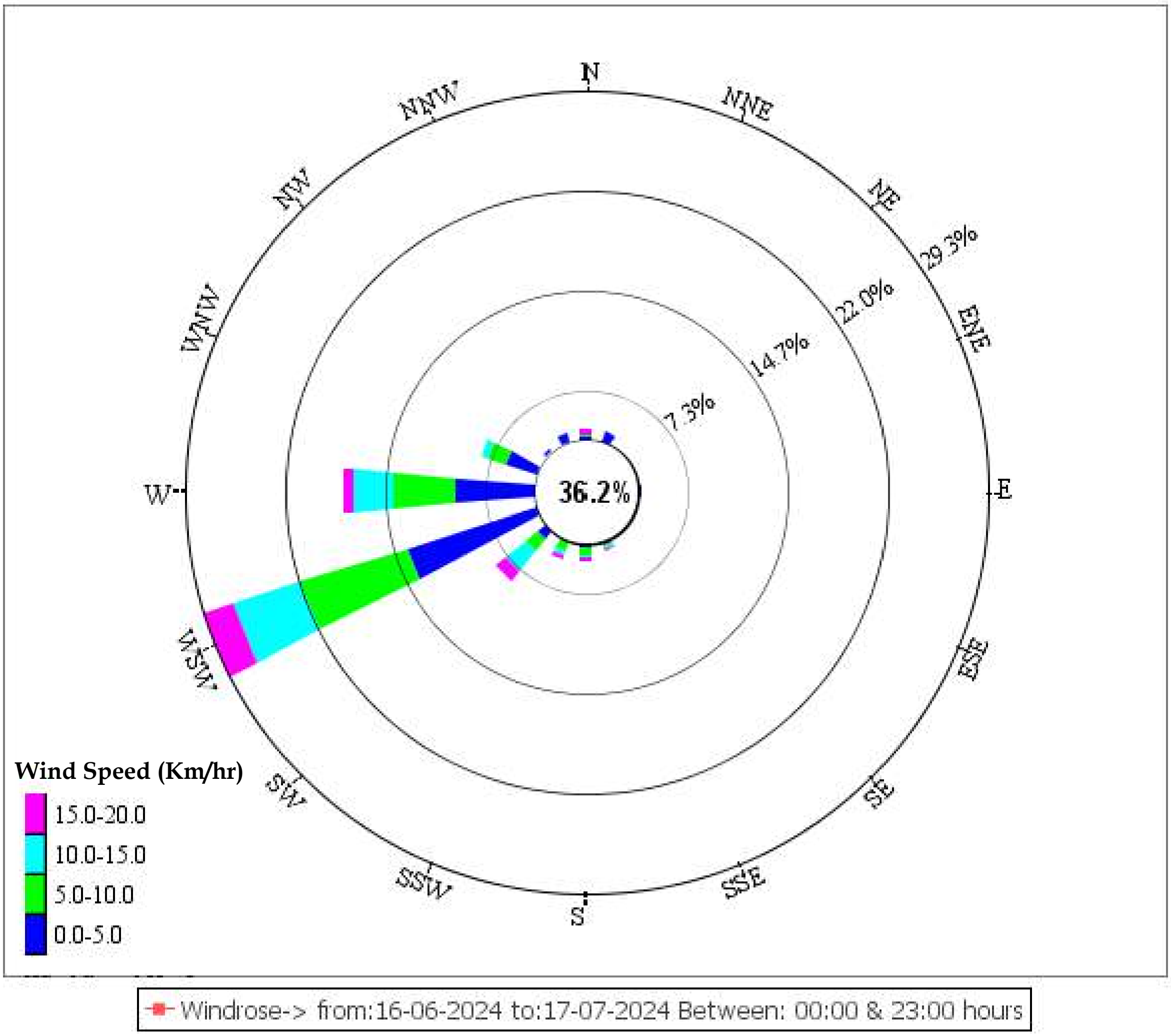
b. **Vadinar:** The average Solar Radiation was recorded as 71.63 W/m^2.

- **Wind rose diagram -**

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

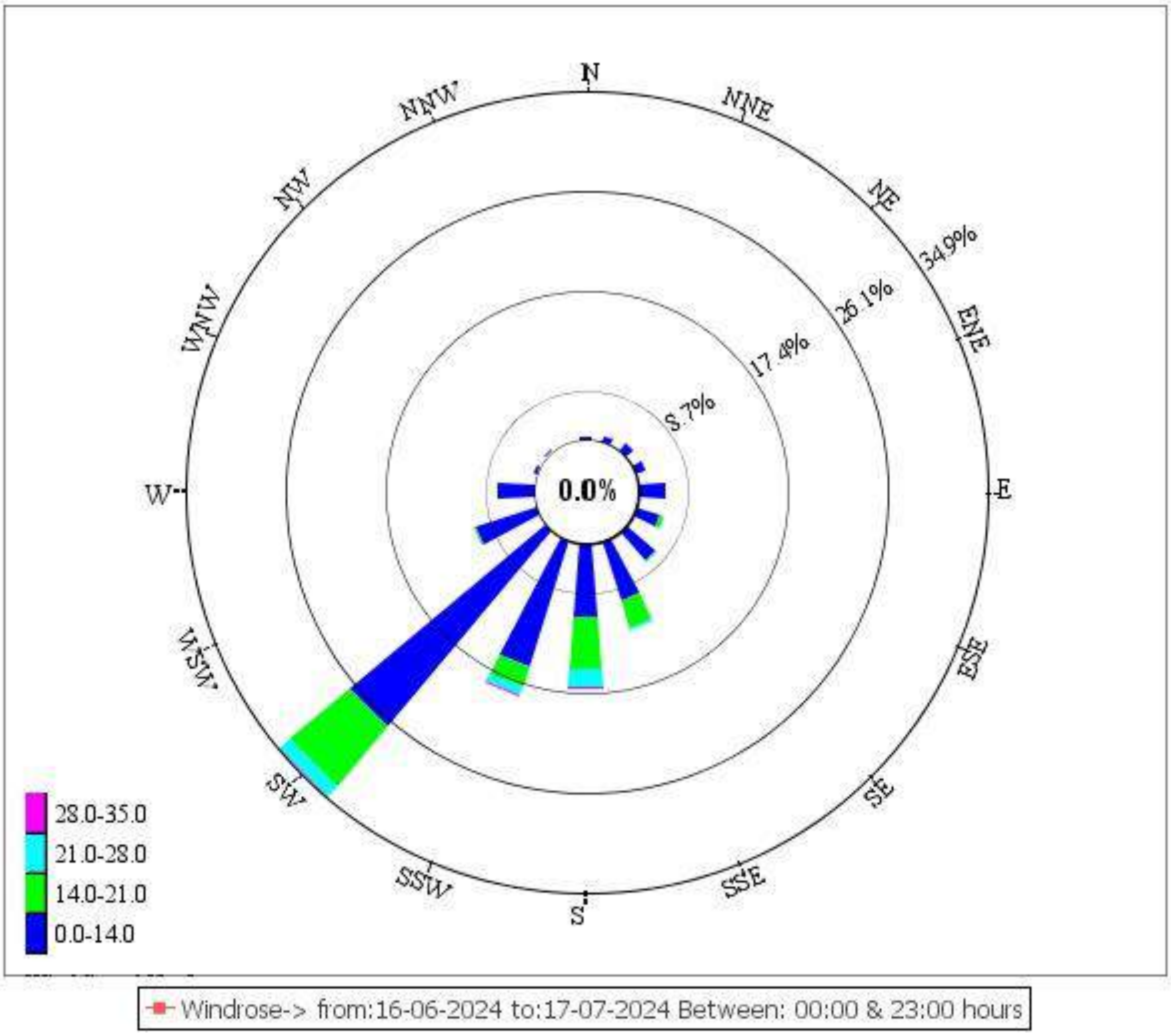
This Wind Rose Diagram reveals that at Kandla and Vadinar, during the monitoring period, the prevailing winds predominantly blow from the West South West direction at Kandla, whereas, high speed winds were also observed to blow from West direction. At Vadinar, the winds were observed to blow from From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

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



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

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



Modeler: Envirotech Instruments Pvt. Ltd. Delhi.

CHAPTER 4: AMBIENT AIR QUALITY MONITORING

4.1 Ambient Air Quality

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

Methodology

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

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

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

Table 4: Details of Ambient Air monitoring locations

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

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

Ambient Air monitoring photos

Kandla

A-1: Oil Jetty No. 1

A-2: Oil Jetty No. 7

A-3: Kandla Port Colony

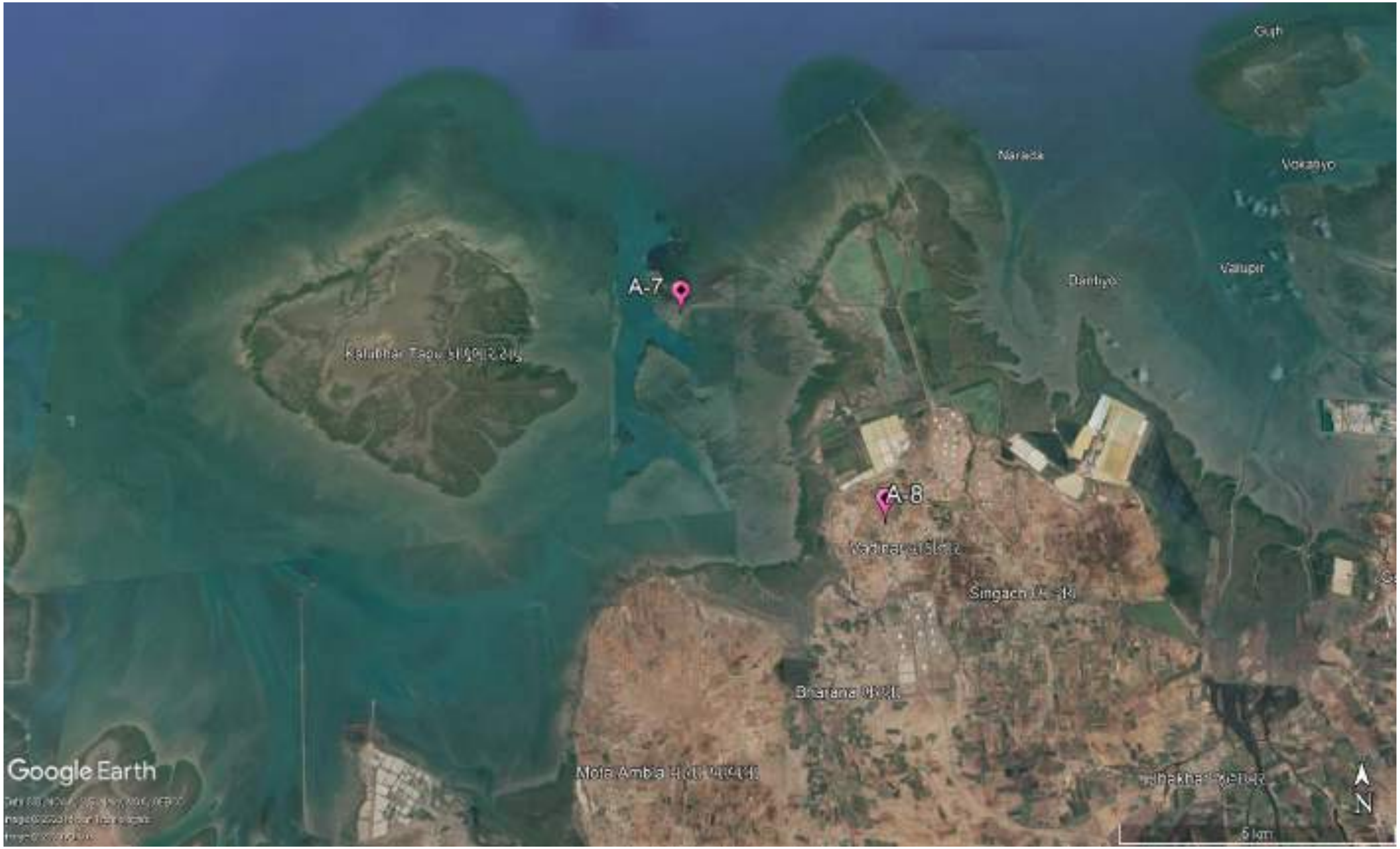
A-4: Marine Bhavan

A-5: Coal Storage Area

A-6: Gopalpuri Hospital

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

Map 4: Locations for Ambient Air Monitoring at Kandla



Map 5: Locations for Ambient Air Monitoring at Vadinar

Frequency

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

Sampling and Analysis

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

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

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

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

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

Table 5: Parameters for Ambient Air Quality Monitoring

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

4.2 Result and Discussion

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

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

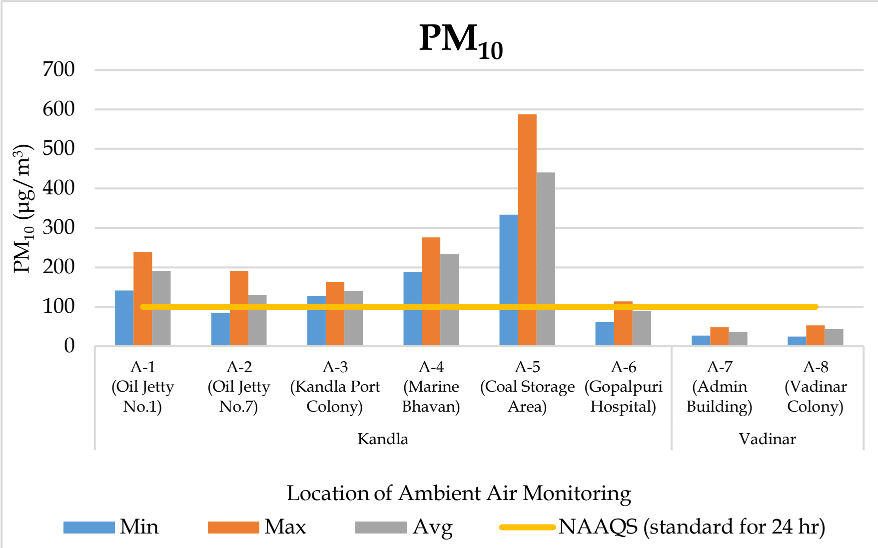
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	**PM_{10} (µg/m³)**	**$PM_{2.5}$ (µg/m³)**	**SO_2 (µg/m³)**	**NO_X (µg/m³)**	**VOC (µg/m³)**	**CO (mg/m³)**
	Duration	**(24 hr)**				**(2 hr)**	**(1 hr)**
	NAAQS by CPCB / **Monitoring days**	**100**	**60**	**80**	**80**	**-**	**2**
A-1: Oil Jetty No.1,	17/06/2024	225.63	39.64	18.34	12.68	0.11	0.80
	19/06/2024	239.33	41.33	22.50	19.33	0.07	0.86
	24/06/2024	196.37	30.50	4.96	6.28	0.22	0.81
	27/06/2024	208.63	34.6	16.64	9.29	0.14	0.74

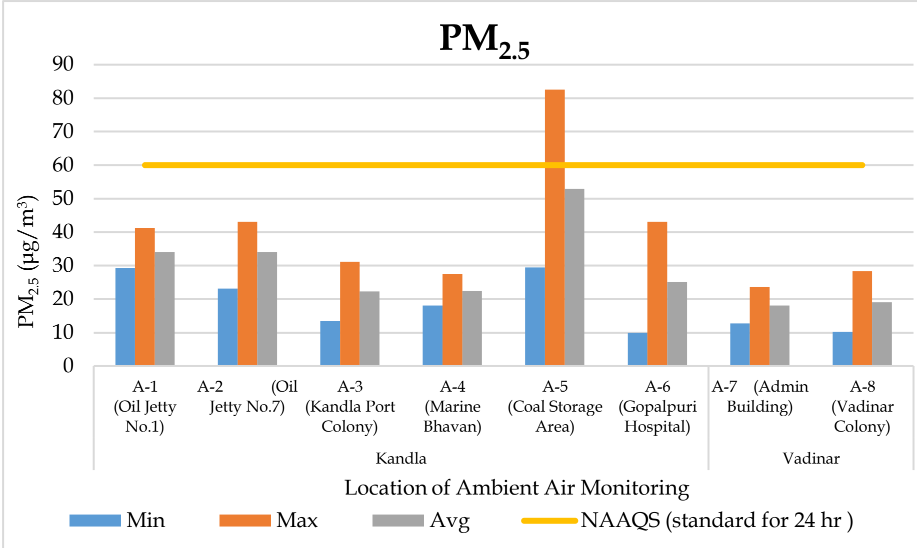
Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_X ($\mu g/m^3$)	VOC ($\mu g/m^3$)	CO (mg/m^3)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
Kandla	2/7/2024	188.37	31.19	23.83	11.51	0.18	0.66
	4/7/2024	141.41	29.24	4.88	<6	0.12	0.84
	8/7/2024	168.27	33.12	11.45	14.2	0.07	0.82
	10/7/2024	156.88	32.79	13.38	21.37	0.14	0.79
	Minimum	**141.41**	**29.24**	**11.45**	**6.28**	**0.07**	**0.66**
	Maximum	**239.33**	**41.33**	**23.83**	**21.37**	**0.22**	**0.86**
	Average	**190.61**	**34.05**	**17.69**	**13.52**	**0.13**	**0.79**
	Std. Deviation	**33.85**	**4.32**	**4.90**	**5.34**	**0.05**	**0.06**
A-2: Oil Jetty No.7, Kandla	17/06/2024	182.61	43.13	36.12	18.21	0.08	0.81
	19/06/2024	191.11	40.62	48.62	10.74	0.03	0.79
	24/06/2024	110.57	36.00	4.92	5.93	0.11	0.78
	27/06/2024	146.32	34.38	30.40	16.77	0.16	0.74
	2/7/2024	119.29	38.64	22.56	8.38	0.09	0.77
	4/7/2024	84.43	23.11	4.89	5.96	0.12	0.75
	8/7/2024	105.63	26.14	16.21	11.41	0.18	0.76
	10/7/2024	96.47	30.22	26.33	10.16	0.05	0.78
	Minimum	**84.43**	**23.11**	**4.89**	**5.93**	**0.03**	**0.74**
	Maximum	**191.11**	**43.13**	**48.62**	**18.21**	**0.18**	**0.81**
	Average	**129.55**	**34.03**	**23.76**	**10.95**	**0.10**	**0.77**
	Std. Deviation	**39.74**	**7.05**	**15.08**	**4.54**	**0.05**	**0.02**
A-3: Kandla Port Colony, Kandla	17/06/2024	146.07	13.39	4.87	5.78	0.20	0.87
	19/06/2024	129.49	14.12	4.96	5.84	0.13	0.86
	24/06/2024	134.77	28.61	29.38	12.34	0.19	0.84
	27/06/2024	163.17	31.16	21.16	9.46	0.12	0.82
	2/7/2024	141.42	27.42	10.27	19.7	0.16	0.85
	4/7/2024	150.52	24.32	4.79	5.94	0.11	0.82
	8/7/2024	126.63	18.38	16.83	12.75	0.27	0.83
	10/7/2024	131.31	21.15	14.77	22.87	0.32	0.86
	Minimum	**126.63**	**13.39**	**4.79**	**5.78**	**0.11**	**0.82**
	Maximum	**163.17**	**31.16**	**29.38**	**22.87**	**0.32**	**0.87**
	Average	**140.42**	**22.32**	**13.38**	**11.84**	**0.19**	**0.84**
	Std. Deviation	**12.40**	**6.67**	**8.92**	**6.52**	**0.07**	**0.02**
A-4: Marine Bhavan, Kandla	17/06/2024	272.90	22.25	4.84	5.76	0.16	0.89
	19/06/2024	253.03	18.10	4..93	5.72	0.21	0.86
	24/06/2024	275.72	22.69	4.89	5.83	0.04	0.84
	27/06/2024	264.42	27.55	27.57	12.25	0.09	0.88
	2/7/2024	218.13	23.41	19.38	14.07	0.11	0.87
	4/7/2024	193.37	25.45	4.97	5.85	0.23	0.85
	8/7/2024	187.73	21.76	13.49	16.19	0.21	0.84
	10/7/2024	203.38	18.93	17.38	23.89	0.25	0.87
	Minimum	**187.73**	**18.10**	**4.84**	**5.72**	**0.04**	**0.84**
	Maximum	**275.72**	**27.55**	**27.57**	**23.89**	**0.25**	**0.89**

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	100	60	80	80	-	2
	Average	**233.59**	**22.52**	**13.22**	**11.20**	**0.16**	**0.86**
	Std. Deviation	**36.88**	**3.11**	**8.84**	**6.68**	**0.08**	**0.02**
A-5: Coal Storage Area, Kandla	17/06/2024	469.24	58.31	36.74	32.68	0.21	0.88
	19/06/2024	522.30	68.62	43.86	10.44	0.14	0.92
	24/06/2024	411.80	82.57	4.94	6.76	0.13	0.94
	27/06/2024	588.16	53.67	31.45	18.87	0.18	0.93
	2/7/2024	446.39	49.22	24.76	26.92	0.10	0.89
	4/7/2024	383.47	29.42	18.66	12.80	0.07	0.91
	8/7/2024	366.11	38.11	29.49	15.37	0.22	0.94
	10/7/2024	333.28	43.66	37.09	18.47	0.12	0.90
	Minimum	**333.28**	**29.42**	**4.94**	**6.76**	**0.07**	**0.88**
	Maximum	**588.16**	**82.57**	**43.86**	**32.68**	**0.22**	**0.94**
	Average	**440.09**	**52.95**	**28.37**	**17.79**	**0.15**	**0.91**
	Std. Deviation	**84.90**	**17.01**	**12.27**	**8.56**	**0.05**	**0.02**
A-6: Gopalpuri Hospital, Kandla	17/06/2024	113.68	43.07	4.97	5.87	0.11	0.73
	19/06/2024	95.01	10.01	4.88	5.92	0.22	0.67
	24/06/2024	78.76	21.78	4.79	5.68	0.19	0.67
	27/06/2024	105.1	29.38	16.23	8.37	0.13	0.7
	2/7/2024	98.34	36.44	11.74	11.33	0.08	0.75
	4/7/2024	61.27	16.27	4.85	5.94	0.16	0.85
	8/7/2024	78.58	25.71	23.58	11.96	0.24	0.78
	10/7/2024	83.67	18.87	9.68	9.79	0.20	0.82
	Minimum	**61.27**	**10.01**	**4.79**	**5.68**	**0.08**	**0.67**
	Maximum	**113.68**	**43.07**	**23.58**	**11.96**	**0.24**	**0.85**
	Average	**89.30**	**25.19**	**10.09**	**8.11**	**0.17**	**0.75**
	Std. Deviation	**16.91**	**10.86**	**6.88**	**2.63**	**0.06**	**0.07**
A-7: Admin Building, Vadinar	17/06/2024	44.86	15.69	15.82	11.76	0.12	0.71
	19/06/2024	47.70	12.78	4.98	5.98	0.10	0.70
	24/06/2024	38.91	13.49	6.68	12.09	0.19	0.68
	27/06/2024	29.72	23.66	4.88	6.33	0.14	0.69
	3/7/2024	27.40	19.44	4.93	5.89	0.04	0.72
	4/7/2024	34.3	21.66	19.73	9.63	0.09	0.7
	8/7/2024	27.08	17.55	22.32	5.91	0.23	0.73
	10/7/2024	42.52	20.69	4.85	5.73	0.11	0.72
	Minimum	**27.08**	**12.78**	**4.85**	**5.73**	**0.04**	**0.68**
	Maximum	**47.70**	**23.66**	**22.32**	**12.09**	**0.23**	**0.73**
	Average	**36.56**	**18.12**	**10.52**	**7.92**	**0.13**	**0.71**
	Std. Deviation	**8.10**	**3.92**	**7.49**	**2.79**	**0.06**	**0.02**
A-8: Vadinar Colony,	17/06/2024	49.61	13.63	9.37	16.18	0.13	0.74
	19/06/2024	52.72	10.30	4.84	5.91	0.18	0.75
	24/06/2024	51.67	28.30	8.37	19.38	0.23	0.72
	27/06/2024	35.58	25.44	4.93	6.52	0.07	0.73

Station Code & Name	Unit of Average Concentration	Average Pollutant Concentration					
	Pollutants	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_X (µg/m³)	VOC (µg/m³)	CO (mg/m³)
	Duration	(24 hr)				(2 hr)	(1 hr)
	NAAQS by CPCB / Monitoring days	**100**	**60**	**80**	**80**	**-**	**2**
Vadinar	3/7/2024	24.57	14.60	4.98	5.78	0.16	0.80
	4/7/2024	47.58	23.53	11.91	8.48	0.11	0.76
	8/7/2024	51.39	15.43	12.55	5.76	0.18	0.79
	10/7/2024	30.02	21.41	4.91	5.93	0.09	0.78
	Minimum	**24.57**	**10.30**	**4.84**	**5.76**	**0.07**	**0.72**
	Maximum	**52.72**	**28.30**	**12.55**	**19.38**	**0.23**	**0.80**
	Average	**42.89**	**19.08**	**7.73**	**9.24**	**0.14**	**0.76**
	Std. Deviation	**11.13**	**6.45**	**3.28**	**5.41**	**0.05**	**0.03**

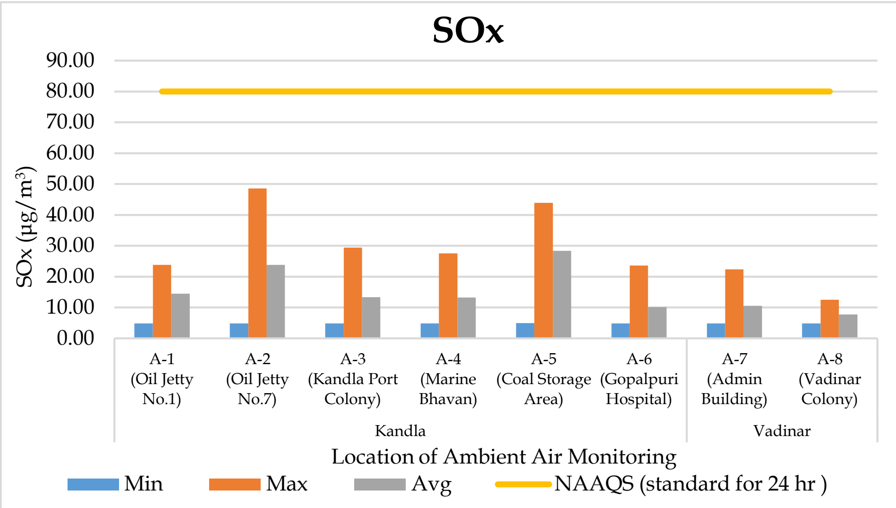
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar



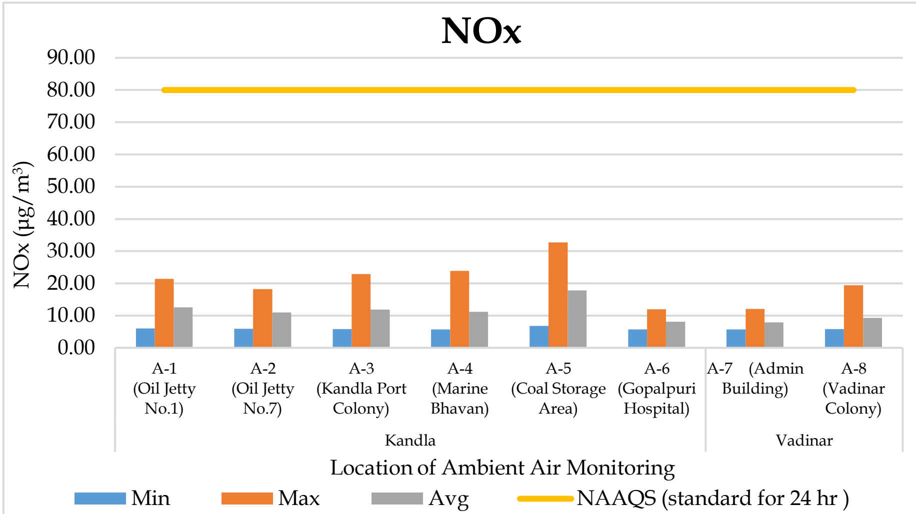


Graph 1: Spatial trend in Ambient PM_{10} Concentration

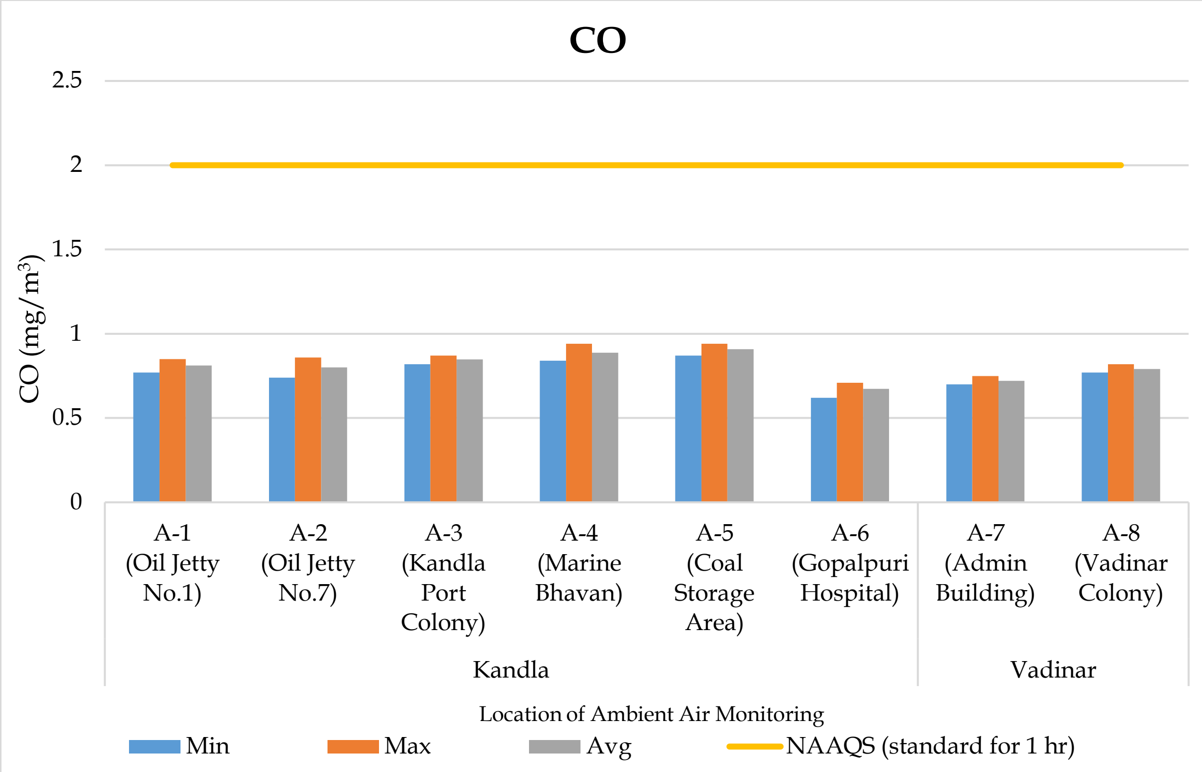
Graph 2: Spatial trend in Ambient $PM_{2.5}$ Concentration



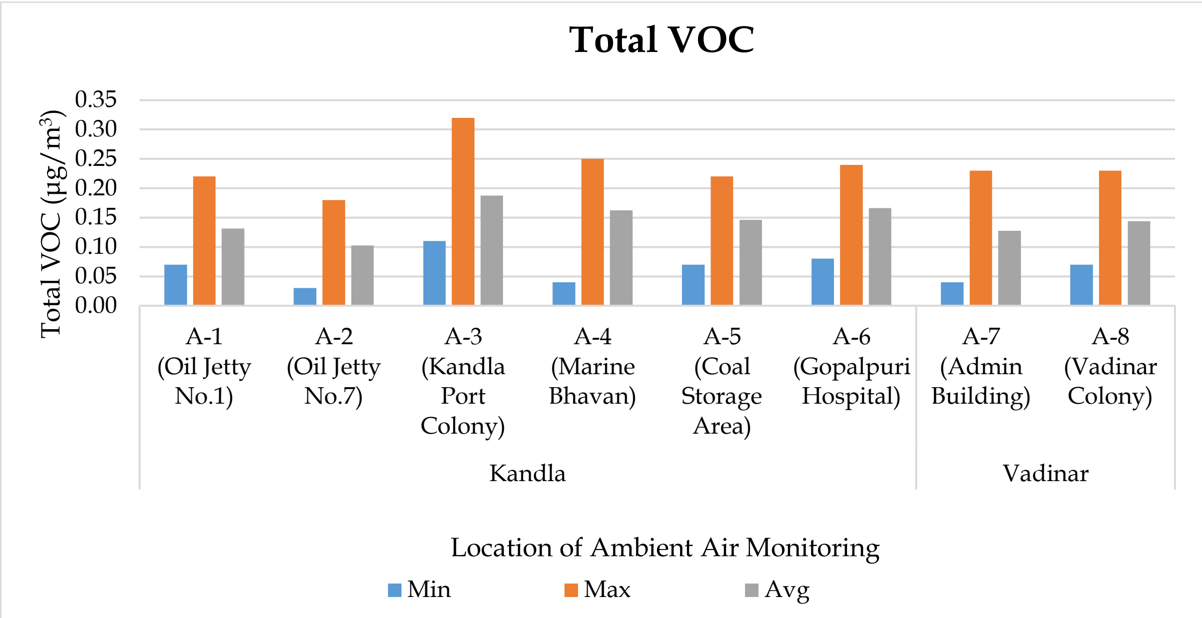
Graph 3: Spatial trend in Ambient SOx Concentration



Graph 4: Spatial trend in Ambient NOx Concentration



Graph 5: Spatial trend in Ambient CO Concentration



Graph 6: Spatial trend in Ambient Total VOCs

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

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

Table 8: Summarized results of Polycyclic Aromatic Hydrocarbons

Sr. No.	Components	Kandla						Vadinar	
		A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	Napthalene	0.25	0.44	0.48	0.60	0.43	0.46	0.01	0.04
2	Acenaphthylene	0.05	0.02	0.08	0.05	0.04	0.08	0.01	0.01
3	Acenaphthene	0.01	0.03	0.00	0.01	0.04	0.03	0.00	0.00
4	Fluorene	0.05	0.02	0.19	0.13	0.56	0.11	0.03	0.02
5	Anthracene	0.07	0.16	0.22	0.51	2.64	0.53	0.18	0.11
6	Phenanthrene	0.00	0.02	0.26	0.18	0.53	0.06	0.01	0.00
7	Fluoranthene	0.03	0.09	0.07	0.21	0.35	0.19	0.09	0.04
8	Pyrene	0.00	0.05	0.42	0.51	0.84	0.31	0.13	0.03
9	Chrycene	0.17	0.20	0.37	0.54	1.22	0.48	0.00	0.00
10	Banz(a)anthracene	0.11	0.06	0.06	0.23	0.58	0.20	0.05	0.02
11	Benzo[k]fluoranthene	0.03	0.01	0.20	0.15	0.36	0.10	0.00	0.00
12	Benzo[b]fluoranthene	0.03	0.05	0.10	0.17	0.32	0.11	0.00	0.00
13	Benzopyrene	0.03	0.04	0.00	0.14	0.84	0.25	0.02	0.04
14	Indeno [1,2,3-cd] fluoranthene	0.08	0.13	0.02	0.12	0.23	0.28	0.04	0.26
15	Dibenz(ah)anthracene	0.03	0.06	0.17	0.15	0.46	0.02	0.02	0.09
16	Benzo[ghi]perylene	0.00	0.01	0.00	0.00	0.00	0.00	0.07	0.18

Table 9: Summarized results of Non-methane VOC

Sr No	Kandla						Vadinar	
	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8
1	1.11	1.08	1.63	1.24	1.43	1.69	1.53	1.27

4.3 Data Interpretation and Conclusion

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

- The concentration of PM_{10} at Kandla varies in the range of 61.27 to 588.16 µg/m³ with an average value of 203.93 µg/m³. PM_{10} exceeded NAAQS of all the monitoring locations in Kandla. Whereas, at Vadinar, the concentration varies from 24.57 to 52.72 µg/m³, with an average value of 39.73 µg/m³, and complies with the stipulated norm (100 µg/m³).
- The highest concentration of PM_{10} at locations A-5 i.e. Coal Storage Area could be attributed to the presence of heavy vehicular traffic in upwind areas which bring

higher impact causing the dispersion of emitted particulate matter in the ambient air. The unloading of coal directly in the truck, using grabs causes the coal to disperse in the air as well as coal dust to fall and settle on the ground. This settled coal dust again mixes with the air while trucks travel through it. Also, the coal-loaded trucks are generally not always covered with tarpaulin sheets and this might result in increased suspension of coal from trucks/dumpers during its transit from vessel to yard or storage site. This might increase the PM_{10} in and around the Coal storage area and Marine bhavan.

- The **$PM_{2.5}$** concentrations at Kandla vary from 10.01 to 82.57 μg/m3, with an average of 31.84 μg/m3. While the **$PM_{2.5}$** concentrations at most locations in Kandla fall within the NAAQS limits, the concentration at location A-5, with a value of 82.57 μg/m3, exceeds the permissible limit. Whereas, at Vadinar its concentration varies from 10.30 to 28.30 μg/m^3 with average 18.60 μg/m^3 which falls within the limit of NAAQS of 60 μg/m^3.
- The concentration of **SO_x** varies from 4.79 to 48.62 µg/m^3 with average concentration as 17.22 µg/m^3 at Kandla and 4.84 to 22.32 µg/m^3 with average as 9.13 µg/m^3 at Vadinar. The average concentration of SO_x complies with the prescribed limit of NAAQS (80 µg/m^3) for both the monitoring site.
- The concentration of **NO_x** varies from 5.68 to 32.68 µg/m^3 with average 12.08 µg/m^3 at Kandla and 5.73 to 19.38 µg/m^3 with average 8.58 µg/m^3 at Vadinar. The concentration of **NO_x** falls within the prescribed limit of NAAQS i.e. 80 µg/m^3 at both the monitoring site of Kandla and Vadinar.
- The concentration of **CO** varies from 0.66 to 0.94 µg/m^3 with average 0.82 µg/m^3 at Kandla and 0.68 to 0.80 µg /m^3 with average 0.73 µg/m^3 at Vadinar. The concentration falls within the norm of 2 mg/m^3 specified by NAAQS at both the monitoring sites
- The concentration of **Total VOCs** levels was recorded in range of 0.03 to 0.32 µg/m^3 and 0.04 to 0.23 µg/m^3 at Kandla and Vadinar respectively. The main source of VOCs in the ambient air may be attributed to the burning of Gasoline and Natural gas in Vehicle exhaust and burning fossil fuels, and garbage that release VOCs into the atmosphere. During the monitoring period, the wind flows towards South direction at Kandla, and hence the wind direction and speed also contribute to increased dispersion of pollutants from the upward areas towards the downward areas.
- **Benzene** was not detected at any of locations of Kandla and Vadinar.
- **Polycyclic Aromatic Hydrocarbons (PAHs)** are ubiquitous pollutants in urban atmospheres. Anthropogenic sources of total PAHs in ambient air emissions are greater than those that come from natural events. These locations are commercial areas where Vehicular activity and dust emission is common. PAHs are a class of chemicals that occur naturally in coal, crude oil, and gasoline. The higher concentration which results from burning coal, oil, gas, road dust, etc. Other outdoor sources of PAHs may be the industrial plants in-and-around the DPA premises.

- The Ambient air Monitoring location of Kandla recorded the **Non-methane VOC** (NM-VOC) concentration in the range of 1.08 to 1.69 µg/m^3. While at Vadinar, the concentration of NM-VOC falls in the range of 1.27 to 1.53 µg/m^3.

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

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

4.4 Remedial Measures:

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

- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle-Mask advised in sensitive areas. Covering vehicles with tarpaulin during transportation will help to reduce the suspension of pollutants in air.
- Ensuring maintenance of engines and machinery to comply with emission standards.
- Frequent water sprinkling on roads to reduce dust suspension due to vehicular movement, this can be use during transporting coal to avoid suspension of coal dust.
- Use of proper transport methods, such as a conveyor belt, for excavated material and screens around the construction site.
- Temporary pavement of roads in construction site could considerably reduce dust emission. Prohibition of use of heavy diesel oil as fuel could be possibly reduce pollutants. Encouraging use of low-sulfur fuels (viz. Marine Gas Oil (MGO)/Liquefied Natural Gas (LNG), can significantly reduce sulfur and PM emissions from ships.

- Retrofitting ships with exhaust gas cleaning systems can help reduce sulfur emissions. Engine upgrades, such as optimizing fuel combustion and improving engine efficiency, can reduce overall emissions.
- Investing in infrastructure for cold ironing allows ships to connect to the electrical grid while docked, reducing the need for auxiliary engines and associated emissions.
- Implementing efficient cargo-handling processes, optimizing logistics to reduce congestion and idling times, and encouraging use of cleaner port machinery and vehicles can all contribute to reducing air pollution in port areas.

CHAPTER 5: DG STACK MONITORING

5.1 DG Stack Monitoring

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

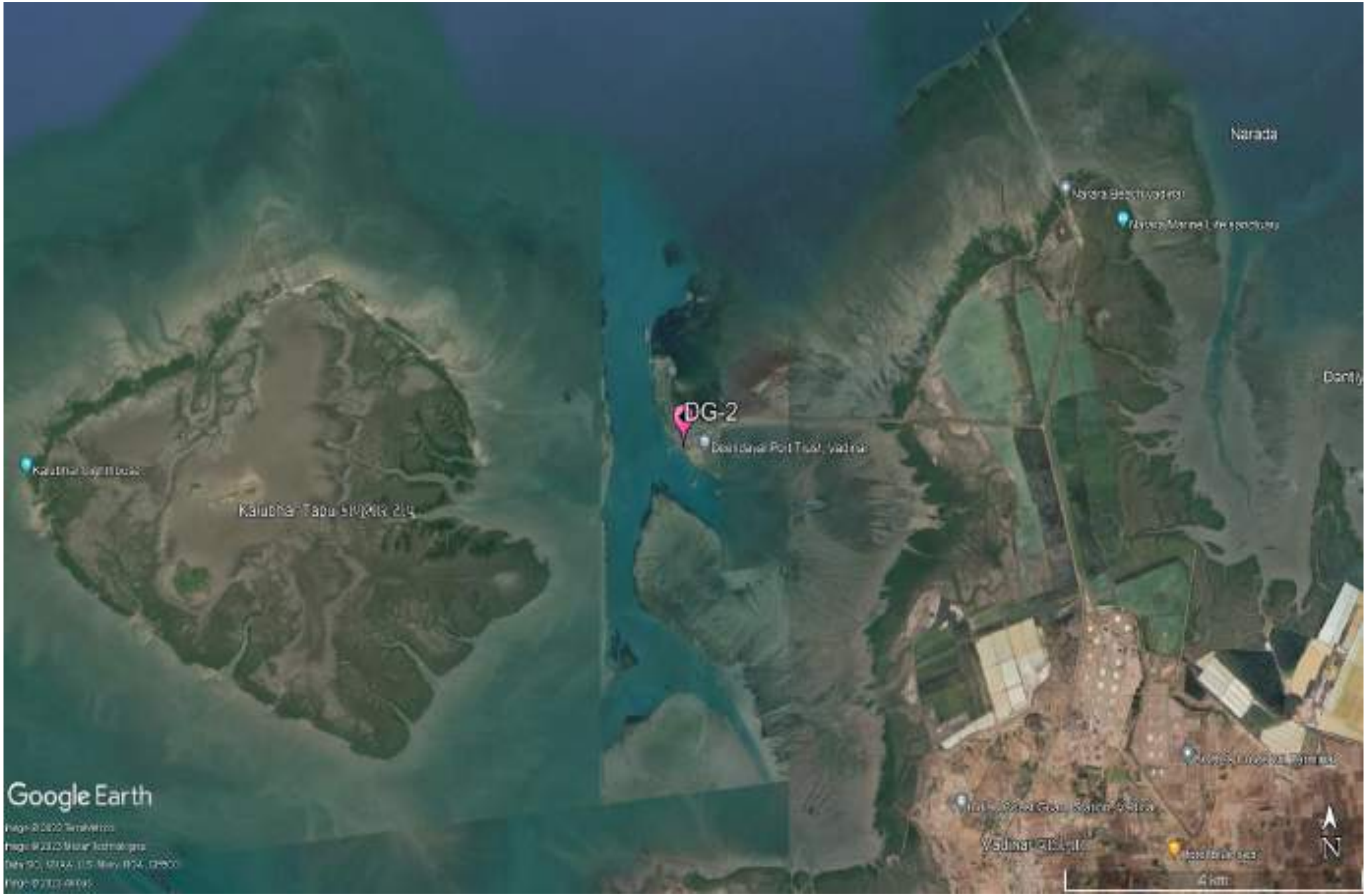
As defined in scope by DPA, the monitoring of DG Stack shall be carried out at two locations, one at Kandla and one at Vadinar. The details of the DG Sets at Kandla and Vadinar have been mentioned in **Table 10** as follows:

Table 10: Details of DG Stack monitoring locations

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

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

Map 6: Locations for DG Stack monitoring at Kandla



Map 7: Locations for DG Stack monitoring at Vadinar

Methodology:

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

Table 11: DG stack parameters

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

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

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

Frequency

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

5.2 Result and Discussion

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

Table 12: DG monitoring data

Sr. No.	Stack Monitoring Parameters for DG Sets	Stack Monitoring Limits / Standards As per CPCB	DG- 1 (Kandla)	DG-2 (Vadinar)
1.	Suspended Particulate Matter (SPM) (mg/Nm^3)	150	85.36	39.56
2.	Sulphur Dioxide (SO_2) (PPM)	100	6.31	N.D.
3.	Oxides of Nitrogen (NO_x) (PPM)	50	38.21	10.32
4.	Carbon Monoxide (CO) (%)	1	0.26	0.11
5.	Carbon Dioxide (CO_2) (%)	-	2.15	1.35

5.3 Data Interpretation and Conclusion

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

CHAPTER 6: NOISE MONITORING

6.1 Noise Monitoring

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

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

Table 13: Details of noise monitoring locations

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

Map 8: Locations for Noise Monitoring at Kandla

Map 9: Locations for Noise Monitoring at Vadinar

Methodology:

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

Frequency

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

Table 14: Details of the Noise Monitoring

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

Standard for Noise

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

Table 15: Ambient Air Quality norms in respect of Noise

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

6.2 Result and Discussion

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

Table 16: The Results of Ambient Noise Quality

Sr. No.	Station Code	Station Name	Category of Area	Standard	Day Time			Standard	Night Time		
					Max.	Min.	Leq dB(A) Total		Max.	Min.	Leq dB(A) Total
1	N-1	Oil Jetty 7	A	75	58.1	38.9	48.5	70	42.6	35.4	39.0
2	N-2	West Gate No.1	A	75	66.1	48.0	57.1	70	50.1	41.1	45.6
3	N-3	Canteen Area	B	65	60.2	44.2	52.2	55	49.2	36.7	43.0
4	N-4	Main Gate	A	75	58.4	46.9	52.7	70	45.4	36.2	40.8
5	N-5	Main Road	A	75	60.2	39.4	49.8	70	47.6	35.6	41.6
6	N-6	Marin Bhavan	B	65	61.9	39.5	50.7	55	42.0	34.6	38.3
7	N-7	Port & Custom Building	B	65	54.6	39.4	47.0	55	46.6	36.4	41.5
8	N-8	Nirman Building	B	65	54.5	42.6	48.6	55	48.1	37.1	42.6
9	N-9	ATM Building	B	65	58.1	41.6	49.9	55	45.9	35.9	40.9
10	N-10	Wharf Area/ Jetty	A	75	61.5	42.6	52.1	70	47.2	40.6	43.9
11	N-11	Near Main Gate	A	75	67.4	57.2	60.3	75	50.4	54.6	62.3
12	N-12	Near Vadinar Jetty	A	75	69.3	63.2	63.7	75	52.1	56.3	59.6
13	N-13	Port Colony Vadinar	C	55	53.5	45.1	45.3	55	43.3	44.7	52.1

6.3 Data Interpretation and Conclusion

The noise level at both the locations (Kandla and Vadinar) was compared with the standard limits specified in NAAQS by CPCB. During the Day Time, the average noise level at all 10 locations at Kandla ranged from 47.0 dB(A) to 57.1 dB(A), while at Vadinar, the noise levels for the three-location ranged from 45.3 dB(A) to 63.7 dB(A). Whereas, during Night Time the average Noise Level ranged from 38.3 dB(A) to 45.6 dB(A) at Kandla and 52.1 dB(A) to 62.3 dB(A) at Vadinar, which was within the permissible limits for the industrial and commercial area, but exceeded slightly for location N-12, which is a residential zone. Overall, the noise levels at Kandla and Vadinar fall within the prescribed norms for both Day and Night times.

6.4 Remedial Measures

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

CHAPTER 7: SOIL MONITORING

7.1 Soil Quality Monitoring:

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

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

Table 17: Details of the Soil quality monitoring

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

Methodology

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

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

Frequency

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

Table 18: Soil parameters

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

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

Map 10: Locations for Soil Quality Monitoring at Kandla

Map 11: Locations for Soil Quality Monitoring at Vadinar

7.2 Result and Discussion

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

Table 19: Soil Quality for the sampling period

Sr. No	Location / Parameters	Unit	Kandla				Vadinar	
			S-1 (Oil Jetty 7)	S-2 IFFCO Plant)	S-3 (Khori Creek)	S-4 (Nakti Creek)	S-5 (Near SPM)	S-6 (Near Vadinar Jetty)
1	pH	-	7.34	7.3	8.64	8.45	7.74	8.14
2	Conductivity	µS/cm	45300	27200	226	219	102	272
3	Inorganic Phosphate	Kg/ha	2.06	2.22	3.14	3.03	0.59	0.55
4	Organic Carbon	%	0.56	0.5	0.29	0.23	0.1	0.52
5	Organic Matter	%	0.96	0.86	0.49	0.39	0.17	0.89
6	SAR	meq/L	24.88	10.06	0.39	0.38	0.09	0.17
7	Aluminium	mg/Kg	11277.15	14127.51	10350.29	7708.929	12783.28	13457.49
8	Chromium	mg/Kg	53.599	62.015	53.667	35.6	51.109	55.378
9	Nickel	mg/Kg	14.22	5.764	13.391	5.668	18.72	24.346
10	Copper	mg/Kg	83.233	123.235	14.591	14.22	63.292	67.75
11	Zinc	mg/Kg	146.081	45.517	32.38	17.203	37.242	55.477
12	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
13	Lead	mg/Kg	15.314	5.068	2.698	1.591	BQL	BQL
14	Arsenic	mg/Kg	0.198	BQL	2.298	0.795	BQL	BQL
15	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL
16	Water Holding Capacity	%	37.98	43.96	40	39.97	37.95	51.9
17	Sand	%	61.52	65.55	77.54	75.53	72.81	74.8
18	Silt	%	33.44	31.41	11.43	13.44	26.15	24.16
19	Clay	%	5.04	3.04	11.03	11.04	1.04	1.04
20	Texture	-	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loamy sand	loamy sand

7.3 Data Interpretation and Conclusion

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

- The value of **pH** ranges from **7.3 to 8.64**, highest at location S-3 (Khori Creek) and lowest at S-2 (IFFCO Plant); while the average pH for Kandla was observed to be 7.93. Whereas, at Vadinar the pH was observed as 7.74 at S-5 i.e., Near SPM and 8.14 at S-6 i.e., Near Jetty Area. The pH in Kandla varies from the **Slightly alkaline to strongly alkaline.** Whereas, pH of Soil at Vadinar was found to be **Slightly alkaline**.

- At entire monitoring locations of Kandla the value of **Electrical Conductivity** ranges from **219 to 45300 µs/cm**, highest at location S-1 (Oil Jetty 7) and lowest at S-4 (Nakti Creek), with the average as **18236.25** µs/cm. Whereas, at Vadinar the conductivity falls within the range of **102 to 272** µs/cm with an average value of **187 µs/cm.**

- At Kandla, the concentration of **Inorganic Phosphate** varied from **2.06 to 3.14 Kg/ha**, with average 2.61 Kg/ha. Whereas, at the locations of Vadinar, the Inorganic Phosphate was observed as 0.59 Kg/ha at S-5 (Near SPM) and 0.55 Kg/ha at S-6 (near Jetty Area), with the average 0.57 Kg/ha. The phosphorus availability in soil solution is influenced by a number of factors such as Organic matter, clay content, pH, temperature, etc.

- The concentration of **Total Organic Carbon** ranges from 0.23 to 0.56% while the average TOC at Kandla was detected as 0.39%. Whereas, at Vadinar the average TOC was found to be 0.31% where the observed TOC value found at S-5 and S-6 to be 0.1% and 0.52% respectively.

- The **Sodium Adsorption Ratio** ranges from **0.38 to 24.88 meq/L** with an average value 8.92 meq/L at Kandla. Whereas, at Vadinar, the average SAR was found to be 0.13 meq/L where the observed SAR value found at S-5 (0.09 meq/L) and S-6 (0.17 meq/L).

- The **Water Holding Capacity** in the soil samples of Kandla and Vadinar varies from 37.98 to 43.96% and 37.95 to 51.9% respectively.

- The Soil Texture was observed as “Sandy loam” at all the monitoring locations in Kandla and Vadinar, except the location S-6 of Vadinar which is “loamy sand”.

Heavy Metals

- For the sampling period, the concentration of **Aluminium** varied from **7708.929 to 14127.509 mg/kg** at Kandla, and **12783.28 to 13457.493 mg/kg** at Vadinar. Whereas, the average Aluminium concentration was observed to be 10865.97 and 13120.39 mg/kg at Kandla and Vadinar monitoring station respectively.

- The concentration of **Chromium** varied from **35.6 to 62.015 mg/kg** at Kandla and **51.109 to 55.378 mg/kg** at Vadinar and the average value was observed to be 51.22 and 53.24 mg/kg at Kandla and Vadinar monitoring station, respectively.

The concentration of **Nickel** varied from **5.668 to 14.22 mg/kg** at Kandla and **18.72 to 24.346 mg/kg** at Vadinar and the average value was observed to be 9.76 and 21.533 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **Zinc** varied from **17.203 to 146.081 mg/kg** at Kandla and **37.242 to 55.477 mg/kg** at Vadinar and the average value was observed to be 60.29 and 46.35 mg/kg at Kandla and Vadinar monitoring station, respectively.

- The concentration of **copper** varied from **14.22 to 123.235 mg/kg** at Kandla and **63.292 to 67.75 mg/kg** at Vadinar and the average value was observed to be 58.81 and 65.52 mg/kg at Kandla and Vadinar monitoring station, respectively.

- Concentration of **Lead** varied from **1.59 to 15.31 mg/kg** at Kandla with average value 6.16 mg/Kg, whereas for Vadinar, the values recorded 6.57 mg/Kg at S-5 and "Below Quantification Limit" at location at S-6 location.

- The concentration of **Arsenic** varied from **0.19 to 2.29 mg/kg** at Kandla with average value 1.09 mg/Kg, whereas for Vadinar, the values recorded 6.57 mg/Kg at S-5 and "Below Quantification Limit" at location at S-6 location.

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

CHAPTER 8: DRINKING WATER MONITORING

8.1 Drinking Water Monitoring

It is necessary to check with the drinking water sources regularly so as to know whether water quality conforms to the prescribed standards for drinking. Monitoring the drinking water quality is essential to protect human health and the environment. With reference to the scope specified by DPA, a total of 20 locations (18 at Kandla and 2 at Vadinar) were monitored to assess the Drinking Water quality.

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

Table 20: Details of Drinking Water Sampling Locations

Sr. No.	Location Code		Location Name	Latitude/ Longitude
1.	Kandla	DW-1	Oil Jetty 7	23.043527N 70.218456E
2.		DW-2	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

Map 12: Locations for Drinking Water Monitoring at Kandla

Map 13: Locations for Drinking Water Monitoring at Vadinar

Methodology

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

Table 21: List of parameters for Drinking Water Quality monitoring

Sr. No.	Parameters	Units	Reference method	Instrument
1.	pH	-	APHA, 23rd Edition (Section-4500-H^+B):2017	pH Meter
2.	Colour	Hazen	APHA, 23rd Edition, 2120 B:2017	Color Comparator
3.	EC	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
4.	Turbidity	NTU	APHA, 23rd Edition (Section -2130 B):2017	Nephlo Turbidity Meter
5.	TDS	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with filtration assembly and Oven
6.	TSS	mg/L	APHA, 23rd Edition, 2540 D: 2017	
7.	Chloride	mg/L	APHA, 23rd Edition (Section-4500-Cl-B):2017	Titration Apparatus
8.	Total Hardness	mg/L	APHA, 23rd Edition (Section-2340 C):2017	
9.	Ca Hardness	mg/L	APHA, 23rd Edition (Section-3500-Ca B):2017	
10.	Mg Hardness	mg/L	APHA, 23rd Edition (Section-3500-Mg B):2017	
11.	Free Residual Chlorine	mg/L	APHA 23rd Edition, 4500	
12.	Fluoride	mg/L	APHA, 23rd Edition (Section-4500-F-D):2017	UV- Visible Spectrophotometer
13.	Sulphate	mg/L	APHA, 23rd Edition (Section 4500-SO4-2-E):2017	
14.	Sodium	mg/L	APHA, 23rd Edition (Section-3500-Na-B):2017	Flame Photometer
15.	Potassium	mg/L	APHA,23rd Edition, 3500 K-B: 2017	
16.	Salinity	mg/L	APHA, 23rd Edition (section 2520 B, E.C. Method)	Salinity /TDS Meter
17.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3- B: 2017	UV- Visible Spectrophotometer
18.	Nitrite	mg/L	APHA, 23rd Edition, 4500 NO2-B: 2017	

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

8.2 Result and Discussion

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

Table 22: Summarized results of Drinking Water quality

Sr. No.	Parameters	Units	Standard values as per IS		Kandla																		Vadinar	
			A	P	DW-1	DW-2	DW-3	DW-4	DW-5	DW-6	DW-7	DW-8	DW-9	DW-10	DW-11	DW-12	DW-13	DW-14	DW-15	DW-16	DW-17	DW-18	DW-19	DW-20
1.	pH	-	6.5-8.5	-	8.34	6.41	7.67	8.78	7.63	8.26	8.48	8.50	7.79	8.15	7.87	7.88	7.90	8.10	7.85	7.01	6.99	6.91	7.58	7.30
2.	Colour	Hazen	5	15	1	1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.	EC	µS/ cm	-	-	15	44.56	677	48.7	1004	88.4	14.05	31	703	210	1041	57.9	123.7	173	169.9	165	158.6	68	499	113.9
4.	Salinity	PSU	-	-	0.02	0.21	0.33	0.03	0.49	0.05	0.02	0.02	0.34	0.10	0.51	0.03	0.06	0.09	0.08	0.08	0.08	0.04	0.24	0.06
5.	Turbidity	NTU	1	5	BQL	BQL	0.52	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.68	BQL
6.	Chloride	mg/L	250	1000	4.96	8.55	119.11	6.95	193.56	17.87	4.47	7.94	119.11	45.16	203.48	14.39	23.33	33.25	36.23	32.26	35.73	17.87	71.47	17.87
7.	Total Hardness	mg/L	200	600	2.5	8	165	13	200	7	BQL	3.5	170	20	210	4	25.0	40	12.5	25	7.5	12	130	20
8.	Ca Hardness	mg/L	-	-	1.5	6	100	10	115	5.5	1	2.5	85	5	125	3	12.5	15	7.5	12.5	2.5	5	60	5
9.	Mg Hardness	mg/L	-	-	1	2	65	3	85	1.5	BQL	1	85	15	85	1	12.5	25	5	12.5	5	7	70	15
10.	Free Residual Chlorine	mg/L	0.2	1	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	4.96	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
11.	TDS	mg/L	500	2000	8	22	356	26	516	46	8	16	362	108	538	30	66	94	88	86	82	36	258	60
12.	TSS	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
13.	Fluoride	mg/L	1.0	1.5	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.318	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.500	0.360
14.	Sulphate	mg/L	200	400	BQL	BQL	33.516	BQL	52.375	BQL	BQL	BQL	38.326	BQL	66.402	BQL	BQL	BQL	BQL	21.771	BQL	BQL	33.620	BQL
15.	Nitrate	mg/L	45	-	BQL	BQL	2.783	BQL	28.36	5.037	BQL	BQL	2.242	1.865	30.93	BQL	BQL	1.330	1.353	BQL	4.432	BQL	3.584	BQL
16.	Nitrite	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	1.638	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
17.	Sodium	mg/L	-	-	BQL	BQL	72.16	BQL	109.19	16.59	BQL	BQL	78.98	28.79	109.58	10.72	16.16	19.30	27.45	21.13	28.99	13.51	54.54	17.05
18.	Potassium	mg/L	-	-	BQL	BQL	BQL	BQL	7.22	BQL	BQL	BQL	BQL	BQL	7.89	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
19.	Hexavalent Chromium	mg/L	-	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	TON	Agreeable		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	**0.01**	**0.05**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	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	BQL	BQL
24.	Iron	mg/L	**0.3**	-	BQL	BQL	BQL	0.119	BQL	BQL	BQL	BQL	BQL	0.126	BQL	0.872	BQL	0.121	BQL	0.252	BQL	0.109	0.128	BQL
25.	Lead	mg/L	**0.01**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
26.	Manganese	mg/L	**0.1**	**0.3**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	0.059	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
27.	Mercury	mg/L	**0.001**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
28.	Total Chromium	mg/L	**0.05**	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Zinc	mg/L	**5**	**15**	BQL	BQL	BQL	BQL	BQL	BQL	BQL	3.964	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Total Coliform*	MPN/ 100ml	**Shall not be detected**		5110	380	695	BQL	3100	130	10	2018	1060	BQL	4250	BQL	35	BQL	3400	BQL	385	85	85	75

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

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

8.3 Data Interpretation and Conclusion

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

- **pH:** The pH values of drinking water samples in Kandla were reported to be in the range of **6.41 to 8.78**, with an average pH of 7.80. In Vadinar, its values ranged from **7.30 to 7.58**, with an average pH of 7.44. Notably, the pH levels at both project sites fall within the acceptable range of 6.5 to 8.5, except the location DW-2 & DW-4, as specified under IS:10500:2012.
- **Colour:** The colour varies from 1 to 5 at the monitoring locations of Kandla. Only locations DW-3 showed the value of 5 Hazen, whereas, all the other locations showed a value of 1 in Hazen at Kandla. At Vadinar, the color was observed to be 1 Hazen at both the monitoring locations.
- **Electrical Conductivity (EC):** It is a measure of the ability of a solution to conduct electric current, and it is often used as an indicator of the concentration of dissolved solids in water. During the monitoring period, the EC values for samples collected in Kandla were observed to range from **14.05 to 1041 µS/cm**, with an average value of 266.26 µS/cm. In Vadinar, the EC values showed variation from **113.9 to 499 µS/cm**, with an average value of 306.45 µS/cm. It's important to regularly monitor EC levels in drinking water as it can provide valuable information about water quality and presence of dissolved substances.
- **Salinity:** Salinity at Kandla varies from **0.02 to 0.51 PSU** with an average of 0.14 PSU, while at Vadinar, salinity was observed to be 0.24 and **0.06 PSU** for locations DW-19 & DW-20 respectively.
- **Turbidity:** At the drinking water locations of Kandla, the turbidity was found BQL for all locations except locations DW-3 (0.52 NTU. Whereas, at Vadinar the value of turbidity was reported 0.68 NTU at DW-19 and BQL at DW-20 respectively.
- **Chlorides:** The chloride concentrations in Kandla varied from **4.47 to 203.48 mg/L**, with an average value of 51.34 mg/L. At Vadinar the locations DW-19 and DW-20, the chloride concentration was observed as 71.47 mg/L and 17.87 mg/L, with an average value of 44.67 mg/L. Thus, the chloride levels at both project sites fall within the acceptable limit of 250 mg/L, as specified under IS:10500:2012.
- **Total Hardness (TH):** The concentration of Total Hardness varies from **2.5 to 210 mg/L**, with an average concentration of 54.41 mg/L. At location DW-11, the total hardness was observed 210 mg/L, which exceeds the acceptable limit but falls within the permissible limit. While at Vadinar, the observed values were 130 & 20 mg/L; at locations DW-19 & D-20, with an average concentration of 75 mg/L. which was found to be within the acceptable norm of 200 mg/L as specified by IS:10500:2012 and is not harmful for local inhabitants.
- **Total Dissolved Solids (TDS):** Monitoring TDS is crucial because it provides an indication of overall quality of the water. During the monitoring period, the TDS concentrations in Kandla were observed to vary in a wide range i.e., between 8 to 538 mg/L, with an average concentration of 138.22 mg/L. At Locations DW-11, the TDS

value is 538 mg/L, which is more than the acceptable limit but within the permissible limit. while in Vadinar, it ranged from 60 to 258 mg/L, with an average of 159 mg/L. It is important to note that the TDS concentrations in both Kandla and Vadinar fall well within the acceptable limit of 500 mg/L.

- **Fluoride:** The concentration was found BQL, at all of the monitoring location except for locations DW-11 (0.31 mg/L) at Kandla. While at Vadinar Fluoride concentration was reported to be 0.500 & 0.360 mg/L respectively at both of the monitoring location.
- **Sulphate:** At the monitoring locations of Kandla, the sulphate concentrations were recorded BQL for majority of the locations except the locations DW-3(33.516 mg/L), DW-5 (52.375 mg/L), DW-9 (38.326 mg/L), DW-11 (66.402 mg/L), and DW-16 (21.771 mg/L). In Vadinar, the sulphate concentration was observed 33.620 mg/L at location DW-19 and BQL at location DW-20. During monitoring period in Kandla and Vadinar, the sulphate concentrations were found to be within the acceptable limits i.e., 200 mg/L as per the specified norms.
- **Nitrate:** During the monitoring period, at Kandla & Vadinar variation in the concentration of Nitrate was observed to be in the range of **1.33 to 30.93 mg/L,** with the average concentration of 8.70 mg/L and locations DW-1, DW-2, DW-4, DW-7, DW-8, DW-12, DW-13, DW-16 and DW-18 were recorded as "BQL". While at Vadinar, the concentration recorded 3.584 mg/L at location DW-19 and BQL at location DW-20.
- **Nitrite:** Except locations DW-11 (1.638 mg/L), all monitoring locations showed the Nitrite concentration as BQL at Kandla & Vadinar.
- **Sodium:** During the monitoring period, at Kandla variation in the concentration of Sodium was observed to be in the range of **10.72 to 109.58 mg/L**, with the average concentration of 42.50 mg/L and Location DW-1, DW-2, DW-4, DW-7 & DW-8 showed the BQL concentration for Sodium. While at Vadinar, the concentration recorded 54.54 mg/L at DW-19 and 17.05 mg/L at DW-20.
- **Odour:** Odour values recorded 1 TON at all monitoring locations of Kandla and Vadinar.
- **Arsenic:** In Kandla & Vadinar, the Arsenic concentrations were recorded BQL for all of the locations.
- **Copper:** In Kandla & Vadinar, the Copper concentrations were recorded BQL for all of the locations.
- **Iron:** Except for locations DW-4 (0.119 mg/L), DW-10 (0.126 mg/L), DW-12 (0.872 mg/L), DW-14 (0.121 mg/L), DW-16 (0.252 mg/L), and DW-18 (0.109 mg/L), the other locations were observed to have concentrations Below the detection Limit at Kandla. Whereas, at Vadinar the Copper concentrations were recorded 0.128 mg/L & BQL for locations DW-19 and DW-20 respectively.
- **Lead:** In Kandla & Vadinar, the Lead concentrations were recorded BQL for all of the locations.
- **Manganese:** All of locations observed to have BQL concentration for both the monitoring locations at Kandla and Vadinar except the location DW-8 (0.059 mg/L).
- **Free Residual Chlorine:** Free Residual Chlorine concentrations at all monitoring locations, including Kandla and Vadinar, were observed to be below quantifiable limits (BQL) except at location DW-11, where a concentration of 4.96 mg/L was

recorded. According to health standards, concentrations exceeding 4 mg/L are considered unsafe for human health, potentially leading to adverse health effects.

- The parameters such as **Free Residual Chlorine, Toal Suspended Solid, Potassium Hexavalent Chromium** and **the metals (Cadmium, Mercury, Total Chromium and Zinc)** were all observed to have concentrations "Below the Quantification Limit (BQL)" at majority of the locations during the monitoring period.
- Bacteriological Analysis of the drinking water reveals that **Total Coliforms (TC)** were detected in higher number at location DW-1 (5110 MPN/100ml), DW-11 (4250 MPN/100ml), DW-15 (3400 MPN/100ml), DW-5 (3110 MPN/100ml) & DW-8 (2018 MPN/100ml). Whereas, TC were also detected at locations DW-2 (380 MPN/100ml), DW-3 (695 MPN/100ml), DW-6 (130 MPN/100ml), DW-7 (10 MPN/100 ml), DW-9 (1060 MPN/100 ml), DW-13 (35 MPN/100 ml), DW-17 (385 MPN/100 ml), DW-18 (85 MPN/100 ml), DW-19 (75 MPN/100 ml) and DW-20 (5 MPN/100 ml) and for the rest of the monitoring locations of Kandla and Vadinar were detected "Below the Quantification Limit (BQL)". Reporting such concentration of Coliforms indicates certain external influx may contaminate the source. Hence, it should be checked at every distribution point.

8.4 Remedial Measures

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

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

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

CHAPTER 9: SEWAGE TREATMENT PLANT MONITORING

9.1 Sewage Treatment Plant (STP) Monitoring:

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

Table 23: Details of the monitoring locations of STP

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

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

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

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

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

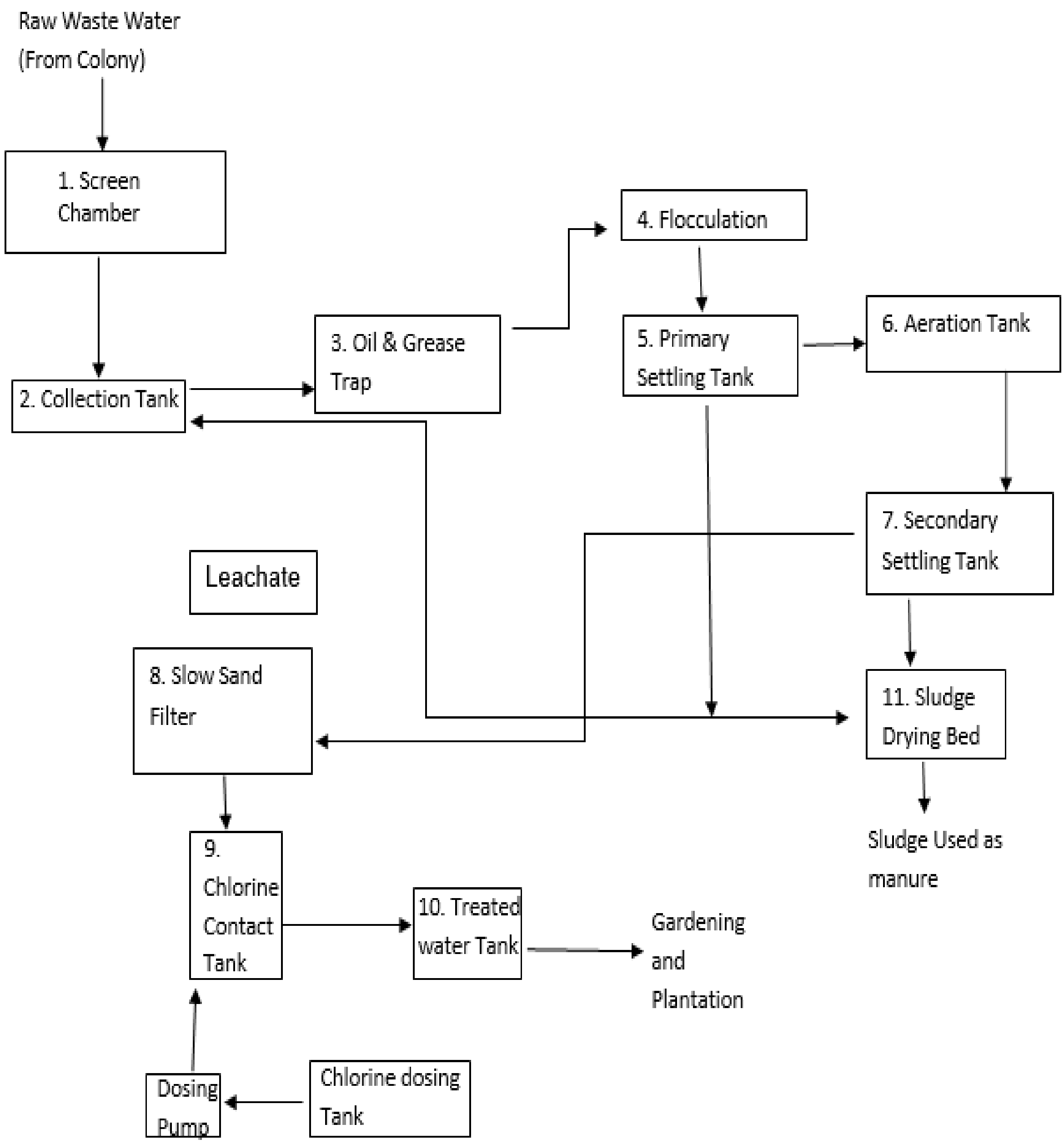


Figure 3: Process flow diagram of STP at Kandla

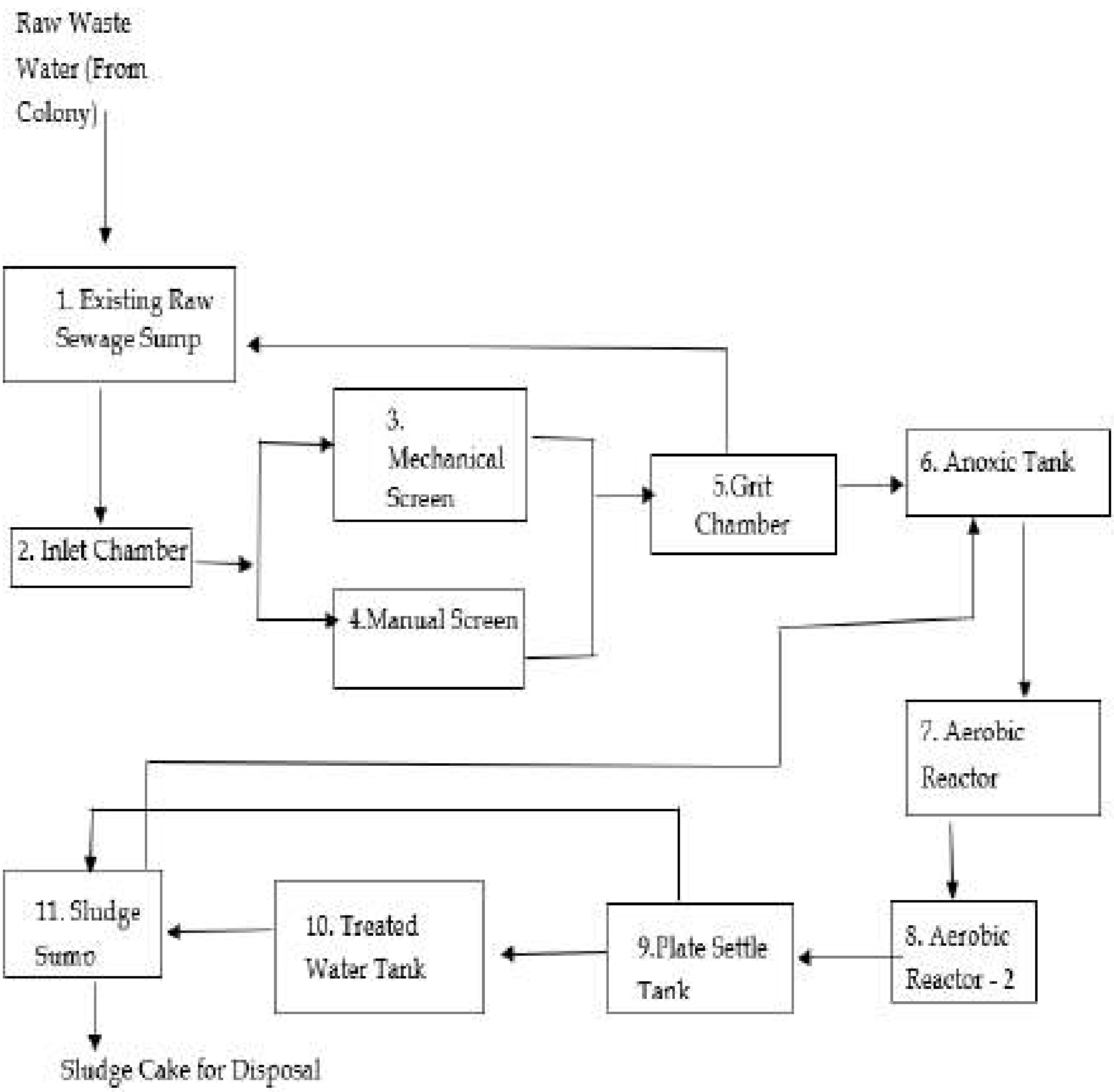


Figure 4: Process flow diagram of STP at Gopalpuri

<u>STP at Vadinar</u>

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

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

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

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

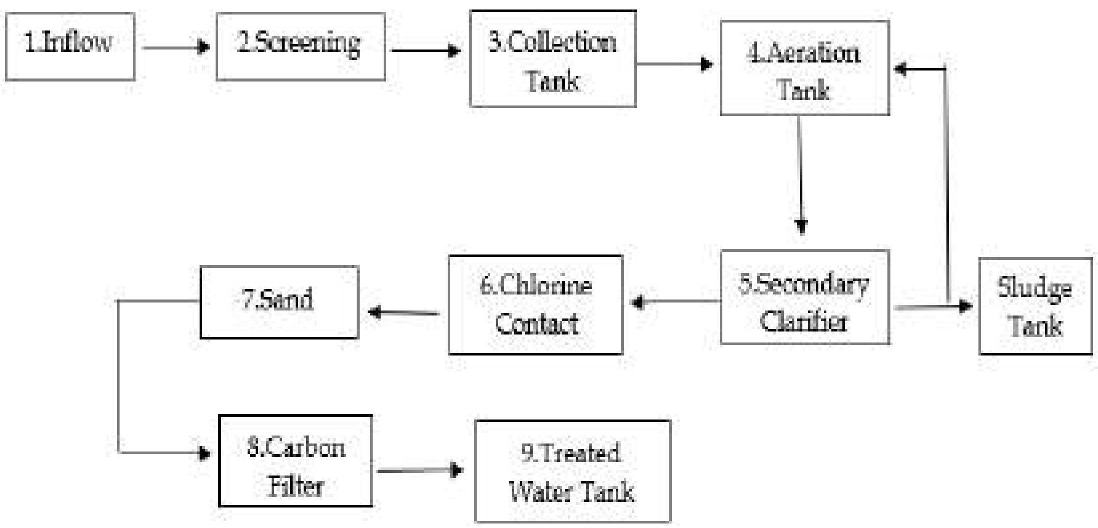
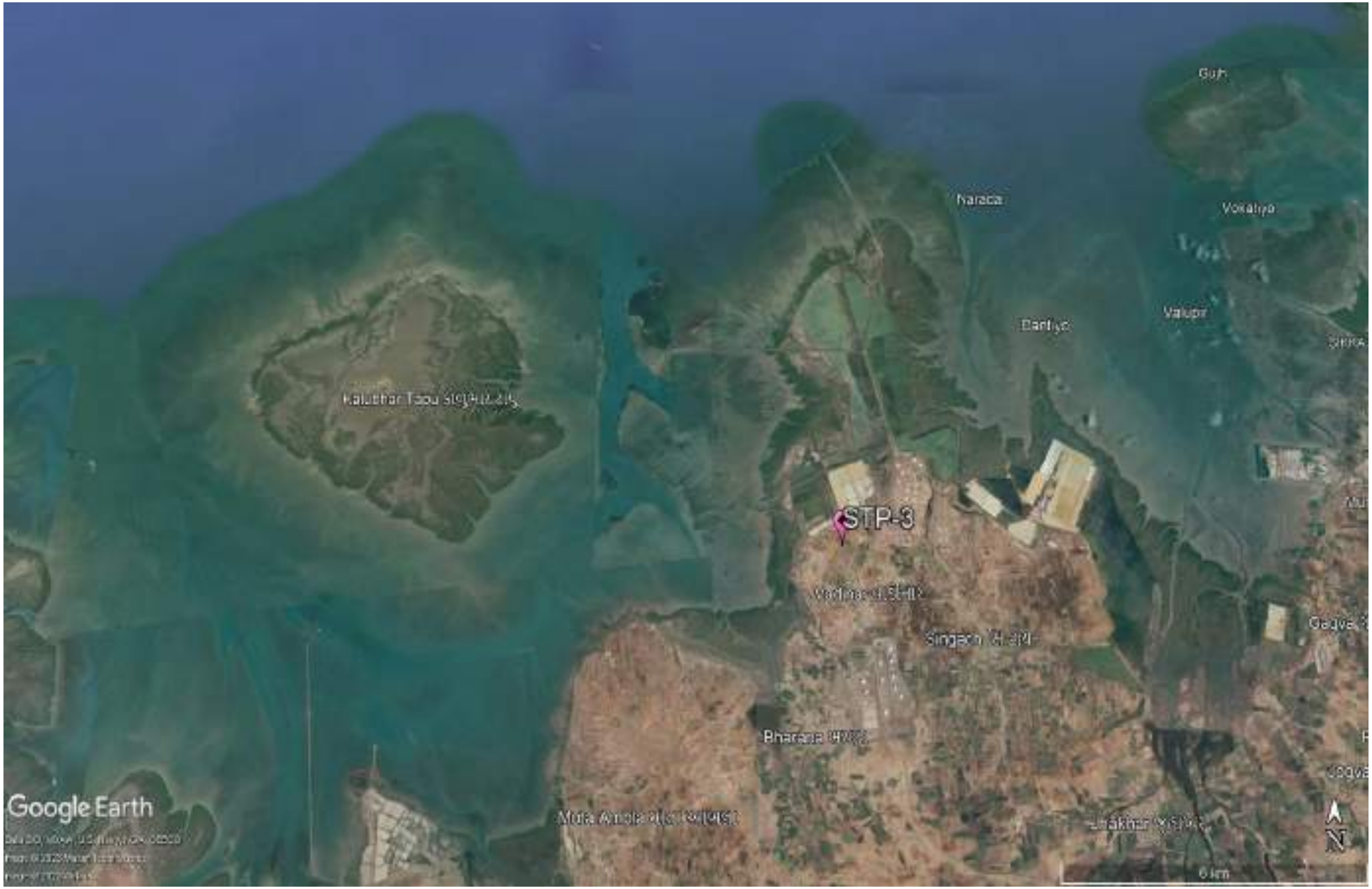


Figure 5: Process flowchart for the STP at Vadinar

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

Map 14: Locations for STP Monitoring at Kandla



Map 15: Locations for STP Monitoring at Vadinar

Methodology

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

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

Frequency

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

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

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

9.2 Result and Discussion

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

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

Sr No.	Parameter	Units	GPCB Norms (Kandla)	Kandla															
				Week 3 of June				Week 4 of June				Week 1 of July				Week 2 of July			
				STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)	STP-1 (Inlet)	STP-1 (Outlet)	STP-2 (Inlet)	STP-2 (Outlet)
1.	pH	-	**6.5-8.5**	7.02	7.22	7.08	7.36	7.18	7.41	7.12	7.29	7.22	7.56	7.08	7.21	7.12	7.48	6.94	7.48
2.	TDS	mg/L	-	1896	1438	708	682	3948	3583	977	745	1869	1624	766	498	6643	3814	962	894
3.	TSS	mg/L	**100**	126	8	88	10	88	12	126	18	72	14	108	10	78	6	62	8
4.	COD	mg/L	-	249	92.4	257	52.2	229	66.47	236	42.7	173.7	66.21	385.7	54.7	233	71.2	184	52
5.	DO	mg/L	-	BQL	5	BQL	3	BQL	4.8	BQL	4.2	BQL	3.9	BQL	5.4	BQL	2.3	BQL	4
6.	BOD	mg/L	**30**	77.81	11.55	80.32	6.53	71.19	14.16	87.19	9.26	68.34	8.27	118.54	7.59	79.46	6.89	57.5	6.5
7.	SAR	meq/L	-	10.69	8.54	4	3.58	18.47	13.91	7.41	5.34	8.79	8.13	4.92	2.78	16.72	5.63	4.75	5.14
8.	Total Coliforms	MPN/ 100ml	**<1000**	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600	1600

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

Sr No.	Parameter	Units	GPCB Norms (Vadinar)	Week 3 of June		Week 4 of June		Week 1 of July		Week 2 of July	
				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**	7.21	7.07	7.22	7.04	7.24	7.05	7.2	7.48
2.	TDS	mg/L	-	584	578	532	442	436	378	452	366
3.	TSS	mg/L	**20**	8	4	8	2	12	6	18	4
4.	COD	mg/L	**50**	116.9	36.3	149.2	52.4	132	52	148.6	36.1
5.	DO	mg/L	-	BQL	4.5	BQL	5.6	BQL	7	0.9	7.8
6.	BOD	mg/L	**10**	36.53	4.54	46.63	6.55	39.6	7.8	46.44	6.77
7.	SAR	meq/L	-	3.08	2.59	3.51	2.96	2.32	2.2	2.4	1.99
8.	Total Coliforms	MPN/100ml	**100-230**	1600	1600	1600	1600	1600	1600	1600	1600

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

9.3 Data Interpretation and Conclusion

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

- The **pH** of treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) conform to their respective stipulated norms of 7.21-7.56 at Kandla and 7.04–7.48 at Vadinar respectively.
- The **TDS** of treated sewage at Kandla was ranges from 498 to 3814 mg/L, whereas for Vadinar it ranges from 366 to 578 mg/L.
- The **TSS** of the Treated effluent for the STP-1 and STP-2 at Kandla and STP-3 at Vadinar falls within the stipulated norms of 100 and 20 mg/L respectively as mentioned in their respective CCA.
- **COD** value for Kandla was observed in the range of 42.7 to 92.4 mg/L. Whereas for Vadinar the value of COD falls within the range of 36.1 – 52.4 mg/L, and conforms the CCA norms of 50 mg/L, except the 4th & 1st week sample of June & July.
- The value of **DO** was observed in the range of 2.3 to 5.4 mg/L, whereas for Vadinar it was observed in the range of 4.5 to 7.8 mg/L.
- The **BOD** of the outlet for the STPs of Kandla and Vadinar falls within the stipulated norms.
- The value of **SAR** for Kandla was observed in the range of 2.78 to 13.91 meq/L, whereas for Vadinar, it was observed in the range of 1.99 to 2.96 meq/L.
- The **Total Coliforms** was observed to exceed the norms at the locations of the STP-1 & STP-2 for the treated effluent at Kandla and STP-3 at Vadinar.

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

9.4 Remedial Measures:

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

reagent (hydrogen peroxide and iron catalyst) and UV/H_2O_2 treatment can help in reducing COD through oxidation.

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

CHAPTER 10: MARINE WATER QUALITY MONITORING

10.1 Marine Water

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

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

Table 29: Details of the sampling locations for Marine water

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

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

Map 16: Locations for Marine Water Monitoring at Kandla

Map 17: Locations for Marine Water Monitoring at Vadinar

Methodology

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

Frequency:

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

Table 30: List of parameters monitored for Marine Water

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

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

10.2 Result and Discussion

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

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

Sr. No.	Parameters	Unit	Primary Water Quality Criteria for Class SW-IV Waters	Kandla						Vadinar	
				MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8
1.	Density	kg/m³	-	1.018	1.024	1.022	1.019	1.02	1.023	1.02	1.023
2.	pH	-	6.5-9.0	7.79	7.89	7.85	7.80	7.79	7.82	7.83	7.88
3.	Color	Hazen	No Noticeable	5	5	5	5	5	5	5	1
4.	EC	µS/cm	-	62,600	57,800	59,400	60,500	61,500	58,900	53,300	55,100
5.	Turbidity	NTU	-	>500	150	>500	323	>500	424	11.7	18.2
6.	TDS	mg/L	-	42,638	39,356	41,264	41,884	42,728	43,544	36,178	37,296
7.	TSS	mg/L	-	744	152	568	348	608	348	12	14
8.	COD	mg/L	-	68.1	58.7	89.4	60.4	88.5	80.9	57.9	46.8
9.	DO	mg/L	3.0 mg/L	5.7	6.2	5.5	5.6	5.6	5.8	6.5	7.8
10.	BOD	mg/L	5.0 mg/L	4.26	3.67	5.59	3.78	5.53	5.05	3.62	5.85
11.	Oil & Grease	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
12.	Sulphate	mg/L	-	3444.7	3473.1	3160.3	3452.6	3344	3045.9	3041.8	2772.6
13.	Nitrate	mg/L	-	4.144	3.599	4.578	3.678	5.200	3.834	2.963	2.371
14.	Nitrite	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
15.	Phosphate	mg/L		0.901	BQL	BQL	BQL	BQL	BQL	BQL	BQL
16.	Silica	mg/L	-	4.23	3.67	3.15	3.75	4.74	3.94	1.80	1.60
17.	Sodium	mg/L	-	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000	>10,000
18.	Potassium	mg/L	-	444	336	454	428	419	441	382	384
19.	Hexavalent Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
20.	Odour	-	-	1	1	1	1	1	1	1	1
21.	Arsenic	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
22.	Cadmium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
23.	Copper	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
24.	Iron	mg/L	-	4.477	0.970	3.887	2.861	4.058	2.876	BQL	0.225
25.	Lead	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
26.	Manganese	mg/L	-	0.17	BQL	0.14	0.094	0.16	0.10	BQL	BQL
27.	Total Chromium	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
28.	Zinc	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
29.	Mercury	mg/L	-	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
30.	Particulate Organic Carbon	mg/L	-	4.82	1.27	3.92	2.86	3.26	4.28	0.08	BQL
31.	Total Coliforms	MPN/ 100ml	500/100 ml	8	2	2	1600	13	4	BQL	9

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	1.018	1.024	1.022	1.019	1.02	1.023	1.02	1.023

10.3 Data Interpretation and Conclusion

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

- **Density** at Kandla was observed in the range of **1.018 to 1.024 kg/m³**, with the average of 1.021 **kg/m³.** Whereas for the location of Vadinar, it was observed 1.02 **kg/m³** at MW-7 and 1.023 **kg/m³** at MW-8, with the average of 1.021 **kg/m³**.
- **pH** at Kandla was observed in the range of **7.79 to 7.89**, with the average pH as 7.89. Whereas for the locations of Vadinar, it was observed in the range of be **7.83 to 7.88**, with the average pH as 7.85. For the monitoring location of both the study areas, pH was found to comply with the norms of 6.5-8.5.
- **Color** range varied from **5 Hazen** at all the monitoring locations in Kandla, and for Vadinar, it found **5 Hazen** at MW-7 and **1 Hazen** at MW-8 location.
- **Electrical conductivity (EC)** was observed in the range of **57,800 to 62,600 µS/cm**, with the average EC as 60116.7 µS/cm for the locations of Kandla, whereas for the locations of Vadinar, it was observed in the range of **53,300 to 55,100 µS/cm**, with the average EC as 54,200µS/cm.
- For all monitoring locations of Kandla the value of **Turbidity** was observed in the range of **150 to 424 NTU**, with average value of 299 NTU, and location MW-1, MW-3 & MW-5 exceeds the quantification limit of 500 NTU. For Vadinar it ranges from **11.7 to 18.2 NTU**, with average of 14.95 NTU. Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and microscopic organisms. Turbidity affects the amount of light penetrating to the plants for photosynthesis.
- For the monitoring locations at Kandla the value of **Total Dissolved Solids (TDS)** ranged from **39,356 to 43,544 mg/L**, with an average value of 41,902.3 mg/L. Similarly, at Vadinar, the TDS values ranged from **36,178 to 37,296 mg/L**, with an average value of 36,737 mg/L.

- **TSS** values in the studied area varied between **152 to 744 mg/L** at Kandla and **12 to 14 mg/L** at Vadinar, with the average value of 461.33 mg/L and 13 mg/L respectively for Kandla and Vadinar.
- **COD** varied between **58.7 to 89.4 mg/L** at Kandla and **46.8 to 57.9 mg/L** at Vadinar, with the average value as 74.33 mg/L and 52.35 mg/L respectively for Kandla and Vadinar.
- **DO** level in the studied area varied between **5.5 to 6.2 mg/L** at Kandla and **6.5 to 7.8 mg/L** at Vadinar, with the average value of 5.73 mg/L and 7.15 mg/L respectively for Kandla and Vadinar. Which represents that the marine water is suitable for marine life.
- **BOD** observed was observed in the range of **3.67 to 5.59 mg/L**, with average of 4.64 mg/L for the location of Kandla and for the locations of Vadinar, it was observed in the range of **3.62 to 5.85 mg/L**, with an average value of 4.73 mg/L.
- **Sulphate** concentration in the studied area varied between **3045.9 to 3473.1 mg/L** at Kandla and **2772.6 to 3041.8 mg/L** at Vadinar. The average value observed at Kandla was 3320.1 mg/L, whereas 2907.2 mg/L was the average value of Vadinar. Sulphate is naturally formed in inland waters by mineral weathering or the decomposition and combustion of organic matter.
- **Nitrate** in the study area was observed in the range of **3.59 to 5.2 mg/L**, with the average of 4.17 mg/L. Whereas for the Vadinar, recorded value was observed as 2.96 mg/L at MW-7 and 2.37 mg/L at MS-8.
- In the study area of Kandla the concentration of **Potassium** varied between **336 to 454 mg/L** and **382 to 384 mg/L** at Vadinar, with the average value as 420.33 mg/L and 383 mg/L respectively for Kandla and Vadinar.
- **Silica** in the studied area varied between **3.15 to 4.74 mg/L**, with the average of 3.91 mg/L, at Kandla. Vadinar, observed value was found to be 1.80 mg/L at MW-7 and 1.60 mg/L at MS-8 locations.
- **Sodium** in the study area at both Kandla & Vadinar the sodium concentration value recorded Above the quantification limit.
- **Odour** was observed 1 for all locations of Kandla and Vadinar.
- **Copper** at the Kandla site as well as both locations at the Vadinar site, had levels below the quantification limit (BQL)."
- **Iron** in the studied area varied between **0.97 to 4.47 mg/L**, with the average of 3.18 mg/L, at Kandla, and for Vadinar value were recorded BQL for location MW-7 and 0.225 mg/L for location MW-8.
- **Lead** concentration was observed BQL at both site of Kandla & Vadinar.
- **Manganese** in the studied area varied between **0.094 to 0.17 mg/L**, with the average of 0.13 mg/L, at Kandla. At Vadinar both location MW-7 and MW-8 observed BQL.
- **Particulate Organic Carbon** in the study area was observed in the range of **1.27 to 4.82**, with the average value of 3.40. Whereas for the Vadinar, the value observed was 0.08 at MW-7 and BQL at MW-8.
- **Oil & Grease, Nitrite, Phosphate, Hexavalent Chromium, Arsenic, Cadmium, Total Chromium, Zinc, Mercury and Floating Material (Oil grease scum, petroleum**

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

- **Total Coliforms** were detected complying with the specified norm of 500 MPN/100ml for all the locations of Kandla and Vadinar, except the location MW-4, which is 1600 MPN/100ml.

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

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

CHAPTER 11: MARINE SEDIMENT QUALITY MONITORING

11.1 Marine Sediment Monitoring

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

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

Methodology

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

Table 32: Details of the sampling locations for Marine Sediment

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

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

Map 18: Location of Marine Sediment Monitoring at Kandla

Map 19: Locations of Marine Sediment Monitoring at Vadinar

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

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

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

11.2 Result and Discussion

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

Table 34: Summarized result of Marine Sediment Quality

Sr No.	Parameters	Unit	Kandla						Vadinar	
			MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Inorganic Phosphate	kg/ ha	2.12	2.41	3.64	2.88	3.42	1.71	1.85	1.06
2.	Phosphate	mg/Kg	288.72	329.62	467.84	363.18	319.45	213.507	217.339	339.31
3.	Organic Matter	%	1.12	1.36	1.02	1.28	0.94	1.43	1.13	1.52
4.	Sulphate as SO^{4-}	mg/Kg	170.55	146.88	133.90	122.57	189.41	169.42	145.05	126.34
5.	Calcium as Ca	mg/Kg	3680.00	3850.00	4600.00	4100.00	3740.00	3500.00	3400.00	3800.00
6.	Magnesium as Mg	mg/Kg	1928.00	2473.00	2541.00	2849.00	2473.00	1342.00	976.00	1865.00
7.	Silica	g/Kg	519.37	521.29	534.91	546.62	554.35	523.5	507.02	534.29
8.	Nitrite	mg/Kg	0.68	0.79	0.61	0.72	0.77	0.29	0.22	0.31
9.	Nitrate	mg/Kg	6.83	7.42	6.21	5.88	6.12	15.28	11.6	5.79
10	Sodium	mg/Kg	8190	10687	7526	13760	9149	11972	9548	12586
11	Potassium	mg/Kg	2671	2149	2375	3460	2549	6376	4447	1172
12	Aluminium	mg/Kg	7234.11	6841.64	8423.36	9864.22	7246.18	12327.688	10215.74	12643.2
13	Chromium	mg/Kg	49.21	53.46	52.15	56.51	48.72	50.009	48.941	86.61
14	Copper	mg/Kg	5.52	5.63	5.75	6.29	5.31	48.227	30.463	4.25
15	Nickel	mg/Kg	24.87	21.79	25.48	27.62	26.73	29.24	22.776	24.37
16	Zinc	mg/Kg	58.75	52.4	61.85	82.41	55.12	62.49	41.691	40.85
17	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
18	Lead	mg/Kg	6.08	6.41	6.19	6.77	6.28	6.54	2.97	4.494
19	Arsenic	mg/Kg	4.61	4.82	4.58	4.72	4.42	4.61	1.485	2.497
20	Mercury	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL
21	Texture	-	Sandy loam	Sandy loam	Silt loam	Sandy loam	Silt loam	Silt loam	Sandy loam	Loam

11.3 Data Interpretation and Conclusion

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

- **Inorganic Phosphate** for the sampling period was observed in range of **2.12 to 3.64** Kg/ha for Kandla. Whereas for Vadinar the value observed at location MS-7 (Nakti creek) is 1.71 Kg/ha and MS-8 (Near Vadinar Jetty) is 1.85 Kg/ha. For Kandla and Vadinar the average value of Inorganic Phosphate was observed 2.81 and 1.78 Kg/ha respectively.

- The concentration of **Phosphate** was observed in range of **288.72 to 467.84 mg/Kg** for Kandla and for Vadinar the value observed at location MS-7 (Nakti creek) as 213.507 mg/Kg and MS-8 (Near Vadinar Jetty) as 217.339 mg/Kg. For Kandla and Vadinar the average concentration of Phosphate was observed 367.238 and 215.423 mg/Kg respectively.
- The **Organic Matter** for the sampling period was observed in the range of **0.94 to 1.36 %** for Kandla with the average value of 1.16% and for Vadinar the value recorded at location MS-7 and MS-8 was observed 1.43% & 1.13% respectively, with average concentration as 1.28 %.
- The concentration of **Sulphate** was observed in the range of **122.57 to 212.27 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 169.42 mg/Kg and at MS-8 is 145.05 mg/Kg. For Kandla and Vadinar the average value of Sulphate was observed 162.596 and 157.235 mg/Kg respectively.
- The value of **Calcium** was observed in the range of 3680 **to 4900 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 3500.00 mg/Kg and at MS-8, is 3400.00 mg/Kg. The average value of Calcium for the monitoring period was observed 4145 mg/Kg and 3450 mg/Kg at Kandla and Vadinar, respectively.
- The value of **Magnesium** for the sampling period was observed in the range of **1928 to 2849 mg/Kg** for Kandla and for Vadinar the value observed at MS-7 is 1342.00 mg/Kg and at MS-8, is 976.00 mg/Kg. For Kandla and Vadinar the average value of Magnesium was observed 2427 mg/Kg and 1159 mg/Kg respectively.
- For the sampling period **Silica** was observed in the range of **519.27 to 559.73 mg/Kg** for Kandla with average value 539.37 mg/Kg and for Vadinar the value observed to be 523.5 and 507.02 mg/Kg at MS-7 and MS-8, respectively with average 515.26 mg/Kg.
- The value of **Nitrate** was observed in the range of **5.88 to 8.19 mg/Kg** for Kandla with average value 6.77 mg/Kg and for Vadinar the value observed to be 15.28 and 11.6 mg/Kg at MS-7 and MS-8, respectively with average 13.44 mg/Kg.
- The value of **Nitrite** was observed in the range of **0.61 to 0.83 mg/Kg** for Kandla with average value 0.73 mg/Kg and for Vadinar the value observed to be 0.29 and 0.22 mg/Kg at MS-7 and MS-8, respectively with average 0.25 mg/Kg.
- The value of **Sodium** was observed in the range of **7526 to 13760 mg/Kg** for Kandla with average value 10327.66 mg/Kg and for Vadinar the value observed to be 11972 and 9548 mg/Kg at MS-7 and MS-8, respectively with average 10760 mg/Kg.
- The value of **Potassium** was observed in the range of **2149 to 3671 mg/Kg** for Kandla with average value 2812.5 mg/Kg and for Vadinar the value observed to be 6376 and 4447 mg/Kg at MS-7 and MS-8, respectively with average 5411.5 mg/Kg.
- The value of **Aluminium**, was observed in the range of **6841.64 to 10157.25 mg/Kg** for Kandla with average value 8294.46 mg/Kg and for Vadinar the value observed to be 12327.68 and 10215.74 mg/Kg at MS-7 and MS-8, respectively with average 11271.7 mg/Kg.

- The value of **Mercury** was observed "Below the Quantification Limit" at all the eight-monitoring location of Kandla and Vadinar.
- Texture was observed to be "**Sandy Loam**" at location MS-1, MS-2, and MS-4 "**Silt loam"** at location MS-3, MS-5 & MS-6 in Kandla. "**Sandy Loam**" at location MS-7 & "**loam"** at location MS-8 in Vadinar during sampling period.

Heavy Metals

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

Table 35: Standard Guidelines applicable for heavy metals in sediments

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

(Source: G Perin et al. 1997)

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

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			MS-1	MS-2	MS-3	MS-4	MS-5	MS-6	MS-7	MS-8
1.	Arsenic	mg/Kg	4.61	4.82	4.58	4.72	4.42	4.61	1.485	2.497
2.	Copper	mg/Kg	5.52	5.63	5.75	6.29	5.31	48.227	30.463	4.25
3.	Chromium	mg/Kg	49.21	53.46	52.15	56.51	48.72	50.009	48.941	86.61
4.	Nickel	mg/Kg	24.87	21.79	25.48	27.62	26.73	29.24	22.776	24.37
5.	Lead	mg/Kg	6.08	6.41	6.19	6.77	6.28	6.54	2.97	4.494
6.	Zinc	mg/Kg	58.75	52.4	61.85	82.41	55.12	62.49	41.691	40.85
7.	Cadmium	mg/Kg	BQL	BQL	BQL	BQL	BQL	BQL	BQL	BQL

- **Arsenic** was observed in the range of **4.42 to 4.82 mg/Kg** for Kandla with average value 4.62 mg/Kg and for Vadinar the value observed to be 1.48 and 2.49 mg/Kg at MS-7 and MS-8, respectively with average 1.99 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to arsenic falls in moderately polluted class.
- **Copper** was observed in the range of **5.31 to 6.54 mg/Kg** for Kandla with average value 5.84 mg/Kg and for Vadinar the value observed to be 48.22 and 30.46 mg/Kg at MS-7 and MS-8, respectively with average 39.74 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to copper falls in non-polluted class.

- **Chromium** was observed in the range of **48.72 to 59.81 mg/Kg** for Kandla with average value 53.31 mg/Kg and for Vadinar the value observed to be 50 and 48.94 mg/Kg at MS-7 and MS-8, respectively with average 49.47 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to chromium falls in moderately polluted class.
- **Nickel** was observed in the range of **21.79 to 29.24 mg/Kg** for Kandla with average value 25.95 mg/Kg and for Vadinar the value observed to be 22.77 and 24.37 mg/Kg at MS-7 and MS-8, respectively with average 38.1mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to nickel falls in moderately polluted class.
- **Lead** was observed in the range of **6.08 to 6.77 mg/Kg** for Kandla with average value 6.37 mg/Kg and for Vadinar the value observed to be 2.97 and 4.49 mg/Kg at MS-7 and MS-8, respectively with average 3.73 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to lead falls in moderately polluted class.
- **Zinc** was observed in the range of **52.4 to 82.41 mg/Kg** for Kandla with average value 62.17 mg/Kg and for Vadinar the value observed to be 41.69 and 40.85 mg/Kg at MS-7 and MS-8, respectively with average 56 mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to zinc falls in non-polluted class.
- **Cadmium** was observed BQL for all locations at Kandla and Vadinar during sampling period. With reference to the guidelines mentioned in table 35, the sediment quality with respect to cadmium falls in non-polluted class.

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

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

CHAPTER 12: MARINE ECOLOGY MONITORING

12.1 Marine Ecological Monitoring

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

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

Table 37: Details of the sampling locations for Marine Ecological

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

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

Map 20: Locations of Marine Ecological Monitoring at Kandla

Map 21: Locations of Marine Ecological Monitoring at Vadinar

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

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

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

Methodology

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

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

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

- **Zooplankton Estimation**

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

- **Benthic Organisms Estimation**

  Benthic macroinvertebrates are small aquatic animals and the aquatic larval stages of insects. They include dragonfly and stonefly larvae, snails, worms, and beetles. Use of benthic macroinvertebrates has been in vogue as indicator organisms for water quality monitoring since long. Traditional methods of water quality monitoring incorporates mostly monitoring of physicochemical parameters. Benthic macroinvertebrates are majorly insects that dwell on the floor of water bodies. They are found in all water bodies, as they have a wide range of pollution tolerance among various species. The benthic macro-invertebrate's community structure depends on the exposure to pollution it receives. Benthic macroinvertebrates have been used as indicator organisms to measure the water quality of water bodies across the world. Evaluating the abundance and variety of benthic macroinvertebrates in a waterbody gives us an indication of the biological condition of that waterbody. Generally, waterbodies in healthy biological condition support a wide variety and high number of macroinvertebrate taxa, including many that are intolerant of pollution. Samples yielding only pollution–tolerant species or very little diversity or abundance may indicate a less healthy waterbody. Biological condition is the most comprehensive indicator of waterbody health. When the biology of a waterbody is healthy, the chemical and physical components of the waterbody are also typically in good condition.

- **Diversity Index**

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

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

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

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

Where, $\sum$ = Summation symbol,

pi = Relative abundance of the species,

ln = Natural logarithm

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

2. **Simpson's index:**

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

The formula for calculating D is presented as:

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

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

3. Margalef's diversity index:

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

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

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

Where, N = total number of individuals collected

S = No. of taxa or species or genera

4. Berger-Parker index:

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

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

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

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

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

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

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

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

Where, H= Shannon value

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

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

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

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

12.2 Result and Discussion

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

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

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
1.	Biomass	mg/L	158	220	92	147	130	108	115	158
2.	Net Primary Productivity	mg/L/hr	0.58	BQL	0.82	BQL	0.72	BQL	BQL	BQL
3.	Gross Primary Productivity	mg/L/hr	1.12	BQL	1.22	0.78	1.19	0.66	0.76	BQL
4.	Pheophytin	mg/m^3	0.88	4	0.78	0.84	1.12	0.97	1.32	BQL

Sr. No.	Parameters	Unit	Kandla						Vadinar	
			ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
5.	Chlorophyll-a	mg/m^3	0.93	1.210	1.87	1.19	1.86	1.52	1.44	1.26
6.	Particulate Oxidisable Organic Carbon	mg/L	1.11	0.78	0.74	0.81	0.92	1.08	0.61	0.62
7.	Secchi Depth	ft	0.62	0.59	0.53	0.71	0.64	0.68	1.05	1.16

- **Biomass:**

  With reference to the **Table 39**, the concentration of **Biomass** reported from location ME-1 to ME-6 in range between **92-220mg/L** where lowest biomass presents in ME-3 (Near Coal Berth) and highest biomass present in ME-2 (Kandla Creek) during sampling period. In Vadinar, the value of biomass was observed 115 mg/L at ME-7 (Near SPM) and 158 mg/L in ME-8 (Near Vadinar Jetty) monitoring station.

- **Productivity (Net and Gross)**

  Gross primary productivity (GPP) is the rate at which organic matter is synthesised by producers per unit area and time (GPP). The amount of carbon fixed during photosynthesis by all producers in an ecosystem is referred to as gross primary productivity. The monitoring location of Kandla reported GPP value in range between **0.66 to 1.22 mg/L/48 Hr** where the highest value recorded for ME-3 and lowest recorded at ME-6 (Nakti Creek (near NH - 8A)). In Vadinar, the value of **GPP** was observed 0.76 at ME-7 (Near SPM) and BQL at ME-8 (Near Vadinar Jetty) monitoring station.

  Net primary productivity, is the amount of fixed carbon that is not consumed by plants, and it is this remaining fixed carbon that is made available to various consumers in the ecosystem. The Net primary productivity of the monitoring location at Kandla from (ME-1 to ME-6) has been estimated to be between **0.58 to 0.82 mg/L/48 Hr**. While in Vadinar, the value of **NPP** was observed BQL at ME-7 (Near SPM) and ME-8 (Near Vadinar Jetty) monitoring station.

- **Pheophytin**

  The level of Pheophytin was detected in the range from **0.78 to 4 mg/m^3** where the highest value observed at ME-2 (Kandla Creek (near KPT Colony)) and the lowest value observed at ME-3 (Near Coal Berth). While in Vadinar, the value of Pheophytin was observed 1.32mg/m^3 at ME-7 and BQL at ME-8 monitoring station.

- **Chlorophyll-a**

  In the sub surface water, the value of Chlorophyll-a reported in range from **0.93 to 1.87 mg/m^3**. The highest value observed at ME-3 (Near Coal Berth) while the lowest value observed at ME-1 (Near Passenger Jetty One). In Vadinar, the value of chlorophyll-a was observed 1.44 mg/m^3 at ME-7 (Near SPM) and 1.26 mg/m^3 in ME-8 (Near Vadinar Jetty) monitoring station.

- **Particulate Oxidisable Organic Carbon**

During the sampling period, the particulate oxidisable organic carbon falls within the range of **0.74 to 1.11 mg/L** from monitoring location ME-1 to ME-6 at Kandla, whereas for Vadinar, the value of POC observed 0.61 mg/L at ME-7 (Near SPM) and 0.62 mg/L in ME-8 (Near Vadinar Jetty) monitoring station.

- **Secchi Depth**

  In monitoring station of Kandla (ME-1 to ME-6) the level of Secchi Depth was observed between **0.53 to 0.71 ft** whereas at Vadinar, the value recorded at ME-7 i.e. Near SPM is 1.05 ft and in Near Vadinar Jetty is 1.16 ft.

Ecological Diversity

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

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

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

Genera	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Bacillaria sp.	-	253	-	-	258	155	-	-
Biddulphia sp.	219	-	377	116	-	-	129	211
Chaetoceros sp.	-	-	-	-	119	-	-	-
Chlamydomonas sp.	189	129	-	268	-	262	355	282
Cyclotella sp.	202	-	324	-	143	-	-	-
Coscinodiscus sp.	-	156	-	179	-	154	166	197
Ditylum sp	225	-	170	-	-	-	-	-
Fragilaria sp.	-	344	-	-	264	255	-	208
Bacteriastrum sp.	176	-	432	202	187	-	345	-
Pleurosigma sp.	-	181	-	-	-	192	-	-
Navicula sp.	281	-	186	-	246	-	-	149
Merismopedia sp.	-	191	-	161	-	164	250	-
Synedra sp.	217	-	-	-	266	-	-	-
Skeletonema sp.	-	131	-	153	-	238	-	294
Oscillatoria sp.	-	-	166	-	169	-	192	-
Thallassiosira	297	198	-	232	-	356	-	189
Gomphonema sp.	-	-	158	-	188	-	221	-
Density-Units/L	**1806**	**1583**	**1813**	**1311**	**1840**	**1776**	**1658**	**1530**
No. of genera	**8**	**8**	**7**	**7**	**9**	**8**	**7**	**7**

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

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from 1311 to 1840 units/L, while for Vadinar its density of phytoplankton observed 1658 units/L at ME-7 and 1530 units/L at ME-8. During the sampling, phytoplankton communities were dominated by *Thallassiosira* and *Cyclotella sp*. in Kandla, while *Chlamydomonas sp*. in Vadinar.

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

Table 41: Species richness Index and Diversity Index in Phytoplankton

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	8	8	7	7	9	8	7	7
Individuals	1806	1583	1813	1311	1840	1776	1658	1530
Shannon diversity	2.06	1.89	1.87	1.62	2.18	2.02	1.81	1.77
Simpson 1-D	0.87	0.86	0.83	0.85	0.88	0.86	0.84	0.85
Species Evenness	0.99	0.91	0.96	0.83	0.99	0.97	0.93	0.91
Margalef richness	0.93	0.95	0.80	0.84	1.06	0.94	0.81	0.82
Berger-Parker	0.16	0.22	0.24	0.20	0.14	0.20	0.21	0.19
Relative abundance	0.44	0.51	0.39	0.53	0.49	0.45	0.42	0.46

- **Shannon- Wiener's Index (H)** of phytoplankton communities was in the range of **1.62 to 2.18** between selected sampling stations from ME-1 to ME-6 with an average value of 1.94 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of phytoplankton communities recorded to be **1.81** at location ME-7 and **1.77** at ME-8 with an average value of 1.79. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla.

- **Simpson diversity index (1-D)** of phytoplankton communities was ranged between **0.83 to 0.88** at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.86 Similarly, for Vadinar Simpson diversity index (1-D) of phytoplankton communities was 0.84 at location ME-7 and 0.85 at ME-8 with an average of 0.85.

- **Margalef's diversity index** (Species Richness) of phytoplankton communities in Kandla and nearby creeks sampling stations was varying from **0.80 to 1.06** with an average of 0.92 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of phytoplankton communities observed 0.81 at ME-7 and 0.82 at ME-8 with an average value of 0.82.

- **Berger-Parker Index (d)** of phytoplankton communities was in the range of **0.14 to 0.24** between selected sampling stations from ME-1 to ME-6 with an average value of 0.19 at Kandla creek and nearby creeks. Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of 0.19to 0.21 with an average value of 0.20. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.83 to 0.99** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed 0.93 at location ME-7 & 0.91 at ME-8 location.

- During the sampling period, **Relative Abundance** of phytoplankton communities was in range of **0.39 to 0.53** between selected sampling stations from ME-1 to ME-6 with an average value of 0.47 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 0.42 at ME-7 and 0.46 at ME-8 with an average value 0.44, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

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

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

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

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

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

Table 43: Species richness Index and Diversity Index in Zooplankton

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	6	6	5	6	6	6	6	6
Individuals	8	8	7	8	8	8	8	7
Shannon diversity	1.73	1.73	1.47	1.73	1.73	1.73	1.73	1.65
Simpson (1-D)	0.93	0.93	0.9	0.93	0.93	0.93	0.93	0.95
Species Evenness	0.97	0.97	0.91	0.97	0.97	0.97	0.97	0.92
Margalef	2.4	2.4	2.06	2.4	2.4	2.4	2.4	2.57
Berger-Parker	0.25	0.25	0.29	0.25	0.25	0.25	0.25	0.29
Relative abundance	75	75	71.43	75	75	75	75	85.71

- **Shannon- Wiener's Index (H)** of zooplankton communities was in the range of **1.47 to 1.73** between selected sampling stations from ME-1 to ME-6 with an average value of 1.68 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of zooplankton communities recorded to be 1.73 at ME-7 and 1.65 at ME-8 with an average value of 1.69. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Near SPM (Vadinar).

- **Simpson diversity index (1-D)** of zooplankton communities was ranged between **0.9 to 0.93** at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.92 Similarly, for Vadinar Simpson diversity index (1-D) of zooplankton communities was 0.93 at ME-7 and 0.95 at ME-8 with an average of 0.94.

- **Margalef's diversity index** (Species Richness) of zooplankton communities in Kandla and nearby creeks sampling stations was varying from **2.06 to 2.4** with an average of 2.34 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of zooplankton communities observed 2.4 at ME-7 and 2.57 at ME-8 with an average value of 2.48.

- **Berger-Parker Index (d)** of zooplankton communities was in the range of **0.25 to 0.29** between selected sampling stations from ME-1 to ME-6 with an average value of 0.25 at Kandla creek and nearby creeks. Berger-Parker Index (d) of zooplankton communities in the sampling stations of Vadinar, was in the range of 0.25 to 0.29 with an average value of 0.27. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The **Species Evenness** is observed in the range of **0.91 to 0.97** for all the six-monitoring station of Kandla whereas, for the Vadinar the species evenness was observed in the range of 0.92 to 0.97, during the monitoring month.

- During the sampling period, **Relative Abundance** of zooplankton communities was in range of 71.43 to 75 between selected sampling stations from ME-1 to ME-6 with an average value of 74.40 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 75 at ME-7 and 85.71 at ME-8 with an average value 80.36, thus it can be concluded that the studied species is stated as neither highly dominant nor rare.

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

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

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

Family/Class	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Gammaridae	-	-	-	-	1	2	-	-
Portunidae	-	-	1	-	-	-	-	-
Turbinidae	2	1	1	1	1	1	1	-
Palaemonidae	-	-	-	-	1	-	1	-
No. of Family	**7**	**5**	**7**	**7**	**7**	**7**	**7**	**9**
No of Class	**5**	**4**	**6**	**5**	**6**	**5**	**6**	**4**

Few Benthic organisms were observed in the collected sample by using the Van-Veen grabs during the sampling conducted for DPA Kandla and Vadinar. Majority of the species were found under the Macro-benthic organisms during the sampling period were represented by *Odonta, Portunidae sp.*, etc. The No. of Family of benthic fauna was varying from 5 to 9. The dominating benthic communities at Kandla Creek and nearby creek (Nakti and Khori creek) were represented Atydae, Turbinidae. While lowest number of benthic species was represented by Portunidae.

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

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

Indices	ME-1	ME-2	ME-3	ME-4	ME-5	ME-6	ME-7	ME-8
Taxa S	5	4	6	5	6	5	6	4
Individuals	7	5	7	7	7	7	7	9
Shannon diversity	1.55	1.19	1.75	1.55	1.75	1.55	1.75	1.36
Simpson 1-D	0.9	0.9	0.95	0.9	0.95	0.9	0.95	0.81
Species Evenness	0.96	0.86	0.98	0.96	0.98	0.96	0.98	0.98
Margalef	2.06	1.86	2.57	2.06	2.57	2.06	2.57	1.37
Berger-Parker	0.29	0.4	0.29	0.29	0.29	0.29	0.29	0.33
Relative abundance	71.43	80	85.71	71.43	85.71	71.43	85.71	44.44

- **Shannon- Wiener's Index (H)** of benthic organism was in the range of **1.19 to 1.75** between selected sampling stations from ME-1 to ME-6 with an average value of 1.55 at Kandla creek and its nearby creeks. While for Vadinar, Shannon Wiener's index of benthic organism recorded to be 1.75 at ME-7 & 1.36 at ME-8 location with an average value of 1.55. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Vadinar.

- **Simpson diversity index (1-D)** of benthic organism was ranged between **0.9 to 0.95** at all sampling stations in the Kandla creek and nearby creeks, with an average of 0.91. Similarly, for Vadinar Simpson diversity index (1-D) of benthic organism was 0.95 at ME-7 and 0.81 at ME-8 location with an average of 0.88.

- **Margalef's diversity index** (Species Richness) of benthic organism in Kandla and nearby creeks sampling stations was varying from **1.86 to 2.57** with an average of 2.19 during the sampling period. While for Vadinar, Margalef's diversity index (Species Richness) of benthic organism observed to be 2.57 at ME-7 and 1.37 at ME-8 location with an average of 1.97.

- **Berger-Parker Index (d)** of benthic organism was in the range of **0.29 to 0.4** between selected sampling stations from ME-1 to ME-6 with an average value of 0.30 at Kandla creek and nearby creeks. Berger-Parker Index (d) of benthic organism in the sampling stations of Vadinar, was observed to be 0.29 at ME-7 and 0.33 at ME-8 location with an average value of 0.31. All the monitoring station signifies a low diversity with an even distribution among the different species.

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

- During the sampling period, **Relative Abundance** of Benthic organisms was in range of **71.43 to 85.71** between selected sampling stations from ME-1 to ME-6 with an average value of 77.61 at Kandla creek and nearby creeks. Whereas for Vadinar the Index value 85.71 at ME-7 and 44.44 at ME-8 location, with an average value 65.08, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla


STP Monitoring


Noise Monitoring


Soil Monitoring


Marine Monitoring


Air Monitoring


Drinking Water Monitoring

Annexure 2: Photographs of the Environmental Monitoring conducted at Vadinar

Air Monitoring

Noise Monitoring

STP Monitoring

Drinking water Monitoring

Marine Monitoring

Soil Monitoring

Source: GEMI

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"We Provide Environmental Solutions"

ANNEXURE E
Final Report of Waste Management

WASTE MANAGEMENT PLAN

A comprehensive Plan for management of Plastic Waste, Solid Waste, C&D Waste, E-waste, Hazardous Waste including Bio-medical Waste and Non-hazardous waste in the Deendayal Port Authority Area

Prepared For:

Deendayal Port Authority

Prepared By:

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DISCLAIMER

This report has been prepared by Gujarat Environment Management Institute (GEMI), solely as a part of the assignment "Preparation of Plan for management of Plastic Waste, Solid Waste, C&D Waste, E-waste, Hazardous Waste including Bio-medical Waste and Non-hazardous waste in the Deendayal Port Authority Area". This report is based on the data and information furnished by DPA and GEMI is not responsible for the accuracy and correctness of the same. GEMI has taken all reasonable precautions in the preparation of this report. However, it is impossible to dismiss absolutely, the possibility of errors or omissions. GEMI therefore specifically disclaims any liability resulting from the use or application of the information contained in this report.

About this Document

Name of the Document:	Plan for Management of Plastic Waste, Solid Waste, C&D Waste, E-waste, Hazardous Waste including Bio-medical Waste and Non-hazardous waste in the Deendayal Port Authority Area
Name of Client:	Deendayal Port Authority
Date of issue:	11/09/2024
Reference no.:	GEMI/844(1)/101/2024-25
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PART-1

WASTE MANAGEMENT PLAN

Table of Contents

List of Tables

List of Figures

Annexures

Chapter-1

Introduction

1.1. About Kandla Port (Deendayal Port Authority, DPA)

Kandla Port, also known as the Deendayal Port is one of the major seaports on the western coast in Kutch District of Gujarat, India. It is located near the city of Gandhidham. It is situated on the west bank of Kandla creek at Latitude 23º 01' N and Longitude 70º 13' E. It is the largest port of India by volume of cargo handled. This port is operational throughout the year as it is an all-weather port. There are no adverse wave effects as it is a sheltered port situated in a creek. The rainfall is scanty in this region making the port most suitable option for handling food grains. It is well connected with the hinterland by broad gauge railway system and National Highway No. 8-A. This port handles dry bulk, break bulk, liquid bulk and container cargo. Kandla is the closest major port to the Middle East and Europe. It is also enroute port for ships calling at Karachi, Pakistan's only major port handling its seaborne cargo. Presently, the Port has total 1-16 dry cargo berths for handling dry cargo, 6 oil jetties, and one barge jetty at Bunder basin, dry bulk terminal at Tuna Tekra, barge jetty at Tuna and two SPMs at Vadinar for handling oil. The off-shore oil terminals at Vadinar, located in the Devbhumi Dwarka district, roughly 300 km away from Kandla by road and 50 nautical miles by sea, is also managed by DPA.

Since its formation in the 1950s, the Deendayal Port caters to the maritime trade requirements of Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana and Gujarat. Because of its proximity to the Gulf countries, large quantities of crude petroleum are imported through this port. About 35% of the country's total export takes place through the ports of Gujarat in which the Deendayal port has a considerable contribution. Assortments of liquid and dry cargo are being handled at DPA Port. The dry cargo includes fertilizers, iron and steel, food grains, metal products, ores, cement, coal, machinery, sugar, wooden logs, etc. The liquid cargo includes edible oil, crude oil and other petroleum products. The layout plan of DPA port at Kandla is given in Figure 1. and details of its berths and jetties is given Table 1.

Deendayal Port Authority is committed to sustainable development by taking adequate measures to maintain the Environmental well-being of the Port and its surrounding. The Ministry of Shipping started, "Project Green Ports‟, an effort to 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". As a part of this initiative DPA has appointed GEMI to formulate a detailed Waste Management Plan for environmentally sound management of all types of waste generated at the Port area and other commercial and residential establishments under jurisdiction of DPA.

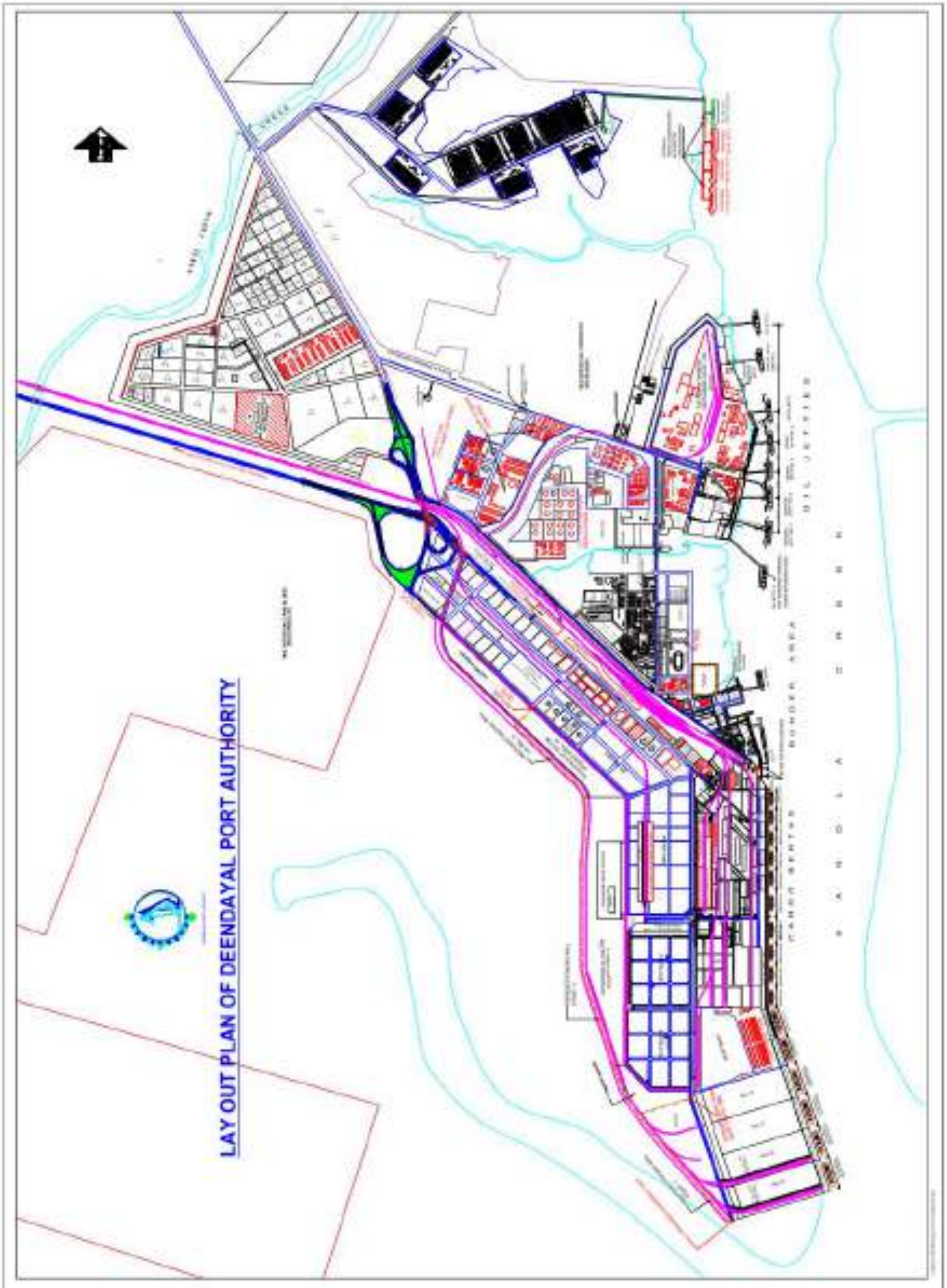

Figure 1: Layout Plan of Deendayal Port Authority (DPA)

Figure 1a. Layout of Gopalpuri Colony

1.2. Details of berths at Kandla and Vadinar ports

Table 1 Details of Jetties at DPA ports

Sr. No.	Berth	No. of Berths	Name of Berth	Type of Berth	Designed/Vessel Depth (Mts) (Draught)
Kandla port					
1	Cargo Berth	16	Cargo Berth 1 to 10	Mainly Dry Bulk	10.5 to 13.50
2			Cargo Berth No. 11 and 12 (KICT)	Container Berth	13.5 to 14.0
3			Cargo Berth 13 to 16	Mainly Dry bulk/Logs	13.5 to 14.0
4	Tuna Tekra	4	Tuna Tekra (AKBPTL) (BOT) Bulk Terminal	Dry Bulk	15.0 (Front) 13.0 (Back)
5	IFFCO Barge Jetty	1	IIFCO Barge Jetty (BOT)	Fertilizer (Captive)	4
6	Oil Jetties	7	Oil Jetty (OJ1)	LPG and Chemicals	10
7			Oil Jetty (OJ2)	Chemicals	10
8			Oil Jetty (OJ3)	Chemicals	9.8
9			Oil Jetty (OJ4)	Chemicals	10.7
10			IFFCO Jetty (OJ5)	Gas Carrier/ Chemicals	9.5
11			IOC Jetty (OJ6)	Petroleum products	10.1
Vadinar Port (SBMs and POL Product jetties)					
12	S.B.M.	3	1st and 2nd SBM: M/s IOCL 3rd SBM: M/s Essar Oil Ltd.	Crude oil	33 m draft
13	Nayra Jetty 1	1	Nayra Jetty 1	Crude oil	-
14	Nayra Jetty 2	1	Nayra Jetty 2	Crude oil	-

1.3. Need for the Waste Management Plan

Having a comprehensive waste management plan, in place, that incorporates all applicable provisions laid by regional and national legislations for the types of wastes generated within its boundary, enables an organization to manage its wastes (generated within its boundary) in environmentally sound manner, from on-site storage, segregation to its final disposal. It acts as a standalone document guiding the organization in making policy level decisions regarding its overall waste management. Appropriate implementation of the waste management strategies detailed in the plan also helps in ensuring protection of the marine environment by reducing discharges into the sea of ship generated wastes and cargo residues, to improve the availability and use of reception facilities and strengthen the enforcement regime.

1.4. Objectives of the Waste Management Plan

The objectives of the waste management plan are as below:

For non-shipping waste viz. Municipal Solid Waste (MSW), Plastic Waste (PW), E-waste, Bio-medical Waste (BMW), and Construction & Demolition (C&D) Waste:

1. Understand the current waste management scenario at DPA followed by identification of opportunities for improvement in the same.
2. Document the legal requirements pertaining to different types of wastes.
3. Formulation of action plan for an efficient and robust waste management system.
4. Preparation of a training module for capacity building aimed at effective waste management.

For shipping waste

1. Understand the current waste management scenario at DPA followed by identification of opportunities for improvement in the same.
2. Identification and categorization of wastes produced at Kandla and Vadinar ports w.r.t MARPOL and applicable Indian legislations.
3. Assess the requirement of Port Reception Facility (PRF) for ship-generated waste w.r.t the identified ship wastes.
4. Suggest suitable Waste Management System for environmentally sound waste management based on available case studies and Standard Operating Procedures.

1.5. Scope of Work

1. Identification & categorization of various Wastes, into hazardous & non-hazardous Biodegradable wastes, Solid wastes including C & D Wastes, Biomedical Waste, plastic

waste, E- waste etc. with assessment of quantity & disposal.

2. Separate identification of Ship waste into hazardous, non-hazardous & Biodegradable waste as per the MARPOL 73/78 (as amended) and other conventions of IMO as applicable for Port and Harbour.

3. Preparation of Training Module for Port officers & Employees.

4. Provide comprehensive reception and safe disposal facilities plan with subsequent monitoring plan including provision for engagement external agencies/private operators.

5. List out requirement of obtaining necessary clearance/license from statutory authorities under respective category of waste management rules.

6. Review Procedure with respect to Audits/Inspection reports of licensed contractors.

7. Provide consultation to DPA in implementation of waste management plan during the period of contract.

8. Preparation of detailed waste management plan for all wastes as per the provisions of covered under Environment Protection Act, EPA 2006.

Chapter-2

Municipal Solid Waste

2.1. Applicable laws and rules

Solid Waste Management Rules, 2016 (SWM Rules, 2016)

2.2. Responsibility of DPA as per Rules:

Definition of Bulk waste generator as per SWM Rules,2016

"Bulk Waste Generator" means and includes buildings occupied by the Central Government Departments or undertakings, State Government Departments or Undertakings, Local Bodies, Public Sector Undertakings or Private Companies, Hospitals, Nursing Homes, Schools, Colleges, Universities, other Educational Institutions, Hostels, Hotels, Commercial Establishments, Markets, Places of Worship, Stadia and Sports Complexes etc. having an average waste generation rate exceeding 100 kg per day (of all waste streams put together).

Rule 4 of Solid Waste Management Rules, 2016 - Duties of waste generator

- Segregate and store the waste generated in three separate streams namely bio-degradable, non-biodegradable and domestic hazardous wastes in suitable bins and handover segregated wastes to authorized waste pickers or waste collectors as per the direction or notification by the local authorities from time to time.
- Wrap securely the used sanitary waste like diapers, sanitary pads etc., in the pouches provided by the manufacturers or brand owners of these products or in a suitable wrapping material as instructed by the local authorities and shall place the same in the bin meant for dry waste or non- bio-degradable waste.
- Store separately construction and demolition waste, as and when generated, in his own premises and shall dispose of as per the Construction and Demolition Waste Management Rules, 2016.
- store horticulture waste and garden waste generated from his premises separately in his own premises and dispose of as per the directions of the local body from time to time.
- No waste generator shall throw, burn or burry the solid waste generated by him, on streets, open public spaces outside his premises or in the drain or water bodies.
- All waste generators shall pay such user fee for solid waste management, as specified in the bye-laws of the local bodies.
- No person shall organize an event or gathering of more than one hundred persons at any unlicensed place without intimating the local body, at least three working days in advance

and such person or the organizer of such event shall ensure segregation of waste at source and handing over of segregated waste to waste collector.

- The bio-degradable waste shall be processed, treated and disposed off through composting or bio-methanation within the premises as far as possible. The residual waste shall be given to the waste collectors or agency as directed by the local body.

2.3. Handling and Management of Waste

2.3.1. Identification of sources, Quantification and Inventory of waste

Based on the population data provided by DPA for its residential, port and slum establishments at Gandhidham, Kandla and Vadinar, MSW is quantified as per provisions stated in Central Public Health and Environmental Engineering Organization (CPHEEO) Manual.

As per CPHEEO Manual guidelines:

- For residential zones MSW generation rate is 0.3 kg per capita per day.
- For commercial zones MSW generation rate is 0.2 kg per capita per day.
- For Floating population MSW generation rate is 0.2 kg per capita per day.

Note: Factor of commercial zone assumed for port area

The factor of 0.125 kg/per capita/per day as outlined in the research paper titled "Solid Waste Disposal Practices in an Urban Slum Area of South India", is assumed for calculation of MSW by slum population at DPA.

The projection of MSW in next 5 and 10 years is calculated based on the assessment finding reported in CPHEEO manual that states that per capita waste generation increases by about 1.3% per year.

The estimated quantity of Solid waste generation for the area is given in Table 2 below.

Table 2 MSW generation at DPA establishment

Sr. No.	Locality	Population (nos.)	Quantity of waste in kg/day		
			Current	Projected after 5 Years	Projected after 10 Years
For Gandhidham and Kandla					
Residential					
1.	Gopalpuri colony	5000	1500	1600	1700

2.	Port colony (Occupied HH + Barracks)	744**	223.2	238.08	252.96
3.	Slum	500*	100	108	115
Commercial					
1.	A.O. office	1577	315.4	331.17	362.71
2.	Port (employees + workers)	505	101	106.05	116.15
3.	Floating	100*	20	21.6	23
Total for Gandhidham and Kandla		-	**2259.6**	**2404.9**	**2569.82**
For Vadinar					
1.	Residential	600	180	190	207
2.	Commercial	50	10	10.5	11.5
3.	Floating	100*	20	21.6	23
Total for Vadinar		-	**210**	**226.8**	**241.5**

**Assumed values; ** calculated based on no. of HH / rooms by applying factor adopted from Ministry of Statistics and Program Implementation, GoI[1]*

2.3.2. Segregation

Current scenario: At present, MSW generated at various DPA establishments at Kandla as well as Vadinar like residential colony, administrative offices, Port offices, slum areas etc., is not segregated into wet or dry waste. Dustbins have been provided at various DPA campuses however there is need for providing different colored bins for collection of wet and dry waste to promote waste segregation at source.

Figure 2: Dustbins provided in DPA office premises, Gandhidham

Figure 3: Concrete bins at Gopalpuri colony campus, Gandhidham

[1] Ministry of Statistics and Program Implementation (*https://shorturl.at/8F4Oz*)

2.3.3. Collection

Current scenario: Door to Door collection of waste is practiced at Gandhidham, Kandla and Vadinar DPA establishments on daily basis. Private agencies have been contracted for collection, transportation and disposal of MSW at these locations. The agencies contracted for this purpose at various locations are given in Table 3.

Table 3 Waste Management Agency appointed at DPA ports

DPA establishments	Waste Management Agency
Gopalpuri and KDLB Colony	M/s Patel Construction Co.
New Port Colony, New Kandla	M/s Acer Infra Trade
Vadinar	M/s. Jay Chamunda Enterprise

Figure 4: Door-to-door waste collection

2.3.4. Storage (on-site and centralized)

Door to Door collection is practiced on daily basis at Gandhidham, Kandla and Vadinar hence there is no requirement of designated onsite storage area for MSW. The collected MSW from each household and offices is directly transferred into the bin loaded on the vehicle.

2.3.5. Intramural transportation and transfer

Depending on requirement, trip length and vehicle capacity, intramural transportation and transfer of waste is carried out by the agency.

2.3.6. Pre-treatment / Pre-processing

No pre-treatment or processing is carried out at present

2.3.7. Disposal

- At Gandhidham, MSW is disposed at a designated site allotted by Gandhidham Municipality.
- At Vadinar, there is a provision of dumpsite behind port colony for dumping of MSW. Here, 12-13 ft. deep trenches are dug into which the MSW is dumped. Once the trench is completely filled, it is systematically covered with layer of top soil.

2.4. Record keeping

There is no statutory requirement of record keeping for MSW, however it is a good practice to maintain the records of MSW generated at various locations and collect the waste receipts for the quantum of waste collected. At DPA establishments record keeping is maintained in terms of no. of trips (for MSW collection) by waste collecting agency.

2.5. Procedure adopted for engagement of external agencies/private operators

The selection of agency is through tendering procedure. The work is a comprehensive maintenance contract for all sanitation works which includes collection, transportation and disposal of MSW, street sweeping etc. The work is awarded to the bidder who meets the minimum eligibility criteria and who has submitted the lowest bid. The contract is usually for a period of 2 years.

2.6. Obtaining Authorization/Clearance/License

DPA is not required to obtain any Authorization/Clearance/License for MSW

2.7. Strategy for management of MSW at DPA

Management of MSW can be broadly categorized into the following steps:

a) Segregation at source
b) Collection
c) Transportation
d) Sorting and Processing
e) Recycling (of recyclable items)

f) Disposal

In the subsequent section, detailed plan for segregation, sorting and processing has been provided. Collection and transportation is already carried out by a dedicated agency.

2.7.1. Segregation at source:

Estimation of no. of bins:

2 different colored bins, Green for wet waste and Blue for dry wastes etc. shall be made available to all households and offices, and awareness be made, encouraging segregating of wastes into designated bins. The provision for collection of waste generated from floating population has been covered under provision of bins made for administrative offices for Gandhidham, Kandla and Vadinar locations, as the bins calculated to be put up on sides of roads inside the colony will suffice, receiving the waste quantum from incoming-outgoing floating population of residential colonies. The bins that are two to be placed along internal roads, DPA may choose to install any of the following type of bins:

a) Conventional bins of 50L capacity OR
b) Smart underground bins of 100L capacity with sensors that sends alert when bins are almost full

Figure 7: Wet and Dry waste collection bins

a) For Kandla and Gandhidham

The current quantum of MSW generation estimated at Gopalpuri is 1.5 tons/day. The calculation of bins to be provided for MSW collection is done for the projected increase after 10 years i.e 1.7 tons/day. Similarly, for Administrative Office the current MSW generation is 0.35 tons/day and projected quantity after 10 years is 0.4 tons/day. For calculation of no. of bins 0.4 tons/day quantum is considered.

Gopalpuri colony, Gandhidham

a. Waste Quantity (W) =1.7 tons/day
b. As per CPHEEO manual bulk density (D) of MSW is 0.5 tons/m^3
c. Total Volume of Waste = W÷D = 1.7 ÷ 0.5 = 3.4 m^3/day

To accommodate 3.4 m^3/day of generated MSW total of 340 bins would be required. However, since there are approx. 1100 households, 2200 bins are recommended (2 bins, for wet and dry waste at each HH).

The approximate length of internal major roads inside the Gopalpuri colony calculated through GIS tool is 6132 m. (Approx 6 kms.). Adopting the provision of providing 1 set of 2 bins (for wet and dry waste) at a distance of 75 m along the length of roads[2], 82 bins are proposed to be provided along the length of all major internal roads of Gopalpuri.

Port colony, Kandla

Waste Quantity – W=0.25 tons/day

- As per CPHEEO manual bulk density(D) of Municipal solid waste is 0.5 ton/m^3

- Total Waste Quantity is Volume = W÷D = 0.25 ÷ 0.5 = 0.5 m^3/day

Assuming 0.01 m^3 bins on 25 Location (50 Bins), so total waste collected will be 50 X 0.01 = 0.5 m^3. So, total waste collected will be around 0.5 X 0.5 = 0.25 tons/day. Waste collection can be increased if more waste deposited in bins.

The approximate length of internal roads inside the port colony, Kandla is 2148 m. (Approx 2.1 kms.). 58 set of 2 bins (for wet and dry waste) at 29 locations at a distance of 75m are proposed to be provided on all major internal roads.

Administrative Office, Gandhidham

Waste Quantity – W=0.36 tons/day

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[2] Optimal Location and Proximity Distance of Municipal Solid Waste Collection Bin Using GIS: a Case Study of Coimbatore City (https://shorturl.at/FPDF4)

- As per CPHEEO manual bulk density(D) of Municipal solid waste is 0.5 ton/m^3

- Total Waste Quantity is Volume = W÷D = 0.36 ÷ 0.5 = 0.72 m^3/day

Assuming 0.01 m^3 bins at 40 office rooms (80 Bins), so total waste collected will be 80 X 0.01 = 0.8 m^3. So, total waste collected will be around 0.8 X 0.5 = 0.4 tons/day, sufficing the waste generation of 0.72 m^3/day.

The approximate length of internal roads inside the AO office at Kandla is 522.4 m. (Approx 0.5 kms.). 07 set of 2 bins (for wet and dry waste) are proposed to be provided on all major internal roads.

Port office (employees + workers), Kandla

Waste Quantity – W=0.12 tons/day

- As per CPHEEO manual bulk density(D) of Municipal solid waste is 0.5 ton/m^3
- Total Waste Quantity is Volume = W÷D = 0.12 ÷ 0.5 = 0.24 m^3/day

Assuming 0.01 m^3 bins on 12 Location (24 Bins), so total waste collected will be 24 X 0.01 = 0.24 m^3. So, total waste collected will be around 0.24 X 0.5 = 0.12 tons/day. Waste collection can be increased if more waste deposited in bins.

The approximate length of internal roads inside the port office, Kandla is 380 m. (Approx 0.3 kms.). 10 set of 2 bins (for wet and dry waste) at 5 locations at a distance of 75m are proposed to be provided on all major internal roads.

Unorganized slum area, Kandla

As per Solid Waste Management Rules, 2016, it is the responsibility of DPA to arrange for door-to-door collection of segregated MSW from all its establishments including slums and informal settlements. 200 bins are proposed to be distributed at these places. In addition, 50 nos. of hand carts are proposed.

Figure 8: Handcart for collection of MSW from slum areas

b) For Vadinar

The current quantum of MSW generation reported at Vadinar port colony is 0.19 tons/day. The calculation of bins to be provided for MSW collection is done for the projected increase in MSW generation after 10 years i.e 0.2 tons/day. Similarly, for administrative office at Vadinar the current MSW generation is 0.02 tons/day and projected quantity after 10 years is 0.023 tons/day. For calculation purpose 0.023 tons/day quantum is considered.

Residential colony

d. Waste Quantity (W)= 0.2 tons/day
e. As per CPHEEO manual bulk density (D) of MSW is 0.5 ton/m^3
f. Total Volume of Waste to be handled = W÷D = 0.2 ÷ 0.5 = 0.42 m^3/day

Since there are around 150 households in the colony, 300 bins would be required.

The approximate length of internal major roads inside the port colony at Vadinar, calculated through GIS is 3687.2 m. (Approx 4 kms.). 50 set of bins (for wet and dry waste) are proposed to be provided on all major internal roads of Gopalpuri.

Administrative Office

g. Waste Quantity (W) = 0.023 tons/day
h. As per CPHEEO manual bulk density (D) of MSW is 0.5 ton/m^3
i. Waste Volume = W÷D = 0.023 ÷ 0.5 = 0.046 m^3/day

A provision of total 50 bins has been estimated.

The approximate length of internal roads inside the AO office at Vadinar is 856 m. 12 set of 2 bins (for wet and dry waste) are proposed to be provided internal roads of the office.

Summary of total no. of bins required is given in Table 4.

Table 4 Summary of total no. of bins required

DPA establishments generating MSW	No. of bins to be provided	Capacity of bin	Identified locations for bins	Remarks (If any)
Gandhidham and Kandla				
Residential				
Gopalpuri colony, Gandhidham	2200	10L ($0.01m^3$)	1100 HH in the colony	2 bins at each HH: 1 Green (wet waste) and 1 Blue (dry waste)
	82	50 or 100 L	6 km long Internal roads and parks of the colony	bin to be provided at a distance of 75m
Port colony, Kandla	840	10L ($0.01m^3$)	120 (currently occupied) HH and 300 barracks	2 bins at each HH and barrack: 1 Green (wet waste) and 1 Blue (dry waste)
	58	50 or 100 L	2.1 km long Internal roads and parks of the colony	1 bin to be provided at a distance of 75m
Commercial				
Administrative office, Gandhidham	80	10L ($0.01m^3$)	2 bins in each office rooms	--
	07	50 or 100 L	On 0.5 km long internal roads inside AO premises	1 bin to be provided at a distance of 75m
Port office, Kandla (Marine + Nirman bhavan)	24	10L ($0.01m^3$)	2 bins in each office rooms	--
	10	50 or 100 L	On 0.4 km long internal roads inside AO premises	1 bin to be provided at a distance of 75m
Slum				
Unorganized slum, Kandla	50 Handcarts	--	--	--
	200	10L ($0.01m^3$)	Around 100 HH	2 bins at each HH: 1 Green and 1 Blue
Vadinar				

Port colony	300	10L ($0.01m^3$)	21 HH in the colony	2 bins at each HH: 1 Green and 1 Blue
	50	50 or 100 L	3.6 km long Internal roads and parks of the colony	1 bin to be provided at a distance of 75m
Administrative office, Vadinar	50	10L ($0.01m^3$)	2 bins in each office rooms	--
	12	50 or 100 L	On 1 km long internal roads inside AO premises	1 bin to be provided at a distance of 75m
Grand Total: 10 L bins: 3344 nos. for Gandhidham and Kandla and 350 nos. for Vadinar Handcarts: 50 nos. for unorganized slum at Kandla port 50 or 100 L bins: 157 nos. for Gandhidham and Kandla and 62 nos. for Vadinar				

HH- Households in the colony

Figure 9: Indicative sizes of 50L and 10L green and blue bins

Salient features of smart underground roadside bins:

- Fitted inside a concrete bunker below the ground
- Sensor-fitted to send alert when bins are 75-90% full
- Waterproof- these units have rubber fittings to make them waterproof
- Bins are established a few inches above the ground level to ensure that there is no flooding of the bins during the rainy season

Figure 9a: Smart underground roadside bins

2.7.2. Door-to-Door collection:

DPA has outsourced door-to-door collection of wastes from residencies and offices by appointing an agency on annual renewal basis. As per current scenario, the agency dumps the MSW collected from door-to-door to a designated site allotted by Gandhidham Municipality without processing. This gap could be addressed by introducing an on-site Material Recovery Facility (MRF), enabling proper segregation of MSW into Organic and Inorganic sections. Thereby the MSW collected from every household and office will get diverted to the MRF.

The characterization of MSW is an important aspect as the composition will determine the applicability of waste processing technology. On an average, garbage is composed of 40-45% of organic fraction and 20-30% inert fraction, rest being plastics, paper, rags and other components.

NEERI's study "Assessment of Status of Municipal Solid Wastes Management in Metro Cities and State Capitals" in 2004–2005 assessed 59 cities (35 metro cities and 24 state capitals). Studies have revealed that waste generation rate varies from 0.12 to 0.60 kg/capita/day. Analysis of physical composition indicates that total compostable matter in the waste is 40%–60%, while recyclable fraction is 10%–25%. The moisture content in the MSW is 30%–60%, while the C/N ratio is 20–40. Typical Fractions of Municipal Solid Waste Generated in DPA is given in Table 5

Table 5 Typical fractions of Municipal Solid Waste Generated in DPA

Sr. No.	Type of Waste	Quantity of Waste Generated (kg/day)					
		Gandhidham		Kandla		Vadinar	
		R	C	R	C	R	C
1.	Biodegradables	711	149.49	105.79	11.85	85.32	4.74
2.	Paper	121.5	25.54	18.08	2.025	14.58	0.81
3.	Plastic	138	29.01	20.53	2.3	16.56	0.92
4.	Metal	7.5	1.57	1.11	0.13	0.9	0.05
5.	Glass	15	3.15	2.23	0.25	1.8	0.1
6.	Rags	66	13.87	9.82	1.1	7.92	0.44
7.	Other	60	12.61	8.92	1	7.2	0.4
8.	Inerts	376.5	79.16	56.02	6.27	45.18	2.51
Total		**1500**	**315.4**	**223.2**	**25**	**180**	**10**
Total Waste Generation		**1840.4**		**248.2**		**190**	

R- Residential; C- Commercial

The calorific value of garbage will help to identify the treatment technologies like Waste-to-Energy and other thermal processes. For secondary segregation MRF is proposed as follows for DPA establishments at Gandhidham.

2.7.2.1 Staff requirement for MSW collection

Manpower requirement for various premises as per provisions given under CPHEEO Manual and Swachh Bharat Mission's Standard Operating Procedures (SOPs) is tabulated below:

Table 6: Staff requirement-MSW collection

Area	No. of cleaning staff to be deployed (Illustrative)		Remarks
MSW collection	Gopalpuri colony, Gandhidham (2 LCVs)	2 drivers and 4 laborers	Manpower is calculated based on recommended nos. of LCVs (Light Commercial Vehicle) of 500-700 kg capacity, for waste collection, as per provisions of CPHEEO Manual for collection of MSW.
	Port colony, Kandla (1 LCV)	1 driver and 2 laborers	
	AO office, Gandhidham (1 LCV)	1 driver and 2 laborers	
	Port admin offices, Kandla (1 LCV)	1 driver and 2 laborers	

	Entire Vadinar premises (1 LCV)	1 driver and 2 laborers	
Street sweeping	Gopalpuri colony, Gandhidham	12 sweepers	Calculation based on the street sweeping norms for medium density roads i.e., 1 person per 500 running meters of road length, as per provisions of CPHEEO Manual for collection of MSW.
	Port colony, Kandla	04 sweepers	
	AO office, Gandhidham	01 sweepers	
	Port admin offices	01 sweepers	
	Residential premises, Vadinar	07 sweepers	
	Commercial premises, Vadinar	02 sweepers	
Office/ hospital corridors	Typically, 1 staff per floor for 1-2 corridors		As per manpower provision made under SOPs for Swachh Resident Welfare Associations and Offices.
Common toilets	Typically, 1 staff per toilet block		
Gardens and parks	Appropriate number as may be needed		
Common utilities like Parking, Gym, Library, Clubs, open spaces etc.			
Additionally, dedicated supervisors should be engaged depending on number of cleaning staff, and number of physically disparate locations (e.g. 1 supervisor per wing/floor).			

Note: *No. of LCVs proposed could be optimized considering the scenario where a single LCV makes multiple trips for waste collection instead of multiple LCVs or as per DPA's discretion.*

Staff requirement should be assessed on annual basis by the Waste Management Cell taking into account following particulars for each DPA establishments:

- Area of the building (Offices, Residential, Recreational etc.)
- Number of rooms
- Area of the open/common spaces like garden, parking etc.
- Number of common toilet blocks
- Number of canteen spaces

2.7.3. Material Recovery Facility (MRF)

A Material Recovery Facility (MRF) is an infrastructure to receive, sort, process and store recyclable/non-recyclables/ RDF and inert materials, with the aim to maximize the quantity of recyclables processed, while producing materials that will generate the highest possible revenues in the market and maximize the reuse of other segregated fraction in different processes/ industries. Schematic of a typical MRF facility is given below:

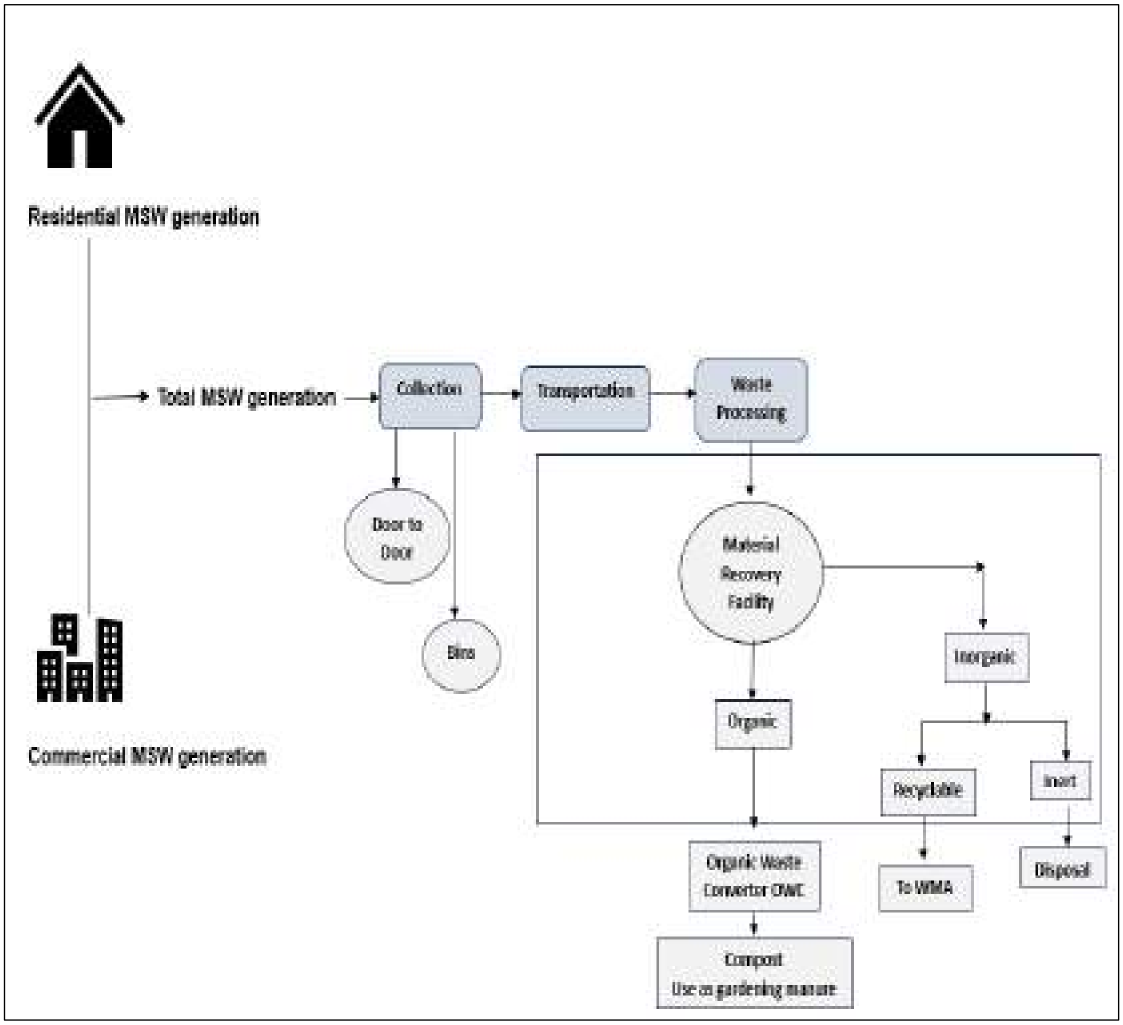


Figure 10: A schematic of proposed MRF for Kandla, Gandhidham

DPA in collaboration with Gandhidham Municipality has proposed to install solid waste processing facility for managing waste of Gandhidham town and DPA premises. There is a provision for a material recovery facility (MRF) to ensure maximum utilization of reusable portion of MSW and minimum waste to be landfilled. The specifications of proposed MRF for Gandhidham are as below:

Table 7 MRF specifications for Gandhidham

MRF Component	Indicative value
Design Capacity	100 tons/day
Infrastructure requirement	Composting shed MRF center Livelihood center
Total area requirement	6 acres

2.7.4. Organic Waste Converter (OWC)

About 40-60% of MSW is comprised of compostable materials. Assuming 50% quantum of MSW to be biodegradable, the calculated biodegradable content in MSW generated from Gopalpuri colony and AO office are 600 kg/day and 200 kg/day respectively. Similarly, for Vadinar, the biodegradable component in MSW is 90kg/day and 10 kg/day for colony and AO office respectively. The nos. and specifications of OWC proposed for DPA establishments at Gandhidham, Kandla and Vadinar are as below:

The following process flow diagram illustrates how organic waste is converted into compost within 30 to 45 days.

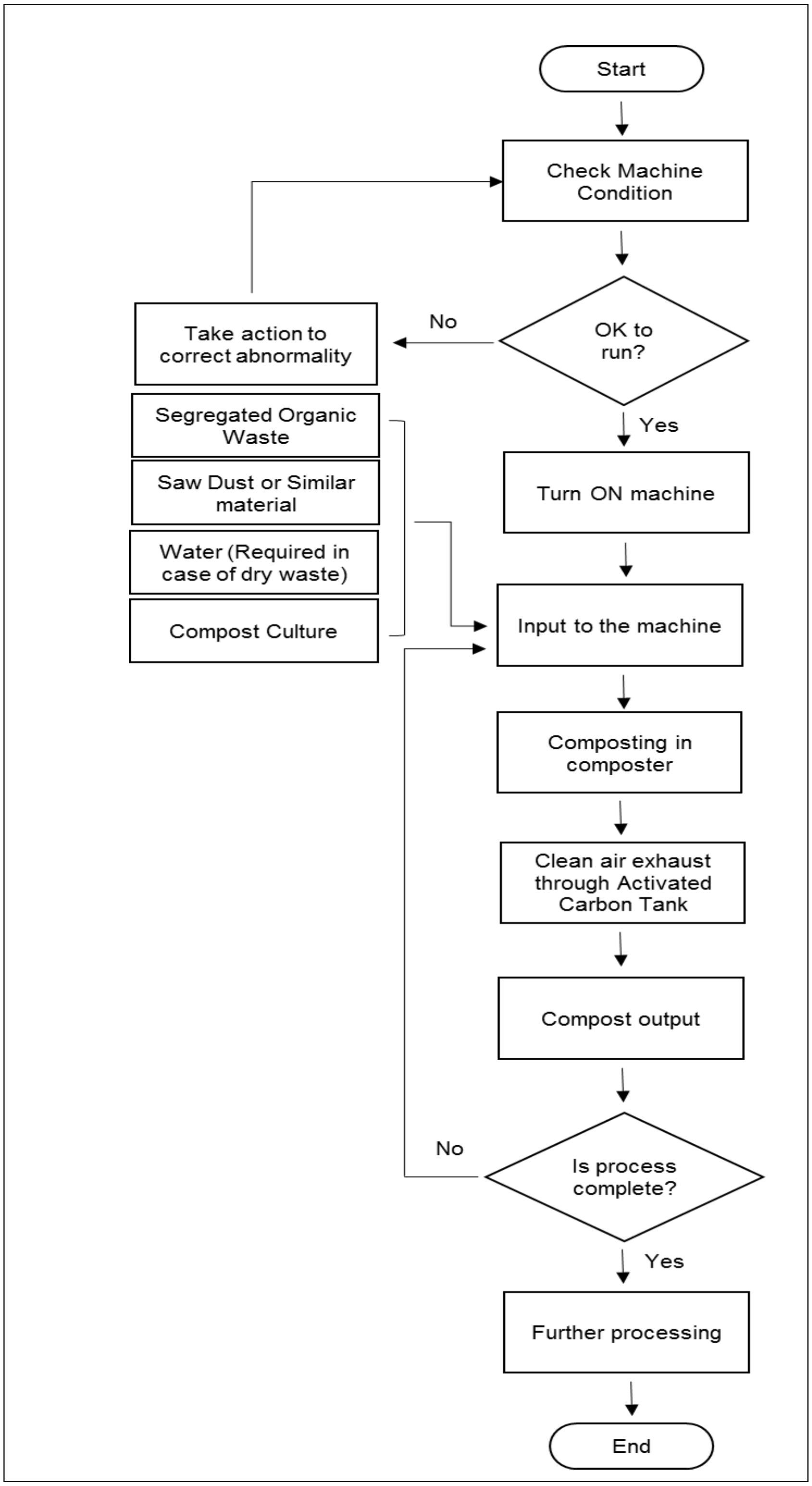


Figure 16: Process flow of Organic Waste Converter

The image of a typical OWC is shown in Figure 17

Figure 17: Typical Organic Waste Convertor

A non-exhaustive list of OWC dealers have been provided at Annexure I. The specifications of the OWC proposed for DPA is given in Table 8.

Table 8 Specifications of OWC proposed for DPA

Sr. No.	Location	Design capacity kg/day	Nos. of OWC proposed	Approx. Space requirement for 1 OWC (m x m X m)	Energy Requirement for 1 OWC Units/day
1	Gopalpuri colony	800	1	3.4×2.3×2.4	57-65
		OR			
		200	4	1.98×1.16×1.68	16-18
2	Kandla AO	200	1	1.98×1.16×1.68	16-18
3	Vadinar colony and AO premises	100	1	5×3×3.5	13-15

2.8. Financial outlay for proposed MSW management

The estimated financial outlay for the proposed provision of MSW management has been given in Table 9. This outlay consists of only capital and recurring cost of items/equipment and does not include manpower and other costs.

Table 9 Financial outlay for proposed MSW management

Sr. no.	Particulars of proposed provisions for management of MSW	Cost per unit in ₹	Capital cost in ₹	Recurring cost per year in ₹
For Kandla and Gandhidham				
1	Waste collection bins HH 10 L capacity	100/-	3,34,400/- (for 3344 bins)	1,00,000/- (considering replacement of around 1000 bins/year due to wear and tear)
2	Waste collection bins (roadside) 50 L capacity 100 L capacity (smart bins)	600/- 15000/-	94200/- (50L) 23,55,000/- (100L) (for 157 bins)	30,000/- (considering replacement of around 50 bins/year due to wear and tear)
3	MRF facility	--	1,50,00,000/-	*
4	OWC units of 800 kg/day for Residential	14,50,000/-	14,50,000/-	145,000/-
5	OWC units of 200 kg/day for Commercial	6,00,000/-	6,00,000/-	60,000/-
6	Handcarts for slum area	8000/-	4,00,000/- (for 50 handcarts)	40,000/- (considering replacement of around 5 handcarts/year due

				to wear and tear)
7	Door-to-door waste collection	As per contract		
Total			**1,77,16,800/- + unaccounted cost***	**20,75,000/- + unaccounted cost***
For Vadinar				
8	Waste collection bins of 10 L capacity	100/-	35000/- (for 350 bins)	5,000/- (considering replacement of around 50 bins/year due to wear and tear)
9	Waste collection bins of 50 L capacity	600/-	37,200/- (for 62 bins)	3000/- (considering replacement of around 05 bins/year due to wear and tear)
10	OWC units of 100 kg/day	3,50,000/-	3,50,000/-	35,000/-
11	Door-to-door waste collection	As per contract		
Total			**4,22,200/- + unaccounted cost***	**43,000/- + unaccounted cost***
Grand Total (for Gandhidham, Kandla and Vadinar)			**1,81,39,000/- + unaccounted cost***	**21,18,000/- + unaccounted cost***

Note: The costs of proposed units have been adopted based on current market price; *unaccounted costs include costs of tendering; costing of roadside smart bins and recurring cost pertaining to MRF.

2.9. Other recommendations:

The Integrated Solid Waste Management (ISWM) hierarchy states 5 approaches for managing wastes.

- Tier 1: Source reduction or waste prevention, which includes reuse, considered the best approach
- Tier 2: Recycling
- Tier 3: Composting of organic matter of waste.
- Tier 4: Energy recovery- the components of waste that cannot be prevented or recycled can be processed for recovering energy
- Tier 5 is disposal of waste in sanitary landfill, which is the least preferred option.

For DPA, Tier 1, 2, 3 and 4 approaches are proposed for management of MSW

Tier 1 & 2: Practicing minimalistic lifestyle by avoiding purchase and use of unnecessary goods/things used in daily lives. Ensuring the usage of goods used in day to day lives for its full designed period or till end of life thereby avoiding accumulation that ultimately results into MSW

Tier 3: Composting of organic waste produces a good manure that can find utility in gardens, recreational parks and kitchen gardening. Proper segregation of MSW in to wet biodegradable and Dry non-biodegradable waste is key to achieve this. To ensure segregation at source, provision shall be made to provide two separate bins at all households in the colonies and other places for discarding of wet and dry wastes thus enabling waste segregation at the source of generation itself.

- Ensure active participation of the community in reducing overall quantities of waste. The different waste reduction strategies, such as take-back, deposit–refund system, etc. should be promoted.
- Promote source reduction programs in the community and encourage handover of recyclable material to sustainable recycling facilities through informal sector, NGOs, etc.
- Campaign for reducing the use of specific non-recyclable, non-reusable, or toxic material. Practice and promote material substitution where possible.
- Generate awareness among people to avoid littering.
- Sensitize citizens to segregate waste at their premises into biodegradable, dry, and special waste and hand over the segregated waste to the collectors.
- Ensure awareness on existing recyclable collection systems, including dedicated collection points. Enforce extended producer responsibility (EPR) initiatives.
- Management shall hold regular meetings among the MSWM staff and other stakeholders to ensure successful uptake of such programs.
- Ensure active participation of the community for successful implementation of primary and secondary collection systems.
- Generate awareness on bye-laws on waste collection and management system as well as user charges levied on different waste fractions.
- The consumer shall wrap the sanitary waste using self-wrapping straps or keep the sanitary waste in leak-proof pouches provided by producer and dispose the same along with dry waste or keep the waste in separate bin provided at the time of door-to-door collection. In case separate bin is not provided by authorized waste picker, the wrapped/pouched sanitary waste should be placed in dry-waste bin for collection by authorized waste picker.

Chapter-3

PLASTIC WASTE

3.1. Applicable laws and rules

Plastic Waste Management Rules, 2016 and subsequent amendments in 2018, 2021, 2022 and 2023.

3.2. Responsibility of DPA as per PWM Rules

Rule 8 of Plastic Waste Management Rules, 2016

Responsibility of waste generator

- Take steps to minimize generation of plastic waste and segregate plastic waste at source in accordance with the Solid Waste Management Rules, 2000 or as amended from time to time.
- Not litter the plastic waste and ensure segregated storage of waste at source and handover segregated waste to urban local body or gram panchayat or agencies appointed by them or registered waste pickers', registered recyclers or waste collection agencies.
- All institutional generators of plastic waste, shall segregate and store the waste generated by them in accordance with the Municipal Solid Waste (Management and Handling) Rules, 2000 notified vide S.O 908(E) dated the 25th September, 2000 under the Act or amendments and handover segregated wastes to authorized waste processing or disposal facilities.
- All waste generators shall pay such user fee or charge as may be specified in the bye-laws of the local bodies for plastic waste management such as waste collection or operation of the facility thereof, etc.

3.3. Current Scenario - Handling and Management of Waste

3.3.1. Identification and Quantification

At all premises of DPA, plastic waste is not segregated from municipal solid waste. Therefore, for estimation of plastic waste quantum, Central Public Health and Environmental Engineering Organization (CPHEEO) manual has been referred. It states that Plastic waste forms approximately 6.92% of the total MSW. Applying this factor to the quantity of MSW generated at the respective locations, estimated PW generation at Gandhidham, Kandla and Vadinar is calculated as below:

Table 10: Estimated quantum of Plastic waste generation for DPA establishments

Location	Waste Quantum in kg/day			
	Current MSW	Estimated Plastic waste (current)	Estimated Plastic waste (after 5 yrs)	Estimated Plastic waste (after 10 yrs)

Gandhidham and Kandla (Colony + AO + Port + Slum)	2259.6	156.36	166.41	177.83
Vadinar (Colony + AO + Port)	210	14.53	15.69	16.71

3.3.2. Sources of waste

Plastics have become an integral part of human day to day life. All type of establishments, residential, commercial, institutional, health care etc. generate plastic waste in varying quantities. At Gandhidham, Kandla and Vadinar, plastic waste is generated from residential areas (residential colonies), Administrative offices, Port area (including ships and vessels) and slum areas.

3.3.3. Segregation

Segregation of waste at source and its timely collection ensures proper utilization and cleanliness of the area. However, to ensure source segregation, proper awareness activities, and strict compliance system is necessary. Presently the segregation of plastic waste at source is not practiced at locations i.e Gandhidham, Kandla and Vadinar. On-site segregation could be encouraged by:

- Providing different colored bins in households/offices: It is recommended that different bins for wet and dry waste be provided at all sources of waste generation.
- Create awareness on benefits and procedure of segregation.
- Regular monitoring of percentage of segregation in each DPA premises.
- Since source segregation of plastic waste is difficult, an alternative is manual / mechanized segregation at centralized storage area or material recovery facility once door to door collection of waste is done.

3.3.4. Recycling / Processing and Disposal

Recycling of plastic is not practiced at present.

3.4. Record keeping

The PWM Rules do not mandate any record keeping requirement for plastic waste generators, however it is a good practice to regularly collect receipts and maintain records of quantum of PW collected by the registered Waste Management Agency.

3.5. Procedure adopted for engagement of external agencies/private operators

Currently DPA has not engaged any plastic waste management agency for environmentally sound management of the plastic waste generated in its premises. It is imperative for DPA to engage such agency registered with GPCB to ensure sound management of plastic waste. The criteria suggested for appointing a waste management agency is it should be holding a valid authorization from GPCB during the tenure of tie-up with DPA. A non-exhaustive list of Plastic Waste Collection and Recycling Agencies has been provided in Annexure III.

3.6. Obtaining Authorization/Clearance/License

The provisions under PWM Rules do not mandate PW generator to obtain any Authorization, Clearance or License.

3.7. Recommendations and strategies

- Avoid use of single use polyethylene (SUP) packaged bottles and other single use cutlery items at events, meetings, seminars etc. Reusable bottles and cutlery shall be encouraged. It is recommended to issue an office order in this regard to ensure compliance.
- Avoid any kind of packaging products made of SUPs.
- Display posters across various locations to avoid and minimize plastic usage especially SUPs.
- DPA shall tie up with GPCB recognized plastic waste collection and processing agency for recycling of its plastic waste.

3 Rs – Refuse, Reduce and Reuse shall be practiced for plastic waste minimization. It is responsibility of individuals in colonies and offices of DPA to limit the use of plastics in day to day lives by encouraging attitudes like carrying a cloth bag to markets, making use of stainless steel/earthen water bottles, making use of recyclable goods used in day to day lives etc. General Do’s and Don’ts regarding plastic usage is as below:

Table 11 Do’s and Don’ts regarding plastic usage

S. No.	Do’s	Don’ts
1	Permit only use of plastic carry bags/ sheet/ or other with size >50µm	Use of <50 µm plastic carry bags/sheets
2	Practice use of Virgin plastic carry bags for storing/ packaging/ food stuffs.	Use of colored & recycled for storing/ packaging/ food stuffs.
3	Promote recycling of plastics 2-3 times before disposing it to landfill	Littering and unorganized dumping of PW

4	Segregation of PW from MSW	Mixing of PW with bio-degradable waste.
5	Recycling PW for use in co-processing in cement kilns, construction of roads etc.	Burning of PW in open.

- The Plastic Waste Management Amendment Rules, 2021, identified certain Single Use Plastics (SUPs) which have low utility and high littering potential for curbing pollution caused by littered and unmanaged plastic waste. The use of these SUPs as listed in Annexure II shall be strictly banned at all DPA premises.
- For the fourth R – Recycle – it is imperative that plastic waste is segregated from MSW.
- The following action points are recommended for effective plastic waste management system:

Table 12 Action points for effective plastic waste management

Sr. No.	Action points	Infrastructure/ actions required	Priority level
1.	Segregation of plastic waste from municipal solid waste	• Provision of separate bins for PW and MSW at households and offices • Segregation at proposed Material Recovery Facility	Immediate
2.	Setting-up of Plastic Waste Management system for safe collection, transport, recycling and disposal of PW.	• Engaging with GPCB registered PW recycling agency.	As soon as possible
3.	Create awareness among all employees and their families about their responsibilities towards minimizing the use of plastics.	• Through social media, campaigns, co-curricular school activities, hoardings etc.	As soon as possible
4.	Ensure that open burning of plastic waste is not permitted	• Constitution of Vigilance Squad	Immediate

- Community awareness is the best means to reduce and manage plastic waste. DPA should organize activities and competitions in its school and community gatherings to engage its residents especially children to create “Best out of Waste” items. A few ideas are given below:

	
Bird-feeder made of PET bottle	**Planter made of PET bottle**
	
Flower pot made of PET bottle	**Pen-stand made of PET bottles**
	
Sculpture made of PET bottles	**Eco-bricks made from plastic waste' filled in PET bottles**
	
Bench made from eco-bricks	**Brooms made from yarn made of PET bottles**

Figure 11: Best out of Waste

Chapter-4

E-WASTE

4.1. Applicable laws and rules

E-Waste (Management) Rules, 2022

4.2. Responsibility of DPA as per Rules:

Rule 8- Responsibilities of consumer or bulk consumer

Bulk consumers of electrical and electronic equipment listed in Schedule I shall ensure that e-waste generated by them shall be handed over only to the registered producer, refurbisher or recycler.

List of electrical and electronic equipment (E&EE) listed in Schedule I of the Rules are mentioned in the Training Manual.

4.3. Handling and Management of Waste

4.3.1. Identification, Quantification and Inventory of waste

A 'bulk consumer' means *"any entity which has used at least one thousand units of electrical and electronic equipment listed in Schedule I, at any point of time in the particular Financial Year and includes e-retailer"*. Based on this definition, DPA falls under the category of a bulk consumer. The E-waste inventory of Gandhidham, Kandla and Vadinar ports is tabulated below:

Table 13 E-waste inventory for DPA Ports

<table>
<tr><th>S.No.</th><th>Name of Port</th><th>Collection agency</th><th>E-waste</th><th>Quantity in nos.</th></tr>
<tr><td rowspan="5">1</td><td rowspan="5">Gandhidham, Kandla</td><td rowspan="5">Under process on MSTC portal</td><td>PC</td><td>121</td></tr>
<tr><td>Printer</td><td>32</td></tr>
<tr><td>CPU</td><td>40</td></tr>
<tr><td>Monitor</td><td>41</td></tr>
<tr><td>UPS</td><td>18</td></tr>
<tr><td colspan="4">Total</td><td>252 units</td></tr>
<tr><td rowspan="6">2</td><td rowspan="6">Vadinar</td><td rowspan="6">*</td><td>Monitor</td><td>5</td></tr>
<tr><td>CPU</td><td>3</td></tr>
<tr><td>Typewriter</td><td>2</td></tr>
<tr><td>Printer</td><td>13</td></tr>
<tr><td>Fax</td><td>1</td></tr>
<tr><td>Keyboard</td><td>10</td></tr>
<tr><td colspan="4">Total</td><td>34 units</td></tr>
<tr><td colspan="4">Total E-waste in storage at DPA</td><td>252+34
= 286 Units</td></tr>
</table>

** E-waste collected from Vadinar is sent to Gandhidham for onward disposal.*

4.3.2. Sources of waste:

Major sources of E-waste are Large Household Appliances, IT and Telecom and Consumer Equipment. At DPA, the E-waste to be managed is of IT and Telecom type generated from administrative and port offices at Gandhidham, Kandla and Vadinar. Another major source is E-waste generated from households in colonies.

4.3.3.Segregation

E-waste at Gandhidham AO is separately stored but there is no mechanism for its segregation at Gopalpuri colony. A methodology for E-waste segregation for DPA is covered in the Training Module.

4.3.4.Storage (on-site)

At Gandhidham AO, the discarded electronic equipments are stored at EDP store. The E-waste from Vadinar is brought to Gandhidham AO for onward disposal as per procedure. Currently 252 and 34 units of obsolete PCs, Monitors, Printers etc. at Kandla and Vadinar respectively are stored until the agency appointed through MSTC collects and channelizes the waste for environment-friendly disposal.

4.3.5.Collection

The responsibility of collecting the stored e-waste is of the agency appointed through MSTC portal. As an alternative to the MSTC portal, a non-exhaustive list of E-waste recyclers registered with GPCB is provided at Annexure V.

Figure 12: E-waste storage room at Vadinar

4.3.6.Disposal

The authorized agency appointed through MSTC is responsible for environment-friendly disposal of DPA's E-waste. As on June 2024, the list of scrap items to be disposed through MSTC portal is attached at Annexure XI.

4.4. Record keeping

The E-Waste rules do not mandate any record keeping requirement for E-waste consumers however it is a good practice to collect receipts and maintain record of E-waste generated on-site and quantity collected by appointed Waste Management Agency. This is being done by Store Department at Gandhidham Administrative Office.

4.5. Procedure adopted for engagement of external agencies/private operators

DPA has entered in agreement with MSTC Ltd. Vadodara for selling / auction of all scrap items including e-waste. This agreement is valid till February, 2025 or until one of the two parties give 1-month notice in writing for termination of the agreement. DPA is in process to engage an E-waste collecting vendor through MSTC Ltd.

4.6. Recommendations and strategies

- It is recommended to maintain records of e-waste generated by them.
- DPA should consider the option of returning the end-of-life electronic items to the producer through its pick up or take back services or through its collection points.
- Create awareness at office as well as residential colonies regarding hazards and harmful environmental impacts of E-waste and not mix E-waste with general waste.

Chapter-5

Bio-medical Waste

5.1. Applicable laws and rules

Bio-Medical Waste Management Rules, 2016 and subsequent amendments in 2018 and 2019.

The biomedical wastes categories and their segregation, collection, treatment, processing and disposal options as per Schedule I of the Rules are specified in Annexure VI

5.2. Responsibility of DPA as per BMWM Rules:

- *It shall be the duty of every occupier (DPA) to*

- Take all necessary steps to ensure that bio-medical waste is handled without any adverse effect to human health and the environment and in accordance with the rules stated above.
- Make a provision within the premises for a safe, ventilated and secured location for storage of segregated biomedical waste in colored bags or containers to ensure that there shall be no secondary handling, pilferage of recyclables or inadvertent scattering or spillage by animals and the bio-medical waste from such place or premises shall be directly transported in the manner as prescribed in the rules to the common bio-medical waste treatment facility.
- Pre-treat the laboratory waste, microbiological waste, blood samples and blood bags through disinfection or sterilization on-site and then sent to the Common bio-medical waste treatment facility for final disposal.
- Phase out the use of chlorinated plastic bags (excluding blood bags) and gloves
- Dispose of solid waste other than bio-medical waste in accordance with the provisions of respective waste management rules made under the relevant laws and amended from time to time.
- Avoid mixing of treated bio-medical waste with municipal solid waste.
- Provide training to all its health care workers and others, involved in handling of bio medical waste at the time of induction and thereafter at least once every year and the details of training programs conducted, number of personnel trained and number of personnel not undergone any training shall be provided in the Annual Report.
- Immunize all its health care workers and others, involved in handling of bio-medical waste for protection against diseases including Hepatitis B and Tetanus that are likely to be transmitted by handling of bio-medical waste
- Establish a Barcode System for bags or containers containing bio-medical waste to be sent out of the premises or for the further treatment and disposal
- Ensure segregation of liquid chemical waste at source and ensure pre-treatment or

neutralization prior to mixing with other effluent generated from health care facilities.

- Ensure treatment and disposal of liquid waste in accordance with the Water (Prevention and Control of Pollution) Act, 1974
- Ensure occupational safety of all its health care workers and others involved in handling of biomedical waste by providing appropriate and adequate personal protective equipments.
- In case of bedded health care units, maintain and update on day-to-day basis the bio-medical waste management register and display the monthly record on its website according to the bio-medical waste generated in terms of category and colour coding
- Report major accidents including accidents caused by fire hazards, blasts during handling of biomedical waste and the remedial action taken and the records relevant thereto to the prescribed authority and also along with the annual report; make available the annual report on the web-site; inform the prescribed authority immediately in case the operator of a facility does not collect the bio-medical waste within the intended time or as per the agreed time;
- In case of bedded health care facilities (any number of beds), make available the annual report on its web-site
- Maintain all record for operation of incineration, hydro or autoclaving etc., for a period of five years;

5.3. Handling and Management of Waste

5.3.1. Identification of sources and Quantification of waste

There are 3 healthcare facilities at Gandhidham and Kandla of which one is a 55 bedded hospital located in Gopalpuri colony and two dispensaries, one each at Kandla port and Adipur village.

There is one operational healthcare facility at Vadinar named Shree Samarpan Wellness Pvt Ltd.

Figure 13: Gopalpuri hospital at Gandhidham

The category wise waste generation details for the identified BMW sources is tabulated below:

Table 14 BMW generation at DPA HCFs

Sr. no	Name of the HCF	Category-wise BMW quantity in kg/month			
		Yellow	**Red**	**White**	**Blue**
DPA HCFs in Gandhidham/Kandla					
GPCB consented quantity as per BMW Authorization		250	170.3	15.5	98.1
Average BMW generated in kg/month					
1	Gopalpuri Hospital	47	30	1.6	33
2	Kandla dispensary	02	--	--	--
3	Adipur dispensary	0.5	--	--	--
HCF at Vadinar port area					

GPCB consented quantity as per BMW Authorization		**6.0**	**5.0**	**0.5**	**2.0**
4	Shree Samarpan Wellness Pvt. Ltd.	2.6	0.57	--	0.45

At Goaplpuri HCF the BMW quantity generated is within the consented quantity as per BMW Authorization provided by GPCB.

At Shree Samarpan Wellness Pvt Ltd. in Vadinar, the BMW quantity generated is within the consented quantity as per BMW Authorization provided by GPCB

5.3.2. Segregation:

Segregation at source into different colored bins for different category bio medical waste is imperative for efficient management of Bio-medical waste management system. Following are the observations for Gopalpuri hospital and HCF at Vadinar:

- Waste is being segregated at the point of generation of source.
- Needles and syringes are destroyed at the working desk or collected in puncture proof containers for treatment at CBWTF.
- Posters/ placards for bio-medical waste segregation are provided near bins and in waste storage area.
- Adequate number of colour coded bins / containers and bags are available at the point of generation of bio-medical waste.
- PPEs have been provided to the bio-medical waste handling staff.

Figure 14: Color-coded bins at Gopalpuri Hospital

Figure 15: Color-coded bins at Shree Samarpan Wellness Pvt. Ltd., Vadinar

5.3.3. Storage (on-site and centralized)

At Gopalpuri Hospital, a designated storage room for the generated BMW is provided. The Distormed Kutch Services Pvt. Ltd. directly collects the waste from this storage room. At Shree Samarpan Wellness hospital, Vadinar, the quantum of waste generated is less hence there is no dedicated storage room.

Figure 16: Designated storage room for BMW at Gopalpuri Hospital

5.3.4. Collection and Intramural Transportation

Ward-wise collection and intramural transportation of BMW is done through trolleys and sent to designated storage room for storage until the waste is picked up the agency.

The GPCB authorized CBWTFs i.e Distormed Kutch Services Pvt. Ltd. and Dev Biomedical Waste Management Services for Gopalpuri and Vadinar respectively have been engaged for collection, transportation and disposal of BMW. The details are as below:

Table 15 Details of CBWTF appointed for DPA HCFs

Sr.no	Name of the CBWTF	Name of HCF
For Gandhidham and Kandla		
1	Distromed Kutch Services Pvt. Ltd.	Gopalpuri Hospital
2		New Kandla Port Hospital
3		Kandla Port Dispensary
Vadinar		
4	Dev Biomedical Waste Management Services	Shree Samarpan Wellness Pvt Ltd

The CBWTFs are responsible for collection, transport, processing, recycling and disposal of BMW. The CBWTFs are mandated to use the vehicles that are specially designed vehicles as per CPCB guidelines and are properly labeled with symbol indicating biohazard, for transporting BMW.

5.3.5. Disposal

The BMW is disposed by CBWTF in accordance with the norms and criteria prescribed in the BMW Rules and CPCB guidelines.

5.4. Record keeping

The Bio-medical Waste Management Rules, 2016 and subsequent guidelines prescribes the below requirements as far as record-keeping is concerned:

- Maintain category-wise records of bio-medical waste generation and its treatment disposal on a daily basis in Annexure VII: Format for Bio-Medical Waste Register / Record
- Category-wise quantity of waste generated from the facility must be recorded in Bio Medical Waste Register/logbook being maintained at the central waste collection area under the supervision of one designated person.
- A weighing machine as per the specifications given in CPCB guidelines for bar code system needs to be kept in central waste collection centre of the HCF having 30 or more than 30 nos. of beds for weighing the quantity of Bio Medical Waste.
- HCFs having less than 30 beds shall maintain records of receipts printed by the CBWTF.
- Records on Annual Report on bio-medical waste management and Accident Report including preventive and corrective actions taken by the HCFs in relation to such accidents shall be submitted to GPCB

- Records shall be maintained on training on BMW Management including both Induction and in service training records.
- Maintain records for Annual Health check-up and Immunization of all the employees.
- Records of testing of Effluent generated from health care facility
- Record of recyclable waste (plastic/glass) handed over to the authorized recycler in kg/annum. The records related to the handling of BMW by healthcare facilities needs to be retained for a period of five years.

The list of information and necessary formats for record keeping have been covered in the Training Manual for Bio-Medical Waste.

5.5. Procedure adopted for engagement of external agencies/private operators

The CBWTFs Association of Gujarat based on CPCB guidelines and in coordination with GPCB have earmarked regions/districts that each CBWTF can cater to. Based on which, no other agency except M/s Distromed Kutch Services Pvt. Ltd. can cater to Kutch district. Same is the case for Devbhumi Dwarka district (HCF at Vadinar). Hence DPA or any other HCF has no choice when it comes to selection of CBWTFs for these regions. All these agencies are registered with GPCB.

5.6. Obtaining Authorization/Clearance/License

Below table 16 lists the requirements for obtaining authorization under Bio-Medical Waste Management Rules, 2016.

Table 16 Requirements of obtaining authorization for HCFs as per BMW Rules

Type of HCF	Type of authorization	Granting authority	Validity	Applicability and status w.r.t DPA's HCFs
Bedded HCF	Fresh authorization and its timely renewal	GPCB	Validity in synchronization with the validity of: Consent under Air (Prevention and Control of Pollution) Act, 1981 and Water (Prevention and Control of Pollution) Act, 1974	Both Hospitals at Gopalpuri and Vadinar are having valid licenses (BMW 364004 & BMW 361012). The licenses need to be updated from time to time as per the Act and applicable Rules.
Non-bedded HCF	One-time authorization*		Deemed valid until amendment sought	It, is applicable to Both the dispensaries at

				Kandla and Adipur and authorization should be done as per the rules.
HCFs situated within 75 km reach of CBWTF	Agreement with Common Bio Medical Waste Treatment Facility (CBWTF)	Monitored by GPCB	Generally, for 3 years or varies as per different CBWTF facility	Bedded HCF Both Hospitals at Gopalpuri and Vadinar are having valid agreements with the CBWTF for a period of one year. Non bedded HCF Both the dispensaries at Kandla and Adipur are having valid agreements with the CBWTF for a period of one year. However, all the bedded and non-bedded HCFs need to renew the agreements from time to time.
HCFs beyond 75 km reach from CBWTF but its operator willing to provide required services	Agreement with Common Bio Medical Waste Treatment Facility (CBWTF)			Not Applicable

* In case there is any change or variance in relation to the activities of HCF, these HCFs have to apply for a fresh authorization to amend earlier authorization

5.7. Recommendations and strategies

At DPA HCFs, Bio-Medical Waste is managed in a sound manner. For further improvement of this system, following points are suggested:

- The substances in bio-medical waste might contain viable microorganism such as bacterium, virus, parasite or fungus that may cause disease in humans or animals.

Therefore, packaging of such bio-medical waste shall be done in triple packaging system comprising of three layers of packaging.

- Exhaust fans should be provided in the waste storage room for ventilation.
- The entrance to the storage room must be labelled with "Entry for Authorized Personal Only".
- DPA shall develop a separate page/web link in its website for displaying the information pertaining to their Gopalpuri hospital. The list of Information for updating on website is provided on Annexure VIII.
- HCF must ensure that a comprehensive health check-up of each employee and other staff involved in BMW handling is carried out at the time of induction and also as a mandatory procedure is followed every year for every employee.
- Concerned HCF authority shall ensure the occupational safety of the healthcare workers and other staff involved in handling of Bio medical waste in the healthcare facility.
- HCF shall impart training to the staff handling BMW in accordance with the Training Manual and maintain Training records in Annual Report (Annexure VII).
- Submit an annual report to the prescribed authority in Form-IV, on or before the 30th June of every year (Annexure VII) for each HCF.

Chapter-6

Construction and Demolition Waste

6.1. Applicable laws and rules

Construction and Demolition Waste Management Rules, 2016.

6.2. Responsibility of DPA as per various Conventions, Acts and Rules:

Rule 4-Duties of the waste generator

- Every waste generator shall prima-facie be responsible for collection, segregation of concrete, soil and others and storage of construction and demolition waste generated, as directed or notified by the concerned local authority in consonance with these rules.
- The generator shall ensure that other waste (such as solid waste) does not get mixed with this waste and is stored and disposed separately.
- Waste generators who generate more than 20 tons or more in one day or 300 tons per project in a month shall segregate the waste into four streams such as concrete, soil, steel, wood and plastics, bricks and mortar and shall submit waste management plan and get appropriate approvals from the local authority before starting construction or demolition or remodeling work and keep the concerned authorities informed regarding the relevant activities from the planning stage to the implementation stage and this should be on project to project basis.
- Every waste generator shall keep the construction and demolition waste within the premise or get the waste deposited at collection center so made by the local body or handover it to the authorized processing facilities of construction and demolition waste; and ensure that there is no littering or deposition of construction and demolition waste so as to prevent obstruction to the traffic or the public or drains.
- Every waste generator shall pay relevant charges for collection, transportation, processing and disposal as notified by the concerned authorities; Waste generators who generate more than 20 tons or more in one day or 300 tons per project in a month shall have to pay for the processing and disposal of construction and demolition waste generated by them, apart from the payment for storage, collection and Transportation. The rate shall be fixed by the concerned local authority or any other authority designated by the State Government.

6.3. Handling and Management of Waste

Since the construction / demolition work is contracted to a civil contractor by DPA, the entire responsibility of transportation, management and disposal of C&D waste lies with the contractor.

6.4. Procedure adopted for engagement of external agencies/private operators

Since the responsibility of handling C&D waste lies with the civil contractor, DPA does not engage any external agency for processing / disposal of C&D waste.

6.5. Recommendations and strategies

- Proper segregation of C&D waste should be practiced to avoid mixing with bio-degradable waste destined for MSW treatment facilities / landfill.
- Explore the possibility of reusing C&D waste materials in construction related activities (Refer Table), thereby decreasing the quantum to be landfilled.
- The Delhi government has issued an advisory on the use of products made out of recycled C&D waste by the Public Works Department (PWD). All Delhi government agencies will be required to incorporate a clause in their tenders that mandates use of a minimum of 2 per cent recycled products from construction waste in all future contracts for building works and 10 per cent recycled products for road works. (Ref. CSE August 26, 2015).
- Filling of low-lying areas, reclamation of land, trenches etc. should be done using C&D wastes.
- Necessary measures to control dust and fugitive emissions must be taken including:
    - Use of water sprinklers
    - Transportation of C&D wastes should be done in covered vehicles to prevent fugitive dust emission

Table 17 Potential uses of C&D waste

C & D waste	Potential use of C & D wastes
Concrete	The utilization of recycled aggregate is particularly very promising as 75% of concrete is made of aggregates.
Bricks	If deconstructed properly, bricks can be reused after removal of mortar. Broken bricks can be used for refilling or for manufacturing debris paver blocks or debris blocks.
Stone	Stone can be reused for plinth formation, masonry construction, landscape purpose, ledges, platforms, window sills, coping etc. depending upon the form of available stones.
Timber	Timber elements from deconstructed building may have aesthetic and antique value. **Opportunity:** Whole timber arising from construction and demolition

	works can be utilized easily and directly for reused in other construction projects after cleaning, de-nailing and sizing.
Plywood and other timber based boards	Plywood and other timber-based boards can be either reused for interior works in new construction or it can be recycled for manufacturing of timber-based boards.
Gypsum	In India, over 10 about of waste gypsum such as phosphor-gypsum, Fluro-gypsum etc., are being generated annually. **Opportunity:** Plaster developed from this waste gypsum has showed improved engineering properties without any harmful effect. Phosphor-gypsum and lime sludge can be recycled for manufacture of Portland cement, masonry cement, sand lime bricks, partition walls, flooring tiles, blocks, gypsum plaster, fibrous gypsum boards, and super-sulphate cement.
Metals & metal alloys-	Ferrous Metals are the most profitable and recyclable material. Scrap steel is almost totally recycled and allowed repeated recycling. Structural steel can be reused as well as 100% steel can be recycled to avoid wastage at construction site. **Advantage:** Generally sold to a scrap metal dealer at a specified price. Metals like scrap iron can be mixed with the virgin metal in the foundry. In India more than 80% scrap arising is recycled.
Nonferrous metal	The main nonferrous metal collected from construction and demolition sites are aluminum, copper, lead and zinc. **Opportunity:** In India aluminum and copper are recycled and are valuable resources
Debris	Construction debris can be recycled to manufacture paver blocks which can be used in light traffic areas and masonry blocks. Other uses of processed debris include use in lean concrete for leveling purpose, as mortar for masonry, as bedding mortar for pavement tiles and used for land filling materials is comparable with new materials.
Composite materials	The plastic wastes are best for recycling if these materials are collected separately and cleaned. Recycling is difficult if plastic wastes are mixed with other plastics or contaminants. Plastic may be recycled and used in products specifically designed for the utilization of recycled plastic, such as street furniture, roof and floor, PVC window noise barrier, cable ducting, panel.

Chapter-7

Shipping Waste

7.1. Applicable laws and rules

The list of international and local legislations applicable to the ports (Port at Kandla and Vadinar) managed by Deendayal Port Authority (DPA) are listed below:

1. MARPOL 73/78 – Consolidated Edition 2002
2. MARPOL 73/78 – Consolidated Edition 1997.
3. Indian Ports Act 1908 (Act No. 15 of 1908)
4. The Merchant Shipping Act 1958 (Act No. 44 of 1958) (2000)
5. International Convention on the Control of Harmful Anti-fouling Systems on Ships
6. Ballast Water Management Convention
7. The Environment (Protection) Act, 1986 and the Environment (Protection) Rules 1986
8. Hazardous and Other Wastes (Management & Handling) Rules, 2016
9. Annex VI of MARPOL 73/78 – Regulation for the Protection of Air Pollution from ships & MOX Technical code.
10. Provision concerning the Reporting of incidents involving harmful substances, under MARPOL 73/78 (1999 Edition)
11. SOLAS consolidated Edition 2001.
12. The Water (Prevention and Control of Pollution) Act, 1974 and Rules 1975
13. The Major Port Trust Act

7.2. Definitions

Important terminologies reflecting in MARPOL documents and other related to shipping wastes have been produced below for ready reference:

1 **Waste from ships** means all waste, including cargo residues, which is generated during the service of a ship or during loading, unloading and cleaning operations and which falls within the scope of Annexes I, II, IV, V and VI to MARPOL Convention, International Convention for the Control and Management of Ships Ballast Water and Sediments (BWM Convention), International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention), as well as waste such as expired medicines, pyrotechnics etc.

2 **Port Reception Facility, (PRF)** means any facility which is fixed, floating or mobile and capable of providing the service of receiving the waste from ships;

3 **Port Authority:** Organizations, either public or governmental, that manages the operations of a port, in whole or part.

4 **Cargo residues**: remnants of any cargo material which are not covered by Annexes I, II, IV and VI of the MARPOL convention and which remain on the deck or in holds following loading or unloading, including loading and loading excess or spillage, whether in wet or dry conditions or entrained in wash water but not including cargo dust remaining on the deck after sweeping or dust on the external surfaces of the ship. Dry bulk cargo residues may include substances that are harmful to the marine environment.

5 **Grey water** means drainage from dishwater, shower, laundry, bath and washbasin drains. It does not include drainage from toilets, urinals, hospitals and animal spaces, as defined in regulation 1.3 of MARPOL Annex IV (sewage) and drainage from cargo spaces. Grey water is not considered garbage in the context of MARPOL Annex V.

6 **E-waste**: means electrical and electronic equipment used for the normal operation of the ship or in the accommodation spaces, including all components, subassemblies and consumables, which are part of the equipment at the time of discarding, with the presence of material potentially hazardous to human health and the environment.

7 **Garbage**: means all kinds of food wastes, domestic wastes and operational wastes, all plastics, cargo residues, incinerator ashes, cooking oil, fishing gear, and animal carcasses generated during the normal operation of the ship and liable to be disposed of continuously or periodically except those substances which are defined or listed in other Annexes to the MARPOL Convention. Garbage does not include fresh fish and parts thereof generated as a result of fishing activities undertaken during the voyage, or as a result of aquaculture activities which involve the transport of fish including shellfish for placement in the aquaculture facility and the transport of harvested fish including shellfish from such facilities to shore for processing.

8 **Anti-fouling system** means a coating, paint, surface treatment, surface, or device that is used on a ship to control or prevent attachment of unwanted organisms.

9 **Ballast Water** means water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship.

10 **Sediments** means matter settled out of Ballast Water within a ship.

7.3. Responsibility of DPA as per various Conventions, Acts and Rules:

This section details the regulatory requirements for Ports mandated under MARPOL, Anti Fouling Convention, Ballast Water Management Convention and Merchant Shipping Act and Rules.

7.3.1. Regulatory Requirements under MARPOL

i. **Regulation 38 of Annex I:** In Annex I, strict requirements are outlined for the storage and discharge of oil from ships. These covers wastes like Oily bilge water, Oil residues, Oil tank washings, Dirty Ballast water, Scale and sludge from tank cleanings. According to Annex I Regulation 38, Parties to the Convention are required to provide facilities for receiving oily mixtures in the following ports:

- All ports and terminals where crude oil is loaded into oil tankers that have completed a ballast voyage of not more than 72 hours or 1,200 nautical miles before arrival.;
- All ports and terminals where oil other than crude oil in bulk is loaded at a rate of more than 1,000 tonnes per day on average;
- All ports having ship repair yards or tank cleaning facilities which are crucial for conducting efficient and safe maritime operations;
- All ports and terminals that are involved in the handling of ships must possess oil residue (sludge) tanks that comply with regulation 12 of Annex I;
- All ports with regard to oily bilge waters and other wastes that cannot be discarded in accordance with Regulations 15 and 34 of Annex I; and
- All bulk cargo loading ports for combination carriers' oil residues that are not permitted to be discharged in accordance with Annex I's regulation 34.

ii. **Regulation 12 of Annex IV** states that all Party States have to ensure adequate facilities in ports and terminals for receiving wastewater/sewage without causing delays for ships, which are adequate to serve the needs of the ships.

iii. **Annex V** This section mentions the provision of a port recycling program for separating recyclable from non- recyclable garbage. The segregation practices on ship should match the requirements of the recycling program of the port. Information concerning recycling programs and their requirements should be passed to the ships. This makes the re-use or recycling of the waste streams effective.

iv. **Regulation 17 of Annex VI:** According to this provision each Party shall undertake to provide facilities for the reception of ODS or equipment containing such substances, washing water from scrubbers and sediment from treatment plants on board. Ports shall provide to meet for:

- Ships utilizing its repair ports are required to receive ODS and equipment containing such substances when they are removed from the ships for repairs

- Ships using its ports, terminals, or repair ports for the purpose of receiving exhaust gas cleaning residues from an exhaust gas cleaning system;

7.3.2. Regulatory requirements under Anti-Fouling Convention

- A party shall take appropriate measures to ensure that wastes from the application or removal of an anti-fouling system are collected, handled, treated and disposed of in a safe and environmentally sound manner to protect human health and the environment.

7.3.3. Regulatory requirements under Ballast Water Management Convention

- Party shall ensure that, in ports and terminals where cleaning or repair of ballast tanks occur, adequate facilities are provided for the reception of Sediments, such reception facilities shall operate without causing undue delay to ships and shall provide for the safe disposal of such Sediments that does not impair or damage their environment, human health, property or resources or those of other States

7.3.4. Regulatory requirements under Merchant Shipping Act, 1958

i. **<u>Section</u> 356-I** states that the powers of the port authority shall include the power to provide reception facilities. However, where the Central Government is satisfied that there are no reception facilities at any port in India or that the facilities available at such port are not adequate for enabling ships calling at such port to comply with the requirements of the Convention, the Central Government may, after consultation with the port authority in charge of such port, direct, by order in writing, such authority to provide or arrange for the provision of such reception facilities as may be specified in the order. **Chapter VI of Merchant Shipping (Prevention of Pollution by Oil from Ships) Rules, 2010** deals with reception facilities and the requirements related to provision of reception facilities, in line with MARPOL Annex I requirements.

ii. **<u>Chapter</u> VIII** of Merchant Shipping (Control of Pollution by Noxious Liquid Substances in Bulk) Rules, 2010 deals with reception facilities and the requirements related to provision of reception facilities are in line with MARPOL Annex II requirements.

iii. **<u>Rule</u> 9 of Merchant Shipping (Control of Anti-fouling System) Rules, 2016** states that the waste from the application or removal of anti-fouling system are collected, handled, treated and disposed of in a safe and environmentally sound manner in accordance with Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 as notified by the

Central Government in the Ministry of Environment and Forests, vide notification number S.O. 2265 dated the 24th September, 2008".

7.3.5. Regulatory requirements under The Hazardous and Other Wastes Management Rules, 2016

I. DPA shall be responsible for safe and environmentally sound management of hazardous and other wastes.

II. The hazardous and other wastes generated and received at DPA Ports shall be sent or sold to an authorized actual user or disposed of in an authorized disposal facility.

III. The hazardous and other wastes shall be transported from DPA Ports to an authorized actual user or to an authorized disposal facility in accordance with the provisions of the rules.

IV. If DPA intends to get its hazardous and other wastes treated and disposed of by the operator of a treatment, storage and disposal facility shall give to the operator of that facility, such specific information as may be needed for safe storage and disposal.

V. DPA shall take all the steps while managing hazardous and other wastes to-

a) contain contaminants and prevent accidents and limit their consequences on human beings and the environment; and

b) provide persons working in the site with appropriate training, equipment and the information necessary to ensure their safety.

7.3.6. Regulatory Requirement under The Plastic Waste Management Rules, 2016

I. Take steps to minimize generation of plastic waste and segregate plastic waste at source

II. Not litter the plastic waste and ensure segregated storage of waste at source and handover segregated waste to agencies appointed for collection of waste.

7.4. Handling and Management of Waste

At every port, for provision of waste collection from ships, its storage, treatment and disposal, an authorized official is appointed to whom the captain of the ship could get in touch regarding wastes generated on the ship.

The captains of the ships that embark at the ports intimates the authorized agencies engaged by DPA for collection of Hazardous and Non-hazardous wastes generated by the ships. This communication is facilitated through Swachh Sagar Portal. There are 22 such agencies, 11 for collection of Non-hazardous wastes and other 11 for collection of Hazardous wastes received at the Kandla and Vadinar ports. These agencies are listed in Table 4 in subsequent section.

7.4.1.Source Identification, Quantification and Inventory of waste at Kandla & Vadinar

The shipping waste being received at the ports of Kandla and Vadinar from the ships have been categorized based on the waste categories identified under below tabulated Law/Rule/Convention.

Table 18 General type and source of wastes generated on ships

Law/ Rule/ Convention	Category	Source and Type of waste
MARPOL	Annexure I	Oily bilge water, Oil residues (Sludge), Oil tank washings, Dirty ballast water, Scale and sludge from tank cleanings.
	Annexure II	Category X, Y Z and Other of Noxious Liquid Substances discharged from tank cleaning or de-ballasting operations
	Annexure IV	Sewage that includes drainage and other wastes from any form of toilets and urinals; drainage from medical premises via wash basins, wash tubs and scuppers located in such premises; drainage from spaces containing living animals; or other waste waters when mixed with the drainages defined above
	Annexure V	All kinds of garbage like Plastics, Food wastes, Domestic wastes, cooking oil, Incinerator ashes, Operational wastes, Cargo residues, Animal carcass(es), Fishing gear, E-waste
	Annexure VI	Ozone-depleting substances (ODS) as defined in Montreal Protocol of 1987. Major sources of ODS are refrigeration equipment; air conditioning equipment and fire extinguishing equipment.
Anti-fouling system	Article 5	coating, paint, surface treatment, surface, or device that is used on a ship to control or prevent attachment of unwanted organisms
Ballast Water Management Convention	Article 5	Matter settled out of Ballast Water
HOWM Rules, 2016	Schedule I	Used Spent Oil (Category 5.1) Waste Residue Containing Oil (Category 5.2)

The inventory of Hazardous as well as Non-hazardous waste generation at Kandla and Vadinar ports for 2022-23 is presented in below Table 19. The generated waste has also been categorized as per the categorization under MARPOL and applicable national legislation i.e., Hazardous Waste Management Rules, 2016.

Table 19 Type and quantum of waste generated at DPA ports

Sr.no	Waste Generated	Waste categorization as per		Waste Generated (MT/ year) during FY 2022-23	Disposal
		HWM Rules	MARPOL		
Hazardous waste quantum received at Kandla and Vadinar ports					
1.	Sludge oil, Used Spent Oil, Slop/Sludge	5.2	Annex I	13,736.37	Collected by authorized agency
2.	Waste Residue containing Oil	5.1	Annex V		
Non-hazardous waste quantum received at Kandla and Vadinar ports					
3.	Garbage including Soild waste, Mooring rope, Drums, Wood etc.	-	Annex V	2,473.19	Collected by authorized agency

The total quantity of Hazardous waste received at Kandla and Vadinar ports per year is 13736.37 MT/year and DPA has a tie-up with agencies for handling Hazardous waste that collectively have GPCB authorization for handling of more than 20,000 MT of waste. Thus, DPA ports have enough provision to cater to the shipping wastes received at its ports.

Similarly, total quantity of Non-hazardous waste received at Kandla and Vadinar ports per year is 2473.19 MT against which the agencies engaged by DPA have a collective provision to cater 2,00,000 MT of waste, thus there is surplus provision to handle non-hazardous waste as well.

7.4.2.Collection, Transport, Processing and Disposal

DPA has a tie-up with 22 agencies that are responsible for management of shipping waste generated from both, Kandla and Vadinar ports. All these agencies are authorized by GPCB for handling of wastes. 11 agencies deal with non-hazardous waste and rest 11 with hazardous waste. Collection, handling, transport and disposal of wastes is the responsibility of these agencies which are listed below.

Table 20 List of Waste Management Agencies operating at Kandla and Vadinar ports

Sr. no	Name of waste collecting agency	Address/Contact of the Agency	Type of waste collected	Name of waste with category	Waste category as per MARPOL	Valid up to
1	**M/S. Harish. A. Pandya***	16, Brahm samaj bldg., Plot No. 106, Sector-8, B/H Oslo Cinema, Gandhidham Kutch Gujarat-370205. **Mobile-** 9426218125, 8000008999 **E-mail-** info@harishpandya.com	Haz	Waste Residue containing oil (5.1) Used Spent Oil (5.2)	Annexure I	30-05-2023
			Non Haz	Garbage	Annexure V	
2	**M/S. Chitrakut Trading & Industries ***	**Factory Address:** 56 to 63 Survey No. 323/1, 323/2, Ghanshyam Park, Village: Kukma Tal: Bhuj (Kutch) Guj. India. **Postal Address:** 15, Brahm Samaj Building, Plot No. 106, Sector No. 8, B/H Oslo Cinema, Gandhidham (Kutch) India. **Mobile no-** +919426218125 **E-Mail -** info@chitrakutshippingservices.com	Haz	Waste Residue containing oil (5.1) Used Spent Oil (5.2)	Annexure I	-
			Non Haz	Garbage, Waste Scrap, Mooring rope, Empty Drums		
3	**Vishwa Trade Link Inc.**	Plot No. 170/2/A, T.P.-3, Anjar (Kutch), Gujarat -370110	Haz	Waste Residue containing	Annexure I	03-11-2023

				oil, Used Spent Oil		16-11-2022
			Non Haz	Scrap, Dunnage Wood, Garbage other (Dry, Solid, Ordinary, Non-hazardous) Wet Garbage	Annexure V	
4	**Revolution Petrochem LLP. ***	Office No. C-214, 2nd Floor, Shop no. 234-235, Kutch Arcade "Platinum", Mithirohar, Gandhidham-370201 **Mobile no**: 98795955087 **E-mail**: revolutionpetrochem@gmail.com	Haz	Waste Residue containing oil (Haz waste/waste oil/sludge) Used Spent Oil	Annexure I	31-03-2023
			Non Haz	1) Container, Scrap, Dunnage Wood, Garbage other (Dry, Solid, Ordinary, Non-hazardous) 2) Wet Garbage	Annexure V	
5		Office No. 2, Plot no. 106, Sector 8,	Haz	Used Oil	Annexure I	-

	Omega Marine Services	Braham Samaj Building, Gandhidham, Kutch Gujarat 370201 **Mobile no**: +919537329203, 9727589185 **E-mail:** operations@omegamarineservices.com, omegamrn@hotmail.com, accounts@omegamarineservices.com	Non Haz	1) Dry garbage 2) Wet Garbage	Annexure V	
6	**United Shipping Company**	Plot no 42, 2nd floor. Opp. Old Court, Sector 1/A. Gandhidham, Kutch **T:** +912836226555 **E-mail:** unitedshipping46@gmail.com	Haz	Waste Residue containing oil (5.1 Sludge oil) Used spent oil (5.2)	Annexure I	
			Non Haz	Dry garbage	Annexure V	
7	**Green Earth Marine Solutions***	Office No. 202, Plot No. 578, Ward 12-C, Shakti Avenue, Gandhidham, (Kachchh) GUJARAT -370201 **Mobile no**: 9537824948 **E-mail:** operation@greenearthmarine.com	Haz	Used Oil (nil)	Annexure I	
			Non Haz	Dry Garbage, Scrap Dunnage, Wood garbage, Other (nil)	Annexure V	
8	**New India Marine Works ***	Plot no:16, Sector 10A, Industrial Area OSLO GIDC, Gandhidham KUTCH-370201 **Mobile no:** +919879072262 **E-mail:** sludgeoil16@yahoo.in	Haz	Waste Residue containing oil (5.1 Sludge oil)	Annexure I	19-02-2024
9	**Naaz Shipping Service**	Office no-35, 1st Floor GMA building, Plot no-297, Ward no-12/B, Grain	Haz	1) Waste Residue containing oil	Annexure I	31-07-2023

	Enterprise *	Merchant Association Building, Nr Old Court Gandhidham **Mobile no:** 9825724120, 9427277088 **E-mail:** naazshippingservice@yahoo.com nasir.khan685@gmail.com		2) Used Spent Oil		
			Non Haz	1) Dry Garbage-Scrap Dunnage Wood Garbage other 2) Wet Garbage	Annexure V	
10	**Alicid Organic Industries Ltd***	207/208, Hanumant Henduva, Opp Gujcomasal, near Khari River Highway, Post- Palavasana, Mehsana -02 (Gujarat) **Mobile no:** 9825604120 **E-mail:** alicidorganic@gmail.com	Haz	1) Waste Residue containing oil 2) Used Spent Oil	Annexure I	05-01-2024
			Non Haz	1) Dry Garbage-Scrap Dunnage Wood Garbage other(nil) 2) Wet Garbage	Annexure V	
11	**Shana Oil Process**	New Good Luck Market, nr Aksha Masjid, Chandola Lake, Narol Road, Ahmedabad-3800028 **Mobile no:** +919824286952, +919879986952 **E-mail:** shanaoil0891@gmail.com	Haz	1) Waste Residue containing oil 2) Used Spent Oil	Annexure I	05-01-2024
			Non Haz	1) Dry Garbage-Scrap Dunnage Wood Garbage other (Dry, Solid, Ordinary, Non-hazardous) 2) Wet Garbage	Annexure V	
12		Kidana Nirmal Nagar, Survey no 133, Plot	Haz	1) Waste Residue	Annexure I	30-05-2023

	Golden Shipping Services*	no 83, Gandhidham-Kutch, Gujarat **Mobile no**: 9638808551 **E-mail**: bharat.ahir8686@gmail.com		containing oil (5.1) 2) Used Spent Oil (5.2)		
			Non Haz	1) Dry Garbage-Scrap Dunnage Wood Garbage other	Annexure V	
13	**K M Enterprise ***	Plot no-13, Sector-8, Near BM Petrol Pump, Opp. Sharma Motors, Gandhidham, Kutch **Mobile no:** 9510514287, 9879986952 or Shop No. 2, Plot No. 16, Sector 1/A, Shakti Nagar Road, Gandhidham-Kutch **Mobile no:** 8141380555 **E-mail:** kmenterprisekandla@gmail.com	Haz	1) Waste Residue containing oil 2) Used Spent Oil	Annexure I	
			Non Haz	1) Dry Garbage-Scrap Dunnage Wood Garbage other (Dry, Solid, Ordinary, Non-hazardous) 2) Wet Garbage	Annexure V	
14	**Atlas Organics Pvt. Ltd.**	Office 204/206, Ellis Bridge Shopping Center, Opp. Town hall, Ashram Road, Ahmedabad - 380006 Mobile no: +919909723532, +918980989015 Email id: atlasorganics@yahoo.com info@sludgeoilindia.com	Non Haz	1) Dry Garbage-Scrap Dunnage Wood Garbage other 2) Wet Garbage	Annexure V	
					Annexure V	
15	**Glorious Marinefuels Pvt. Ltd.**		Haz	1) Used oil 2) Waste oil	Annexure I	

16	**Priyansi Corporation**	C1 804-8096, GIDC, BAMANBORE, TA: CHOTILA, DIST-SURENDRANAGAR **MOBILE NO:** 9825226095, 9825785270 **E-mail::** operation.priyansicorporation@gmail.com	Haz	Sludge oil (5.2)	Annexure I	21/04/2024
17	**Amar Hydrocarbon Pvt. Ltd ***	FF-12, Sahara Complex, B/h, Navajivan Hotel S.G. Highway, Sarkhej, Ahmedabad – 3822210 **Mobile no:** 9328334205 **E-mail:** operations@amarhydrocarbon.com amarhydrocarbon@gmail.com	Haz	1) Used oil 2) Waste oil	Annexure I	30/06/2024
18	**Aditya Marine Ltd**	Room no 11,12,13, Dhiraj Chambers, Plot No. 36, Sector 9/A, Gandhidham, Kutch 37020, Gujarat, India email: info@adityamarine.com Phn no: +912836222053	Haz	1) Used oil 2) Waste oil	Annexure I	-
19	**Fine Refiners Pvt. Ltd.**	Plot no. 40, Vartej GIDC, Tal. Bhavnagar, Dist. Bhavnagar	Haz	1) Used oil 2) Waste oil	Annexure I	30/09/2022
20	**Mahalaxmi Asphalt Pvt. Ltd.**	Survey no. 343, Village: Bandhadi, Tal. Bhachau, Dist. Kutch	Haz	Waste oil	Annexure I	21/09/2027
21	**M/s. Kutch Energies Pvt. Ltd.**	Plot no. 72, shop no. 1,2,3 and 4, Hotel Bansal Building, Sector- 9/C, Gandhidham, Kutch.	Haz	Sludge	Annexure I	27/03/2025

		Email: shree_shree_in2004@yahoo.com Mob. 9998237716 9879072262				
22	**M/s. Bhavya Engineering Works and Multiservices**	Near Tee Bhanushali nagar, Bhuj-Kutch-370001 Email: bhavyaengineeringworks21@gmail.com Mob. 9427704592 9824682718	Non Haz	Garbage	Annexure V	27/05/2025

***Waste agencies also operating at Vadinar port**

7.4.3.Storage:

The shipping waste of ships calling at DPA ports is directly picked up by Waste Management Agencies in timely manner hence there is no requirement and provision for storage of waste on-site

7.4.4.Intramural transportation

Intramural transportation of any kind of waste is not required as the agency collects the waste from the ships directly, offloads and transfers it through agency's vehicle itself.

7.5. Record keeping

As per HWM Rules, 2016,

a. DPA Ports shall maintain a record of hazardous and other wastes received at ports and collected from port by WMA in a specified Form 3

b) Prepare an annual return containing the details specified in a specified Form 4 and submit it to the Gujarat Pollution Control Board on or before the 30th June following the financial year to which that return relates.

The guidelines for filling of Forms as mandated under the HOWM Rules have been covered in detail in Training Manual.

7.6. Procedure adopted for engagement of external agencies/private operators

DPA has appointed 22 Waste Management Agencies for management of its shipping waste management. It yearly renews the contract of these agencies. The selection criteria of the WMA, as followed by DPA includes:

- The agency dealing in Hazardous wastes shall hold a valid authorization from GPCB
- The agency shall obtain No Objection Certificate (NOC) from DPA customs department and Public Health Officer, Kandla
- The agency shall have required equipments and incinerator installed for environmentally sound management of wastes.
- The waste shall be collected, transported and disposed in timely manner
- The agency should be certified as collector, transporter and actual user. Further uploading on Swachh Sagar Portal with be in-line with entries of hazardous waste collected from each ship to be made in relevant Form (3) and to be uploaded on Swachh Sagar Portal. Form 4 maintained by occupier and pages of passbook required to be maintained by actual user to be uploaded on Swachh Sagar portal annually by 30th June every year.

7.7. Obtaining Authorization/Clearance/License

- DPA is required to and has obtained authorization under Hazardous and Other Waste Management Rules, 2016 from the Gujarat Pollution Control Board as an occupier. The details of Authorization obtained by DPA from GPCB are given below:

Table 21 Details of Authorization

Consent order no.	Date of Issue	Validity	Hazardous waste (HW) at the ports	Consented quantity of HW MT/year
AWH-110594	22/01/2021	21/07/2025	Used spent oil	4250
			Waste residue containing oil	8500

7.8. Recommendations and strategies

- Various types of garbage are received at ports from ships. These wastes differ in type, size and hazardousness. It is recommended that a port recycling program be developed for sustainable management of shipping garbage. The garbage can be segregated into streams like:
  - **Non-recyclable**; Plastics and plastics mixed with non-plastic garbage
  - **Recyclable**: Cooking oil, glass, wood, metal, paper, cardboard, Styrofoam plastic etc.
  - **Potentially Hazardous garbage**: oily rags, light bulbs, acids, batteries, chemicals, medical waste etc.

  - **E-waste generated on ships**: electronic cards, gadgets, instruments, equipment, computers, printer cartridges, etc.
- Information of such recycling programs and their requirements should be communicated to the ships. This would enhance the reuse or recycling of the waste streams.
- A procedure for annual assessment should be put in place to assess the need for capacity expansion in terms of employment of various agencies for waste collection, taking into account possible changes in traffic in the upcoming years and data collected from Swachh Sagar portal.
- DPA should formulate and disburse a document describing the procedures for advance notification by ships in accordance with Swachh Sagar requirements and the reception and collection of waste from ships through the Swachh Sagar Portal.
- DPA should have in place the procedure followed for approval and re-approval of agencies for Hazardous waste, taking into account the points mentioned below:
  i. The waste receipts shall be collected from each agency which should contain particulars regarding the type and quantity of the waste substances, the means of transport and details regarding the producer or generator, carrier and party attending to the disposal. In this manner, the route taken by the waste material becomes evident step by step for the competent authorities and also for the companies involved.
  ii. A storage facility should be provided at port area as a provision of waste storage on account of untimely waste collection by the agencies. These areas should be such that they do not create unhygienic and insanitary conditions around it. Following criteria shall be taken into account while establishing and maintaining storage facilities, namely:
  - Storage facilities shall be created and established by taking into account quantities of waste generation and densities. A storage facility shall be so placed that it is accessible to users; Its design should be such that the wastes stored are not exposed to open atmosphere and shall be aesthetically acceptable and user-friendly.
  - Storage facilities or bins shall have ‘easy to operate’ design for handling, transfer and transportation of waste. Bins for storage of bio-degradable wastes shall be painted green, those for storage of recyclable wastes shall be printed white and those for storage of other wastes shall be printed black.
  - Manual handling of waste shall be prohibited. If unavoidable due to constraints, manual handling shall be carried out under proper precaution with due care for safety of workers.

- The vehicles used by the agencies for transportation of wastes to authorized processing facilities shall be covered. Waste should not be visible to public, nor exposed to open environment preventing their scattering.
- The storage facilities set up shall be daily attended for clearing of wastes. The bins or containers wherever placed shall be cleaned before they start overflowing.
- Transportation vehicles shall be so designed that multiple handling of wastes, prior to final disposal, is avoided.
- In case the agency responsible for disposal do not provide a receipt of waste collected from transporter, a means for tracking transporting vehicle shall be employed.
- In case of oil spill accidents provisions stated in Oil Spill Management Plan shall be strictly adhered to

* Specific recommendations for waste categories defined under MARPOL are as below:

MARPOL Annexures	Recommendations
Annex I	Oily-water mixture collected from an incident to be transferred directly to Reception Facility Area for storage and disposed through Port authorized recycler
	The Waste material containing oil like oil-soaked rags, overalls, sand, saw dust, absorbent pads, absorbent booms etc., collected during an Incident to be disposed to the authorized recycler for incineration
	The authorized recycler must take the permission from the Port and Custom for the disposal of Waste material containing oil etc. generated from an oil spill incident
	The authorized recycler must submit the detailed information on authorized GPS vehicle and details of authorized drivers.
	After collecting the material, the authorized recycler must declare to the Port and Custom as per category of Hazardous waste management rules 2016 schedule I along with Quantity
	E-manifest entries and Form-10 will be generated and it shall be given to authorized recycler for transportation.
	After the incineration the final disposal certificate and pass book copy for the same to be submitted to DPA
	The following documents has to be submitted by the authorized recycler Drive, License Number Vehicle fitness letter Emission certificate

	GPS Number Weigh bridge receipt Form-10 Final Disposal Certificate
Annex V	Through Swachh Sagar Portal, the master/ steamer agent on behalf of vessel to intimate the garbage collecting agency approved by the Port for collection of garbage about the category of waste in order to arrange necessary receptacles and vehicles for proper collection without undue delay.
	On the request from the vessel, the garbage collecting agency has to obtain necessary permission from the Port Authority & Customs for each vessel in order to board the vessel for collection of garbage in each case.
	The garbage should be collected by the designated Agency duly following the terms and conditions of the work order issued by the Port and Segregation of the garbage to be carried out as per the Municipal Solid Waste Rule, no mixing of garbage is allowed at any point of time.
	The copy of waste delivery receipt to be submitted/forwarded to the concerned department after collection of garbage from each and every ship.
	Copies of the Waste Delivery Receipt, Permission letter obtained from the Port/Customs and any other documents as required at the gate are to be produced while going out from the Port.
	The Garbage Collecting Agency of the Port shall provide copies of following to the Port: Permission letters issued by the port/customs for clearing of waste/garbage along with type and quantity. Waste Delivery Certificate signed by the Master of the vessel and issued to the vessel.
Annex V	Through Swachh Sagar Portal the master/ steamer agent on behalf of the vessel to intimate the collecting agency designated by the Port for collection of wastes such as used cooking oil, expired medicine, Fishing Gear, e-waste and used batteries in order to arrange necessary receptacles and vehicles for proper collection before vessel berthing.
	On the request from the vessel, the collecting agency has to obtain necessary permission from the Port & Customs for each vessel in order to board the vessel for collection of cooking oil, expired medicine, Fishing Gear, e-waste and used batteries.
	A standard format of waste delivery receipt provided by the D.G. Shipping to be filled up and signed by the vessel and garbage collecting

	agency for collection of used cooking oil, fishing gear, expired medicine, e-waste and used batteries.
	The copy of waste delivery receipt to be submitted/forwarded to the concerned department by the collecting agency soon after collection for every ship.
	Fishing Gear, used cooking oil, E-waste and used batteries has to be declared to the Customs. Collecting agency has to obtain the bill of entry with applicable duty paid if any or otherwise declaration of customs may be submitted to the concerned department.
	Copies of the Waste Delivery/ Receipt, Permission letter obtained from the Port/Customs and any other documents required at the port gate are to be produced while going out from the Port.

7.8.1 Provision of an Effluent Treatment Plant (ETP)

An effluent treatment plant (ETP) is proposed to be installed at the port to treat the following types of wastes / effluent:

- Wastewater, waste oil or any liquid waste from any ship (Only in case of exigency situation when the waste collection agency is unable to collect waste timely resulting the ship to remain docked and causing delays)
- Effluents from proposed Green Hydrogen plants (salts, waste from electrolysis etc.)
- Waste oil from routine maintenance of tugs, cranes, crafts etc.

The following unit operations and processes are proposed for the ETP:

1. Preliminary Treatment

- **Screening**: to remove large particles and debris from the wastewater.
- **Equalization Tank**: to balance the flow rate and homogenize the wastewater composition as two streams of wastewater from the ships/port and Green Hydrogen unit are to be treated in the ETP.
- **Dissolved Air Flotation (DAF)**: for oil removal

2. Primary Treatment

- **Neutralization**: Use acid dosing (e.g., hydrochloric acid) to neutralize the high pH caused by alkaline salts.

- **Coagulation and Flocculation**: Adding coagulants (like aluminum sulfate) to agglomerate suspended particles and trace metals.

3. Secondary Treatment

- **Chemical Precipitation**: Adding agents (such as lime or sulfides) to precipitate heavy trace metals like nickel, iron, and chromium.
- **Sedimentation**: Settling tanks to remove the precipitated metals and other suspended solids.

4. Tertiary Treatment

- **Reverse Osmosis (RO) or Electrodialysis**: to reduce TDS and conductivity. These processes will help in removing dissolved salts and metals.
- **Deaeration:** To remove dissolved gases like oxygen and hydrogen, typically using vacuum deaeration or stripping.

5. Advanced Treatment

- **Ion Exchange:** To further remove specific ions (e.g., Na+, K+).
- **Adsorption (Activated Carbon):** For any remaining organic contaminants or trace metals.

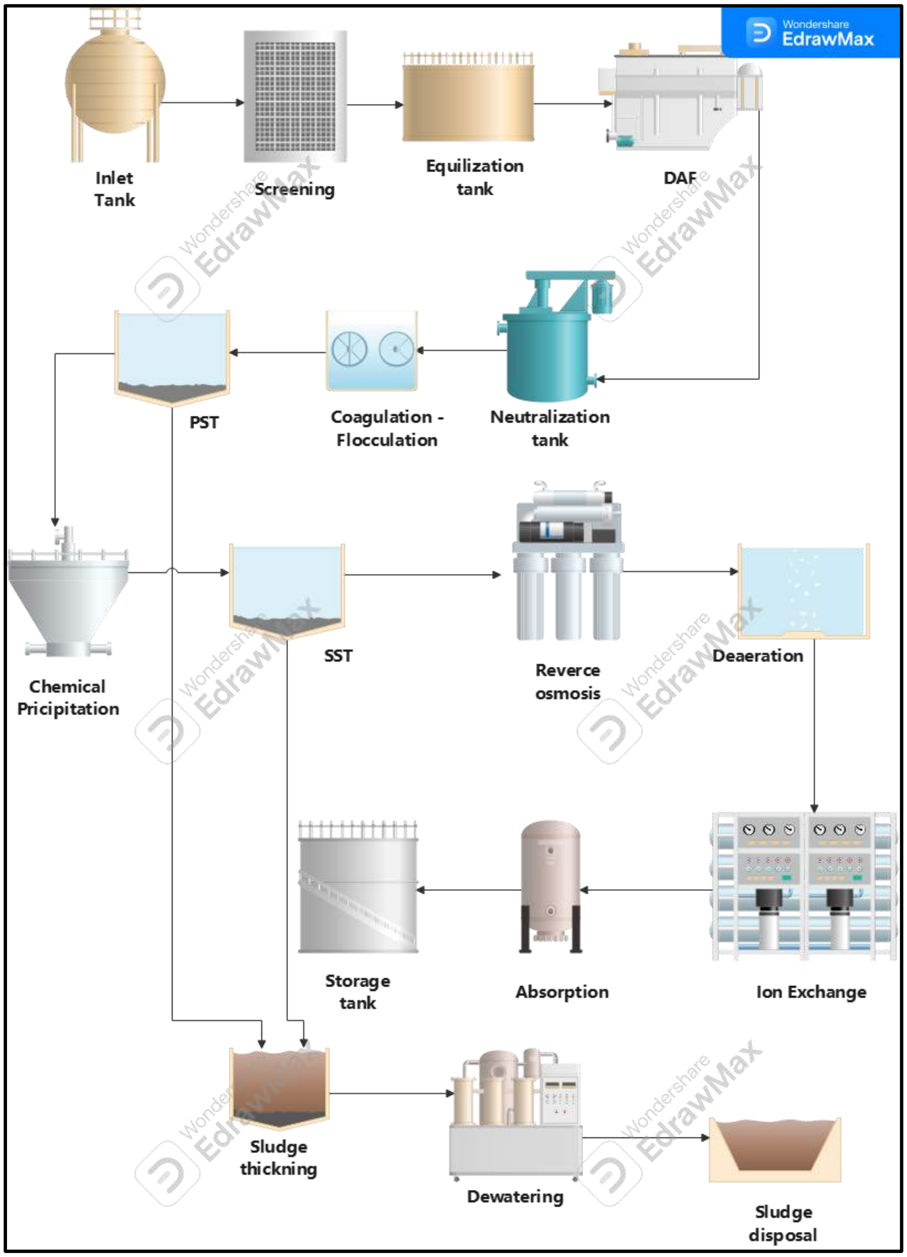
6. Final Treatment

- **pH Adjustment:** Ensuring that the final effluent is within the acceptable pH range for discharge.

7. Sludge Handling

- **Sludge Thickening:** To reduce the volume of sludge.
- **Dewatering:** Use of filter presses or centrifuges to further reduce sludge volume.
- **Sludge Disposal:** Depending on the composition, sludge may be disposed of in landfills or incinerated.

Schematic of proposed ETP is as below:



The proposed ETP, its capacity and treatment processes need to be carefully designed after taking into consideration the following factors:

- Estimated quantity of wastewater to be treated
- Quality of the wastewater to be treated
- Outlet quality of the effluent to be achieved

ANNEXURES

Annexure I: Non-exhaustive list of Organic Waste Convertor (OWC) dealers

Sr. no.	Name	Location	Contact number	Capacity range of available OWC in kg/day	Quantity of Compost produced kg/day
1	Green-era Engineering LLP	Ahmedabad	8048955688	15-1000	10-15 %
2	Greenautics Solution		6353318966	50-700	
3	Unique Industries		9998600358	25-225	
4	Aaspa Equipment Pvt. Ltd.		9898341024	15-1000	
5	Envipure		9998319355	10-1000	
6	Envcure Technocrate LLP		7874757199	15-1000	
7	Envicare Solutions Pvt. Ltd.	Kheda	9727678804	5-2000	

Annexure II: List of Single Use Plastic items banned under the Plastic Waste Management Rules, 2016 (and subsequent amendments)

Sr. no	List of banned Plastic items
1	Plastic Sticks for Balloons
2	Plastic Flags
3	Candy Sticks
4	Ice Cream Sticks
5	Polystyrene (Thermocol) for Decoration
6	Plastic Plates, Cups, Glasses
7	Cutlery Such as Forks, Spoons, Knives, Straw, Trays
8	Wrapping or Packing Films Around Sweet Boxes
9	Invitation Cards
10	Cigarette Packets
11	Plastic or PVC Banners Less Than 100 micron
12	Plastic Stirrers.
13	Plastic carry bags having thickness less than 120 micron

Annexure III: Non-exhaustive list of GPCB approved plastic waste management agencies (Recyclers)

Sr No.	Name & Address of recyclers	Name of Product	Quantity (MT/M
1.	Imperial overseas Pvt Ltd. (U-2)Shed No-93-96, Sec-1, KASEZ, Ta-Gandhidham, Dist.- Kutch	Recycled Agglomerates/Granules	300
2.	Add polymer Pvt Ltd, (U-2) Plot No-3, Sec-2, KASEZ, Ta- Gandhidham, Dist.- Kutch	Recycled Agglomerates/Granules	202
3.	Prasar Enterprises Shed No-335, A-II, MarshalingYard, KASEZ, Ta- Gandhidham, Dist.- Kutch	Recycled Agglomerates/ Granules/ Flakes/ Lumps/ Palltes/ Powder/ Shreddings	500
4.	Harish Processors Ltd.,Shed No- A/305, 408, Marshelling Yard, KASEZ, Ta-Gandhidham, Dist.- Kutch	Recycled Agglomerates/Granules	285
5.	Kutch Polymers (U-1), Shed No- A/1, 180, 181, Sec- 1, KASEZ, Ta-Gandhidham, Dist.- Kutch	Recycled Agglomerates/	250
6.	Kutch Polymers (U-2), Shed No- 334, Sec- 2, KASEZ, Ta- Gandhidham, Dist.- Kutch	Recycled Agglomerates/ Granules	250
7.	Plasto fine Industries (U-1), Plot No-271, 276, Sec-3, KASEZ, Ta-Gandhidham, Dist- Kutch	Recycled Agglomerates/ Granules	300
8.	Luckystar International Pvt Ltd., Shed No-336, Sec-1, KASEZ, Ta-Gandhidham, Dist- Kutch	Plastic agglomerates /Granules /Grindings/Offcuts/Sheets/Extruded Product/Blow Film/Molded Articles & plastic products	400
9.	Lucky star International Pvt Ltd., Plot No-23, 24, 33, 34, Sec-1, KASEZ, Ta-Gandhidham, Dist- Kutch	Plastic Agglomerate s/ Granules/ Grindings/ Offcuts/ Sheets/ Extruded product/ Blow Film/ Molded Articles & plastic products	900
10.	Mokshstar International, Shed No-337, 338, Sec-1, KASEZ, Ta-Gandhidham, Dist- Kutch	Plastic Agglomerates/ Granules/ Grindings/ Offcuts/ Sheets/ Extruded Product / Blow Film/ Molded Articles & Plastic Products	850
11.	Shreeji Polymers, Plot No-8A, Sec-2, KASEZ, Ta- Gandhidham, Dist- Kutch	Plastic Agglomerates/ Granules/ Grindings/ Offcuts/ Sheets/ Extruded Product/ Blow Film/ Molded Articles & Plastic Products	750
12.	Polyrec Processors Pvt. Ltd., Plot	Recycled Agglomerates/ Granules	250

	No-278, 279, Sec- 3, KASEZ, Ta-Gandhidham, Dist- Kutch		
13.	Oswal Polymers, Plot No-4 & 11, Sec-2, KASEZ, Ta-Gandhidham, Dist-Kutch	Recycled Agglomerates/ Granules	200
14.	Balze International, Shed No- 292, Sec-2, KASEZ, Ta-Gandhidham, Dist-Kutch	Recycled Agglomerates/ Granules	300

Annexure IV: Non-exhaustive list of GPCB approved E-waste Recyclers

Sr. no.	Details of WMA	Services provided	Contact details	Capacity MT/Year	Validity
1	Pruthvi E-recycle Pvt Ltd. Survey No.160/1, Plot no: 12, Tirupati Estate, Lothada-360002, Rajkot- 360002	Collection, Segregation, Transportation, Dismantling, & Primary Processing	9825196768, 9909138598 pruthvirecycle@ymail.com	6600	05/01/2028
2	Galaxy Recycling Sr. no: 36/P1, P2, 37/P2, 38/P2, Plot no: 52 & 53, Near Tirth agro. Pvt. Ltd., At: bharudi, Tal: Gondal, Rajkot	Collection, Segregation, Dismantling, Recycling, transportation	9328259627 galaxyrecyclng@gmail.com	521	25/09/2026
3	Star Recycling, Survey no: 44 P1P1 44P1P2 & 46, Plot no: 45, R K Industrial Zone-09, Kuwadva-Wankaner Road, Ranpur-360023, Tal & Dist: Rajkot	Collection, Transportation, Storage, Dismantling, Recycling	9925116383 Starrecycling2018@gmail.com	629	10/03/2025
4	GL Recycling LLP, Survey No. 108, Village: Soliya, Ta.:Kotda Sangani, Dist.: Rajkot-360030	Collection, Transportation, Storage, Dismantling, Recycling) Of Items Covered Under Schedule-I Of Except Fluorescent And Other Mercury Containing Lamp	9016864546 info@glrecycling.co.in	14500	27/05/2026
5	Reart Recycling Private Limited., Plot No.365, Survey No.111p1, Golden Green Industrial Park (phase- D), Khambha-360311, Tal:Lodhika, Dist:Rajkot	Collection, Segregation, Transportation, Shredding, Crushing, Grinding Etc. I.E. Primary Processing For PCBs Only	9023566456, 9426320055 cmsavsani@gmail.com	300	23/06/2026

6	Unity E-Recycling Co, Sr. No: 310/p, Plot No: 4, Danilimda, Ahmedabad-380028	collection, transportation, Storage, Dismantling, Recycling) Of Items Except CRT / LCD / Plasma TV, Fluorescent and Other Mercury Containing Lamp	9726810910 unityerecyclingco@gmail .com	383	31/12/2025
7	Mahaarana Industries Pvt. Ltd., Survey No. 466 & 475, Village: Timba, Ta: Daskroi, Dist; Ahmedabad	Collection, Transportation, Storage, Dismantling, Recycling) Of Items Except Fluorescent and Other Mercury Containing Lamp	8866025118 ewastemanagemant216@ gmail.com	16585	15/05/2026
8	Kalpana E-Recyclers, Plot No. 2486, Madhuban Industrial Park, Village: Kuha, Ta: Daskroi, Dist: Ahmedabad	Collection, Storage, Segregation, Dismantling, Transportation, Refurbishing, Repairing, Shredding, Cutting, Recycling	9998680123 prakashnagora1822@gm ail.com	876	22/01/2026
9	E -Ali Recyclers, (GPCB ID: 89636) Plot No.:730, Survey No. 730, Plot No. 3, Village: Paldi Kankaj, C448, Ta. : Daskroi, Dist.: Ahmedabad - 382425	Collection, Transportation, Storage, Dismantling, Recycling) Of Items Except Fluorescent and Other Mercury Containing Lamp	7096969252 ealirecyclers22@gmail.com	730	31/12/2027
10	Mangalam ECS Environment Pvt. Ltd., (Unit -2) Block No 24 Paiki, Vautha, Tal : Dholka, Dist.:	Collection, Transportation, Storage, Refurbishing of items ITEW1, ITEW2, ITEW3	8980005008 8980005066 hardik.mandora@ecscorp oration.com	4999.92	30/09/2027

	Ahmedabad-387810	and ITEW4 as per EPR except Fluorescent and other mercury containing lamps			

Annexure V: List of items to be disposed through GeM portal as on June 2024

Sr.	Items / Lot Description	Qty.	UOM
1	M.L. Mrignayani Mooring Launch	1	No
2	M.L. Megha Mooring Launch	1	No
3	ML Parijatham	1	No
4	M.L. Arali Mooring Launch	1	No
5	Tank Lorry GJ 12G 8128	1	No
6	Tata Xenon Pick Up Van GJ-12-1388	1	Nos.
7	Fire Fighting Pumps - Dismantled condition (As per list)	1	Nos.
8	Fire Fighting Pumps - 02 Nos. Dismantled condition (As per list)	1	Lot
9	Water cum foam Monitor (Mobile)	2	Nos.
10	Trolley Mounted DCP Unit	3	Nos.
11	Workshop Machines	1	Lot
12	Hospital Items	1	Lot
13	Old M.S Propeller hollow shaft (Assorted size)	11	Nos.
14	Old S.S Propeller shaft (Assorted size)	51	Nos.
15	Old engine (Assorted)	5	Nos.
16	Old Propeller Brass (Assorted size)	13	Nos.
17	Empty Mobile Grease/Oil Drums (i.e. 39 (Store) & 50 (Elect. division)	89	Nos
18	Waste Oil (Transformer/Hydraulic Oil)	5000	Ltrs
19	Uniform Cloths	1	Lot
20	Unserviceable Ceiling Fan	1600	Nos.
21	Electronic waste	7	MT
22	Aluminium & Die Cast Light Fittings (Assorted Sizes)	8	Ton
23	Assorted Marine Steel Scrap	1.5	Ton
24	Plastic Scrap	3.112	MT
25	Rubber Scrap	31.75	MT
26	U/s A.c and Water Cooler Scrap	2.45	MT
27	MS Scrap Assorted	16	Ton
	i. Stainless Steel Feeder Piller -02 Ton		
	ii. Control Gear Box with Choke - 05 Ton		
	iii. Iron Cable Drum - 03 Ton		
	iv. Operator Cabin -06 Ton		
28	Aluminium Cable Scrap	5	Ton
29	Wooden Cable Drum	5	Ton

30	Brass Scrap	455	Kgs
31	Slew Bearing	3	Ton
32	Wire Rope	4	Ton
33	Tyre	50	Nos.
34	Water Tender No. 1 GJ-12G-8125	1	Nos.
35	Foam Tender No. 1 GJ-12G-8124	1	Nos.
36	Water Tender No. 1 GJ-12G-8126	1	Nos.
37	Distilled Water Plant (SS) Cap: 4 to 5 Ltr	1	Nos.
38	Water Mist and CAF Fire Extinguisher Back Pack	1	Nos.
39	Air Compressor (BA Set Cylinder)	1	Nos.

Annexure VI

Biomedical wastes categories and their segregation, collection, treatment, processing and disposal options as per Schedule I of BMW Rules, 2016

Category	Type of Waste	Type of Bag or Container to be used	Treatment and Disposal options
(1)	(2)	(3)	(4)
Yellow	**(a) Human AnatomicalWaste:** Human tissues, organs,body parts and fetus below the viability period (as per the Medical Termination of Pregnancy Act 1971, amended from time to time).	Yellow coloured non-chlorinated plastic bags	Incineration or Plasma Pyrolysis or deep burial*
	(b)Animal Anatomical Waste: Experimental animal carcasses, body parts, organs, tissues, including the wastegenerated from animals used in experiments or testing in veterinary hospitals or colleges or animal houses.		
	(c) Soiled Waste: Items contaminated with blood, body fluids like dressings, plaster casts, cotton swabs and bags containing residualor discarded blood and blood components.		Incineration or Plasma Pyrolysis or deep burial* In absence of above facilities, autoclaving or micro-waving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent for energy recovery

	(d) Expired or Discarded Medicines: Pharmaceutical waste like antibiotics, cytotoxic drugs including all items contaminated with cytotoxic drugs along with glass or plastic ampoules, vials etc.	Yellow colored non-chlorinated plastic bags or containers	Expired `cytotoxic drugs and items contaminated with cytotoxic drugs to be returned back to the manufacturer or supplier for incineration at temperature >1200 ^{0}C or to common bio-medical waste treatment facility or hazardous waste treatment, storage and disposal facility for incineration at >1200^{0}C Or Encapsulation or Plasma Pyrolysis at >1200^{0}C. All other discarded medicines shall be either sent back to manufacturer or disposed by incineration.
	(e) Chemical Waste: Chemicals used in production of biologicaland used or discardeddisinfectants.	Yellow coloured containers or non-chlorinated plastic bags	Disposed of by incineration or Plasma Pyrolysis or Encapsulation in hazardous waste treatment, storage and disposal facility.
	(f) Chemical Liquid Waste: Liquid waste generateddue to use of chemicals in production of biological and used or discarded disinfectants, Silver X-ray film developing liquid, discarded Formalin, infected secretions, aspirated body fluids**,** liquid from laboratories and floor washings, cleaning, house-keeping and disinfecting activities etc.	Separate collection system leading to effluent treatment system	After resource recovery, the chemical liquid waste shall be pre-treated before mixing with other waste water. The combined discharge shall conform to the discharge norms given in Schedule- III.

	(g) Discarded linen, mattresses, beddings contaminated with blood or body fluid, routine mask and gown.	Non-chlorinated yellow plastic bags or suitable packing material	Non- chlorinated chemical disinfection followed by incineration or Plazma Pyrolysis or for energy recovery. In absence of above facilities, shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent for energy recovery or incineration or Plazma Pyrolysis.
	(h) Microbiology,Biotechnology and other clinical laboratory waste: Blood bags, Laboratory cultures, stocks or specimens of micro- organisms, live or attenuated vaccines, human and animal cell cultures used in research, industrial laboratories, production of biological, residual toxins, dishes and devices used for cultures.	Autoclave or Microwave or Hydroclave safeplastic bags or containers;	Pre-treat to sterilize with non- chlorinated chemicals on-site as per as per World Health Organisation guidelines on Safe management of Waste from healthcare activities and WHO Blue Book,2014 and thereafter sent for incineration;
Red	**Contaminated Waste(Recyclable)** (a) Wastes generated from disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes (without needles and *fixed needle syringes*) andvaccutainers with their needles cut) and gloves.	Red coloured non-chlorinatedplastic bags or containers	Autoclaving or micro-waving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent to registered or authorized recyclers or for energy recovery or plastics to diesel or fuel oil or for road making, whichever is possible. Plastic waste should not be sent to landfill sites.

White (Translucent)	**Waste sharps including Metals:** Needles, syringes with fixed needles, needles from needle tip cutter or burner, scalpels, blades,or any other contaminated sharp object that may cause puncture and cuts. This includes both used, discarded and contaminated metal sharps	Puncture proof,Leak-proof, tamper-proof containers	Autoclaving or Dry Heat Sterilization followed by shredding or mutilation or encapsulation in metal container or cement concrete; combination of shredding cum autoclaving; and sent for final disposal to iron foundries (having consent to operate from the State Pollution Control Boards or Pollution Control Committees) or sanitary landfill or designated concrete waste sharp pit.
Blue	**(a) Glassware:** Broken or discarded and contaminated glassincluding medicine vialsand ampoules except those contaminated withcytotoxic wastes.	Puncture proofand leak proof boxes or containers withblue colored marking;	Disinfection (by soaking the washed glass waste after cleaning with detergent and Sodium Hypochlorite treatment) or through autoclaving or microwaving or hydroclaving and then sent for recycling.
	(b) Metallic Body Implants	Puncture proof and leak proof boxes or containers with blue colored marking	**Implants**

Annexure VII

ANNUAL REPORT (Form – IV) of BMW Rules, 2016

Sr. No.	Particulars		
1.	Particulars of the Occupier	:	
	(i) Name of the authorised person (occupier oroperator of facility)	:	
	(ii) Name of HCF or CBMWTF	:	
	(iii) Address for Correspondence	:	
	(iv) Address of Facility		
	(v)Tel. No, Fax. No	:	
	(vi) E-mail ID	:	
	(vii) URL of Website		
	(viii) GPS coordinates of HCF or CBMWTF		
	(ix) Ownership of HCF or CBMWTF	:	(State Government or Private or Semi Govt. or any other)
	(x). Status of Authorisation under the Bio-Medical Waste (Management and Handling) Rules	:	Authorisation No.: …………………………………… ……………… valid up to ……….
	(xi). Status of Consents under Water Act and Air Act	:	Valid up to:
2.	Type of Health Care Facility	:	
	(i) Bedded Hospital	:	No. of Beds:
	(ii) Non-bedded hospital (Clinic or Blood Bank or Clinical Laboratory or Research Institute or Veterinary Hospital or any other)	:	
	(iii) License number and its date of expiry		
	Details of CBMWTF	:	

3.	(i) Number healthcare facilities covered by CBMWTF	:				
	(ii) No of beds covered by CBMWTF	:				
	(iii) Installed treatment and disposal capacity of CBMWTF:	:	________Kg per day			
	(iv) Quantity of biomedical waste treated or disposed by CBMWTF	:	________Kg/day			
4.	Quantity of waste generated or disposed in Kg perannum (on monthly average basis)	:	Yellow Category:			
			Red Category:			
			White:			
			Blue Category:			
			General Solid waste:			
5.	Details of the Storage, treatment, transportation, processing and Disposal Facility					
	(i) Details of the on-site storage facility disposal facilities	:	Size :			
			Capacity:			
			Provision of on-site storage : (cold storage or any other provision)			
			Type of treatment Equipment	No of units	Capacity kg/day	Quantity treated or disposed in kg per annum
			Incinerators			
			Plasma Pyrolysis			
			Autoclaves			
			Microwave			
			Hydroclave			
			Shredder			
			Needle tip cutter Or Destroyer			
			Sharps Encapsulation or concrete pit			
			Deep burials pit:			
			Chemical			

			Disinfection: Any other treatment equipment:			
	(iii) Quantity of recyclable wastes sold to authorized recyclers aftertreatment in kg per annum.					
	(iv) No of vehicles used for collection and transportation of biomedical waste					
	(v) Details of incineration ash and ETP sludge generated and disposed during the treatment of wastes in Kg per annum		Incineration Ash ETP Sludge	Quantity generated	Where disposed	
	(vi) Name of the Common Bio- Medical Waste Treatment Facility Operator through which wastes are disposed of					
	(vii) List of members HCF not handed over bio-medical waste.					
6.	Do you have bio-medical waste management committee? If yes, attach minutes of the meetings held during the reporting period					
7.	Details trainings conducted on BMW					
	(i) Number of trainings conducted on BMW Management.					
	(ii) number of personnel trained					
	(iii) number of personnel trained at the time of induction					
	(iv) number of personnel not undergone any training so far					
	(v) whether standard manual for training is available?					
	(vi) any other information)					
8	Details of the accident occurred during the year					

	(i) Number of Accidents occurred		
	(ii) Number of the persons affected		
	(iii) Remedial Action taken (Please attach details if any)		
	(iv) Any Fatality occurred, details.		
9.	Are you meeting the standards of air Pollution from the incinerator? How many times in last year could not met the standards?		
	Details of Continuous online emission monitoring systems installed		
10.	Liquid waste generated and treatment methods in place. How many timesyou have not met the standards in a year?		
11	Is the disinfection method or sterilization meeting the log 4 standards? How many times you have not met the standards in a year?		
12	Any other relevant information	:	(Air Pollution Control Devices attached with the Incinerator)

Certified that the above report is for the period from

…………………………………………………………..…………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

Name and Signature of the Head of the Institution

Date:

Place

Annexure VIII: List of Information related to HCFs to be updated on website

Sr. no.	List of Information to be updated on website
1.	Contact Address and details of the Healthcare Facility:
2.	No. of beds:
3.	Details of: a) Authorisation under BMWM Rules, 2016: b) Consent under Water (Prevention and Control of Pollution) Act, 1974 and Air(Prevention and Control of Pollution) Act, 1981:
4.	Quantity of bio-medical waste generation (in kg/day):
5.	Mode of disposal of bio-medical waste (through CBWTF or through captivetreatment facility):
6.	Name and address of the CBWTF through which waste is disposed off (as applicable)
7.	In case, HCF is having captive treatment facility, a) bio-medical waste treated (in kg/day) b) Details of treatment equipment c) Total nos. and capacity of each treatment equipment (in kg/day) d) Operating parameters of the treatment equipment as per BMWM Rules, 2016
8.	8 Monthly records of bio-medical waste generation (category wise):
9.	No. of trainings conducted on Bio-medical Waste Management in the current year: Stats of immunization of Health Care Workers involved in handling of BMW:

Annexure IX: Potential Uses of C & D Wates

C & D waste	Potential use of C & D wastes
Concrete	The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. **Opportunity:** The enormous quantities of demolished concrete can easily be recycled as aggregate and used in concrete. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness. Work on recycled concrete has been carried out at few places in India by CBRI and CRRI, but waste and quality of raw material produced being site specific, tremendous inputs are necessary if recycled material has to be used in construction for producing high grade concrete.
Bricks	If deconstructed properly, bricks can be reused after removal of mortar. Broken bricks can be used for refilling or for manufacturing debris paver blocks or debris blocks.
Stone	Stone can be reused for plinth formation, masonry construction, landscape purpose, ledges, platforms, window sills, coping etc. depending upon the form of available stones.
Timber	Timber elements from deconstructed building may have aesthetic and antique value. **Opportunity:** Whole timber arising from construction and demolition works can be utilized easily and directly for reused in other construction projects after cleaning, de-nailing and sizing.
Plywood and other timber based boards	Plywood and other timber-based boards can be either reused for interior works in new construction or it can be recycled for manufacturing of timber-based boards.
Gypsum	In India, over 10 about of waste gypsum such as phosphor-gypsum, Fluro-gypsum etc., are being generated annually. **Opportunity:** Plaster developed from this waste gypsum has showed improved engineering properties without any harmful effect. Phosphor-gypsum and lime sludge can be recycled for manufacture of Portland cement, masonry cement, sand lime bricks, partition walls, flooring tiles, blocks, gypsum plaster, fibrous gypsum boards, and super-sulphate cement.
Metals & metal alloys-	Ferrous Metals are the most profitable and recyclable material. Scrap steel is almost totally recycled and allowed repeated recycling. Structural steel can be reused as well as 100% steel can be recycled to avoid wastage at construction site. **Advantage:** Generally sold to a scrap metal dealer at a specified price. Metals like scrap iron can be mixed with the virgin metal in the foundry. In India more than 80% scrap arising is recycled.
Nonferrous metal	The main nonferrous metal collected from construction and demolition sites are aluminum, copper, lead and zinc. **Opportunity:** In India aluminum and copper are recycled and are valuable resources

Debris	Construction debris can be recycled to manufacture paver blocks which can be used in light traffic areas and masonry blocks. Other uses of processed debris include use in lean concrete for leveling purpose, as mortar for masonry, as bedding mortar for pavement tiles and used for land filling materials is comparable with new materials. **Opportunity:** Market potential on an average in Pune city estimates about 40 crores of bricks in a year.
Composite materials	The plastic wastes are best for recycling if these materials are collected separately and cleaned. Recycling is difficult if plastic wastes are mixed with other plastics or contaminants. Plastic may be recycled and used in products specifically designed for the utilization of recycled plastic, such as street furniture, roof and floor, PVC window noise barrier, cable ducting, panel. **Constraint:** The third largest consumer of composite materials is construction sector, automobile and aeronautics being first two largest consumers. Composite materials like thermoplastics are not only using non-renewable resources, they are non-biodegradable products. Thermoplastics (Polycarbonate, polyethylene, polypropylene, PVC etc.) can be recycled, but recycling involves high costs, whereas thermosets (Epoxy adhesives) are difficult to recycle. The lack of adequate markets, high recycling cost, and lower quality of the recyclates are the major commercialization barriers in recycling of composite materials. PVC-U sourced mostly from window and door fabricators is being recycled into wiring accessories and cable management systems including skirting and trunking. Composite materials can be down-cycled.
Ref : https://www.researchgate.net/publication/256677141_construction_and_demolition_waste_management_with_reference_to_case_study_of_Pune	

Annexure X: Proposed responsibility and constitution of the Waste Management Cell (WMC) for DPA

Note: DPA managed premises mentioned herein refers to all residential, commercial and other area under the control of DPA in Gandhidham, Kandla and Vadinar.

The broad scope of work for proposed WMC are as below:

1. Develop, implement and manage Waste Management Systems for all types of wastes i.e., Municipal Solid, Plastic, Bio-medical, Construction & Demolition, e-waste and Shipping wastes in accordance with the Waste Management Plan.
2. Co-ordinate with all departments of DPA and maintain records pertaining to all generated wastes in designated format.
3. Monitor the segregation and storage of all types of wastes generated at all DPA premises.
4. Monitor the activities like collection, transport and disposal by all Waste Management Agencies appointed by DPA.
5. Maintain all documentation (Waste inventories/Forms/Records/Receipts etc.) as per the requirements mentioned in the Waste Management Plan.
6. To coordinate and comply with all applicable statutory requirements.
7. Prepare and submit documents (Forms/ Returns/ Compliances etc.) to concerned authority.
8. Conduct regular visits, in and surrounding all DPA premises for reviewing implementation and updating of the waste management systems.
9. Training and capacity building of waste management staff from time to time.
10. Assist concerned DPA officials in legal and regulatory matters pertaining to waste management.
11. Remain up to date with any new legal or other requirement pertaining to waste management.
12. Organize awareness programs/ campaigns and other IEC activities from time to time, relating to waste management.

Constitution of WMC

Sr. No	Category of professionals	Qualification	Experience
1.	Manager (Waste): 02 personnel	A Post-graduate in Environmental Sciences/ Environmental Engineering/ Coastal/Marine Environmental Science and Marine Science	Minimum 02-years' experience in waste management and in-depth knowledge about environmental regulations pertaining to all types of wastes i.e., (Municipal Solid, Plastic, Bio-medical, Construction & Demolition, battery, Shipping and E-waste)
2.	Assistant (Waste) -: 04 personnel	A Graduate in Environmental Sciences/ Environmental Engineering/ Coastal/Marine Environmental Science and Marine Science	Minimum 01-year experience in areas like Inventorization, audit, EPR and awareness programs related to waste management.

PART-2
TRAINING MANUAL

Table of Contents

List of Table

List of Figures

Chapter-1
Municipal Solid Waste

1.1. Introduction

Waste (or wastes) is unwanted or unusable material. Waste is any substance which is discarded after primary use, or is worthless, defective and of no use. A by-product by contrast is a joint product of relatively minor economic value. A waste product may become a by-product, joint product or resource through an invention that raises a waste product's value above zero.

Municipal solid waste (MSW) includes waste from households, non-hazardous solid waste from industrial, commercial and institutional establishments (excluding bio-medical waste in present context), market waste, yard waste, agricultural wastes and street sweepings. Industrial and community hazardous waste and infectious waste, is not considered as MSW and should be collected and processed separately. MSW (Management and Handling) Rules 2000 defines MSW as *"commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes"*. MSW management encompasses the functions of collection, transfer & transportation, processing & recycling, and disposal of MSW. Safe and cost-effective management of MSW is a significant environmental challenge for modern society. Inadequately managed waste disposal has the potential to affect the health and environment. Ideally MSW management should incorporate the principles of waste minimization, recycling, resource recovery as well as an integrated processing & disposal facility, leading to effective service delivery in a sustainable manner

1.2. Different categories of Wastes

- **Municipal Solid waste**: Municipal solid waste includes commercial and domestic wastes generated in municipal or notified areas or either solid or semi-solid form excluding industrial hazardous wastes but including treated biomedical wastes.
- **Domestic Waste**: Domestic waste is one of the most important components of MSW. Domestic wastes include food waste, paper, glass, metals, plastics, textiles, etc. A large part of domestic waste consists of plant and animal waste such as vegetables, fruit peel, bone and meat waste etc. which are considered wet wastes. Paper, cardboard, old newspapers, books, plastic items, disposable dishes, toys, metal, glass cans obsolete items etc. also make up another large portion of domestic dry waste.
- **Commercial Waste:** Commercial waste consists of waste from premises used mainly for the general purposes of a business or trade or recreation, education, sport, or entertainment. It does not include household, agricultural, or industrial waste as a result of construction activities. It doesn't matter whether the waste is generated in a residential

or a commercial area. For example, the waste generated by a lawn-mowing company on the premises of the client's home is commercial waste. Commercial waste is non-hazardous

- **Industrial solid waste including Hazardous waste:** The term industrial waste describes toxic waste from industrial operations including mining, refining the metallic and non-metallic resources and using these resources in the manufacturing processes to produce different intermediates of products. Sectors like food processing industries, metallurgical, crude petroleum refining, chemical and pharmaceutical operations, fertilizer, cement, and breweries among other sectors produce industrial waste. The most affected is the health of people residing nearby the dumping sites. Industrial waste causes harm to the water bodies causing the destruction of fish, pollution of groundwater and release of foul odors.

  Hazardous waste: Any waste that poses a threat to human health and the environment if not handled or managed properly. For this reason, many countries have strict regulations on the storage, collection and treatment of hazardous waste. The Basel Convention and the OECD Decision include lists of waste streams, characteristics and components that fall within the definition of hazardous waste. Most hazardous waste originates from industrial production.

- **Agricultural Waste**: The waste generated by agriculture includes waste from crops and livestock. Some of the waste is produced by agro-based industries viz. rice milling, tobacco etc. Agricultural wastes include rice husk, stubble/parali, degasses, ground nut shells and straws of cereals etc.
- **Biomedical Waste**: It is a form of infectious waste and involves waste from the treatment of diseases in humans and animals. This type of waste usually consists of medicines, sharp objects, bandages, chemicals, pharmaceuticals, body fluids and body parts (from amputations and surgery). Healthcare waste may be infectious, toxic or radioactive.
- **Plastic Waste**: Plastic is the general common term for a wide range of synthetic or semi-synthetic organic amorphous solid materials derived from oil and natural gas. The word 'Plastic' is derived from the Greek word 'Plastikos' meaning fit for moulding & 'Plastos' meaning moulded.
- **E-waste:** E-waste is a generic term for waste originating from out of life electric and electronic equipment, such as computers, televisions mobile phones and home appliances etc. Some component of E-waste is categorized as hazardous waste due to their toxic

components, such as lead, quicksilver, cadmium, mercury and brominated flame retardants. These materials can cause health damage if not treated properly.

- **Construction and Demolition waste:** Construction and demolition (C&D) waste is generated from construction, renovation, repair, and demolition of houses, large building structures, roads, bridges, piers, and dams. C&D waste is made up of wood, steel, concrete, gypsum, masonry, plaster, metal, and asphalt. C&D waste is notable because it can contain hazardous materials such as asbestos and lead. Estimates vary, but a commonly accepted estimate is that between 15 per cent and 20 per cent of municipal solid waste comes from construction and demolition projects.

1.3. Training on Municipal Solid Waste Management for various stakeholders

There is an urgent need to train and enhance the capacities of all stakeholders involved in MSW management activities to ensure efficient implementation of MSW management system from handling at the point of generation to its disposal. The following are all stakeholders involved in capacity building in MSWM as shown in figure 1

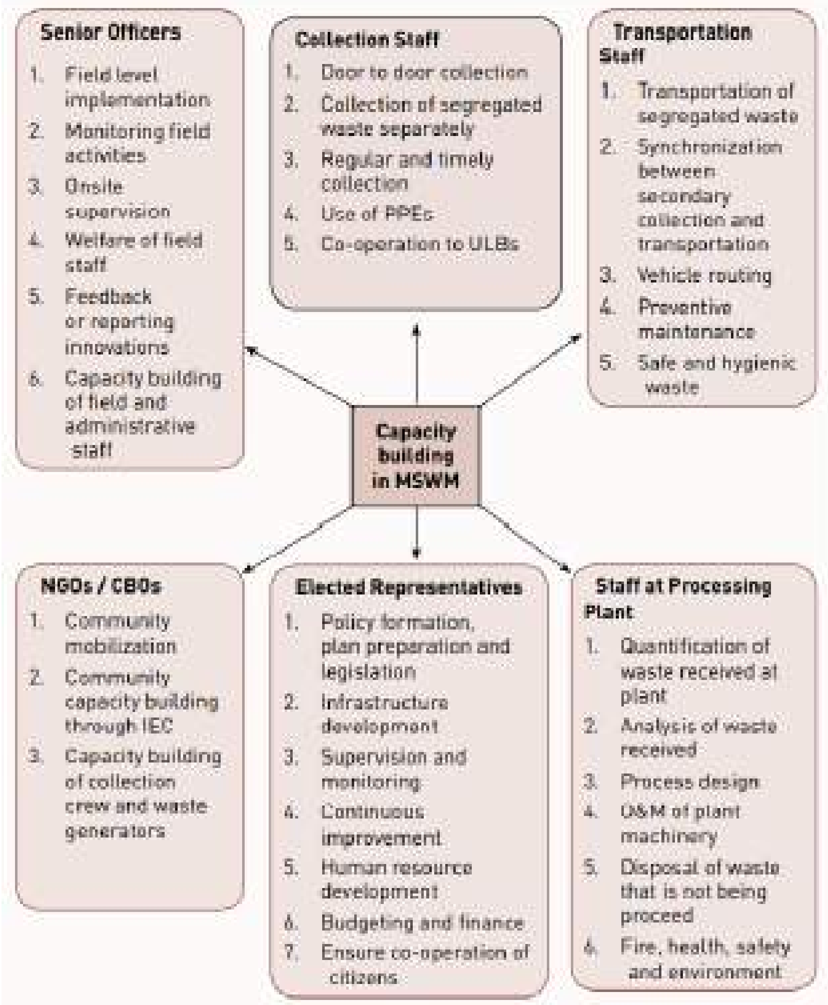


Figure 1 Capacity building in MSWM

Target audience: Citizens (Residents, office and port staff)

Citizen's involvement in MSW management is key to its effective implementation. One of the important role that the citizens can play is minimization and segregation of waste at the source of segregation.

Household-level Storage of Segregated Waste

- At the household level, dry waste, wet waste, and domestic hazardous waste should be stored in separate garbage bins, of appropriate capacity and color. The colour of the garbage bins should be as follows: Wet waste is to be placed in a covered green bin and dry waste in a covered blue bin.
- The general guidelines regarding which waste item to be placed in which bin is shown in Table 1.

BASIC SEGREGATION					
Wet waste (green bin)	Dry waste (Blue bin)				Domestic Hazardous'
	With further sub-segregation BASIC+				
Food wastes of all kinds, cooked and uncooked, including eggshells and bones, flower, fruit and waste including juice, vegetable peels and household garden/plant wastes. Soiled tissues, food wrappers, paper towels; fish and meat	Paper cardboard and cartons	Containers & packaging of all kinds excluding those containing hazardous materials Compound packaging (tetrapak, blisters etc.) Plastics	Rags Rubber Wood Discarded clothing Furniture	Metals Glass (all kinds) Inerts House sweepings and inerts (not garden, yard or street sweepings)	E-waste* Hazardous wastes** Household medical waste*** Batteries from flashlights and button cells. Lights bulbs, tube lights and Compact Fluorescent Lamps (CFL) Car batteries, oil filters and car care products and consumables
* E-waste: Printer & printer cartridges, electronic parts and equipment and others ** Hazardous wastes: Chemicals and solvents and their empty containers, paints, oil, lubricants, glues, thinners and their empty containers, insecticides, pesticides and herbicides and their empty containers, photographic chemicals, bleaches and household kitchen & drain cleaning agents *** Household Medical Waste: Thermometers and other mercury containing products, discarded medicines, injection needles and syringes after destroying them both, sanitary wastes and diapers (should be collected daily)					

Table 1 Basic Segregation

1.3.2. Responsibility and duties of Senior officials

The officials dealing with waste management shall endeavour to create awareness among the citizens regarding adverse impacts of mismanaged MSW along with by implementation and monitoring of the Waste Management Plan.

Rule 4 of Solid Waste Management Rules, 2016 - Duties of waste generator

- Segregate and store the waste generated in three separate streams namely biodegradable, non-biodegradable and domestic hazardous wastes in suitable bins and handover segregated wastes to authorized waste pickers or waste collectors as per the direction or notification by the local authorities from time to time.

- Wrap securely the used sanitary waste like diapers, sanitary pads etc., in the pouches provided by the manufacturers or brand owners of these products or in a suitable wrapping material as instructed by the local authorities and shall place the same in the bin meant for dry waste or non- bio-degradable waste.
- Store separately construction and demolition waste, as and when generated, in his own premises and shall dispose off as per the Construction and Demolition Waste Management Rules, 2016.
- store horticulture waste and garden waste generated from his premises separately in his own premises and dispose of as per the directions of the local body from time to time.
- No waste generator shall throw, burn or burry the solid waste generated by him, on streets, open public spaces outside his premises or in the drain or water bodies.
- All waste generators shall pay such user fee for solid waste management, as specified in the bye-laws of the local bodies.
- No person shall organize an event or gathering of more than one hundred persons at any unlicensed place without intimating the local body, at least three working days in advance and such person or the organizer of such event shall ensure segregation of waste at source and handing over of segregated waste to waste collector.
- The bio-degradable waste shall be processed, treated and disposed off through composting or bio-methanation within the premises as far as possible. The residual waste shall be given to the waste collectors or agency as directed by the local body. The general dry waste items that can be segregated in MRF are listed in Table 3.

Table 2 Checklist for periodic verification of premises of bulk waste generators

S. No	Activities	Yes / No
1.	Is segregation done as per SWM Rules, 2016	
2.	Are all the Segregated wastes being stored in separate bins, containers or bags etc.?	
3.	Has a separate space for the segregation, storage of municipal solid waste in society, gated community, offices etc. been demarcated	
4.	Is storing of Construction and Demolition waste practiced separately?	
5.	Is storing of the Garden and Horticulture waste practiced separately?	
6.	Is recyclable waste handed over to the authorized waste picker or recycler?	

S. No	Activities	Yes / No
7.	Is processing bio-degradable (wet) waste done on-site?	
8.	Mention the process of composting or bio-methanation or any other.	
9.	Is the residual waste from processes handed over to the waste collector oridentified agency?	
10.	Has the bulk waste generator tied up for authorized agency for collection of segregated waste?	

1.3.3. Target audience: Staff involved in collections of MSW

Imparting awareness and training regarding good practices od MSW management will not only build the capacities of workers to perform more effectively and efficiently in the existing conditions, but will also inculcate a sense of responsibility and pride towards their profession.

Figure 2 Wet Waste and Dry Waste Segregation

- The work force involved with door-to-door collection of MSW shall be educated and trained to collect dry and wet waste separately as shown in the figure 2.
- The staff shall be educated regarding ideal MSW storage at various locations

Storage of Municipal Solid Waste in Public Places or Parks

With a view to ensure that streets and public places are not littered with waste, litter bins may be provided at important streets, markets, public places, bus and railway pick up stations, commercial complexes, etc. at a distance ranging from 25m to 250m depending on the local conditions. The collection from these bins should be segregated into wet and dry waste that has been shown in figure 2.

Storage of Yard Waste or Garden Waste

Horticulture waste from parks and gardens should be collected separately and treated on-site to make optimum use of such wastes and also to minimise the cost of its collection and transportation.

Storage and Processing of Special Wastes Including Domestic Hazardous Waste

Special wastes including domestic hazardous wastes can pose a substantial or potential threat to health and environment because of their constituents which may be hazardous. A municipal waste component is hazardous if it contains one of the following characteristics: (i) ignitability, (ii) corrosivity, (iii) reactivity, and (iv) toxicity.

Care must be taken to not mix special waste including domestic hazardous waste with either the wet waste or dry waste and store such wastes separately and hand-over to the special waste collection centres, established by the urban local bodies or to collection schemes through retail trade.

1.3.4. Responsibility of MRF Operating Staff

Unloading of Incoming Waste

- Unload dry waste in the waste receiving area
- Weigh the incoming dry waste
- Remove wet/inert waste if any

Weighbridge and Weighing Scales:

- Weighing of large quantities of incoming waste
- Weighing of incoming waste and sorted recyclables

Segregation and Sorting:

- The staff is responsible for segregating and sorting non-biodegradable or recyclable solid waste collected from the doorstep into different streams of waste fractions such as paper, plastic, packaging paper, and bottles.

Table 3 Categories of dry waste that can be segregated in MRF

S. No	Paper	Plastic Items (non-PVC)	Plastic items (PVC)
1	Glass Items	Rubber Items	Metal Items (Ferrous)

2	Leather Items	Thermocol	Aluminum Coated Paper
3	Wooden Items	X-ray Films	Clothes
4	Cardboards	Jute bags	Electronic Items
5	Aluminum Coated Plastic	Metal Items (Non- ferrous)	Medical Waste/ Tablet Cover

Recovery of Recyclable Waste:

- Recovering various components of recyclable waste from the incoming waste materials for resale to intermediaries who supply bulk material to the recycling industries.

Bundling & Storage of Sorted Waste:

- Bale and pack the sorted waste in large bags or keep it bundled in the waste storage area
- MRF operating staff are responsible for managing large storage spaces to temporarily store sorted recyclables, which can be made available to recyclers in bulk for improved resale value

Weighing of Waste

- Weigh the bundled or packed waste daily and record it
- The sorted waste should be weighed at the MRF only

Maintain Safety and Personal Hygiene

- Wear personal protective equipment before starting the work
- Maintain personal hygiene. Wash your hands and legs with soap before and after your daily work
- Regular maintenance of personal protective equipment
- Proper storage of PPE

Regular Cleaning of Waste Sorting Area

- Clean the MRF area daily

1.3.5. Sound Practices in operating the MRF

Do's

1. A regular check on the working, performance and maintenance etc, of the processing machinery shall be done once in a month.

2. Indoor air quality and adequate lighting shall be monitored continuously for healthy working environment
3. Provision of suitable exhausts/vents/scrubbers, etc.
4. Adequate fire protection measures
5. All workers covered under social security and insurance scheme's
6. Compulsory use of Protection gears
7. Good Hygiene and Sanitation practices including safe drinking water
8. MRF kept Clean and Tidy
9. Ensure Proper Segregation and Low Rejects
10. Periodic Meetings of workers for drills, training
11. Keeping detailed logbook of MRF
12. Good housekeeping and cleaning all machinery after use
13. First Aid

Don'ts

1. No Inflammable objects in premise
2. No Smoking
3. No Child Labor
4. Pregnant women to avoid operating machinery
5. Avoid Water and Electricity Wastage
6. No Discrimination
7. No Littering
8. No animals allowed
9. Do not Burn Waste
10. No explosives or firearms in MRF
11. Keep hands away from moving parts of machinery
12. Do not wear loose clothing around machinery
13. Avoid long term storage of RDF

➢ **Safety Practices adopted at MRF**

The process of collection, segregation, transportation and recycling involves exposure to contaminants and hazardous waste. The safety aspects to be considered are mentioned below:

Table 4 Safety Practices

Sr.No	Hazard	Precaution	Cure
1.	Cuts and injuries due to presence of broken glass, sharps, needles which may lead to septic wounds and tetanus	Use of Safety Gloves	Medical help should be immediately sought in case of injury
2.	Exposure to fumes causing irritation of nose, throat and lungs.	Suitable masks should be used by the Safaii Mitra while working at Swachhta	Medical help should be immediately sought
3.	Contact with faecal matter and the risk of contracting gastrointestinal diseases and worm infestations	Along with wearing gloves, sanitizers should always be carried and used	Medical help should be immediately sought
4.	Vulnerable to blood borne diseases if hospital waste is collected	Gloves should be worn and direct contact with any waste (especially faecal matter and hospital waste should be avoided)	Medical help should be immediately sought
5.	Exposure to sun, radiation and rain	Areas with radiation should be avoided.	In case of contact with any radioactive waste, they should immediately contact a doctor
6.	Callosities on the fingers observed		Should immediately contact a doctor
7.	Health problems like body ache, leg ache due to long distances travelled	Can be provided with a garbage truck to pick up waste	

- **Hygiene Practices**

It is mandatory to provide a safe working environment for staff, working personnel and any other occupants or visitor at the MRF.

- Keep the MRF dry & clean always
- Keep sorting & storage area dry and free from pest & flies
- Regularly spray disinfection liquid as better prevention practices
- All working personnel and any other occupant at the MRF must use reusable safety gloves, boots and mask. It is advisable to wear uniform while working.
- Use disposable mask & gloves for visitors.
- Make provision for hand wash and disinfectant, hands must be washed with soap before

eating/ leaving the MRF.

- Monthly cleaning & Pest-Control Treatment routine has to be fixed within the MRF and should be followed without ignorance.

➢ **First Aid Box**

This is only for designing a basic first aid kit and its components and should not be taken as a first aid procedure or training. It is important to have a well- stocked first aid kit at the MRF to deal with minor accidents and injuries. The first aid kit should be kept in a cool and dry place out of the reach of children.

A basic first aid kit should contain:

Emergency telephone numbers for emergency medical services 1092/102/108

- Bandages in a variety of different sizes and shapes
- Small, medium and large sterile gauze dressings
- A box of adhesive bandages
- Crêpe rolled bandages
- Safety pins
- Disposable sterile gloves
- Tweezers, scissors
- Micro-porous, sticky tape
- Thermometer (preferably digital)
- Cream or spray to relieve insect bites and stings
- Antiseptic cream
- Directions for requesting emergency assistance.

➢ **Safety Photo Illustration for MRF**

The following photos provide specific comment on safety issues related to those operations.

Photo 1

Hand sorting operations may require additional safety attention to include high visibility clothing, training on ergonomics and possibly job rotation.

Photo 2

An example of safety signage indicating required personal protective equipment.

Photo 3

Safe operation of heavy equipment requires constant attention to avoid contact with fixed objects and minimizing personnel foot traffic.

Photo 4

An illustration of labeling on an electrical disconnect identifying the affected equipment.

Photo 5

Fire extinguishers should be located throughout the facility with clear access paths maintained.

The proper type of fire extinguisher should be evaluated based on fire exposures.

Figure 3 Safety Photo Illustration for MRF

1.4. Other Important Guidelines

- The entrance and exit should be kept clear always
- The emergency exits should be kept clear always and should never be used for any temporary/ permanent activity
- A minimum safe distance between two machineries as advised by the manufacturer.
- From maintenance perspective, min 1-metre clearance around each equipment.
- Shed should be constructed with the stipulated structural stability and always keep out rains
- The MRF should be certified by a structural engineer/local ULB engineer and the fire department as per rules.

Awareness Posters

Chapter-2
Plastic Waste

2.1. Introduction

The rapid rate of urbanization and development has led to increase in consumption of plastic products vis-à-vis plastic waste generation. It is a fact that plastics waste constitutes a significant portion of the total municipal solid waste (MSW) generated in India. Plastics are non-biodegradable and remains on earth for thousands of years. The burning of plastics waste under uncontrolled conditions lead to generation of different hazardous air pollutants (HAPs), depending upon the type of polymers and additives used. However, the end-of-life plastics can be recycled into a second life application but after every thermal treatment/recycling deterioration in quality of recycled plastic products. Thus, plastic waste can be recycled only 3-4 times. The visibility of huge quantity of plastic waste has been perceived as a serious problem and made plastics a target in the management of solid waste. Different types of plastics and their uses are given in figure 4.

Plastics are generally categorized into two types:

- **Thermoplastics**: Thermoplastics or Thermosoftening plastics are the plastics which soften on heating and can be molded into desired shape such as PET, HDPE, LDPE, PP, PVC, PS, etc.
- **Thermosets**: Thermoset or thermosetting plastics on heating, but cannot be remolded or recycled such as Sheet Molding Compounds (SMC), Fiber Reinforced Plastic (FRP), Bakelite etc. are the examples of the same.

  For efficient management of plastic waste, the Government of India has superseded with the earlier Plastic Waste (Management & Handling) Rules, 2011 and notified Plastic Waste Management (PWM) Rules, 2016 on 18th March, 2016. These rules shall apply to every Waste Generator, Local Body, Gram Panchayat, Manufacturer, Importer, Producer and Brand Owner throughout India.

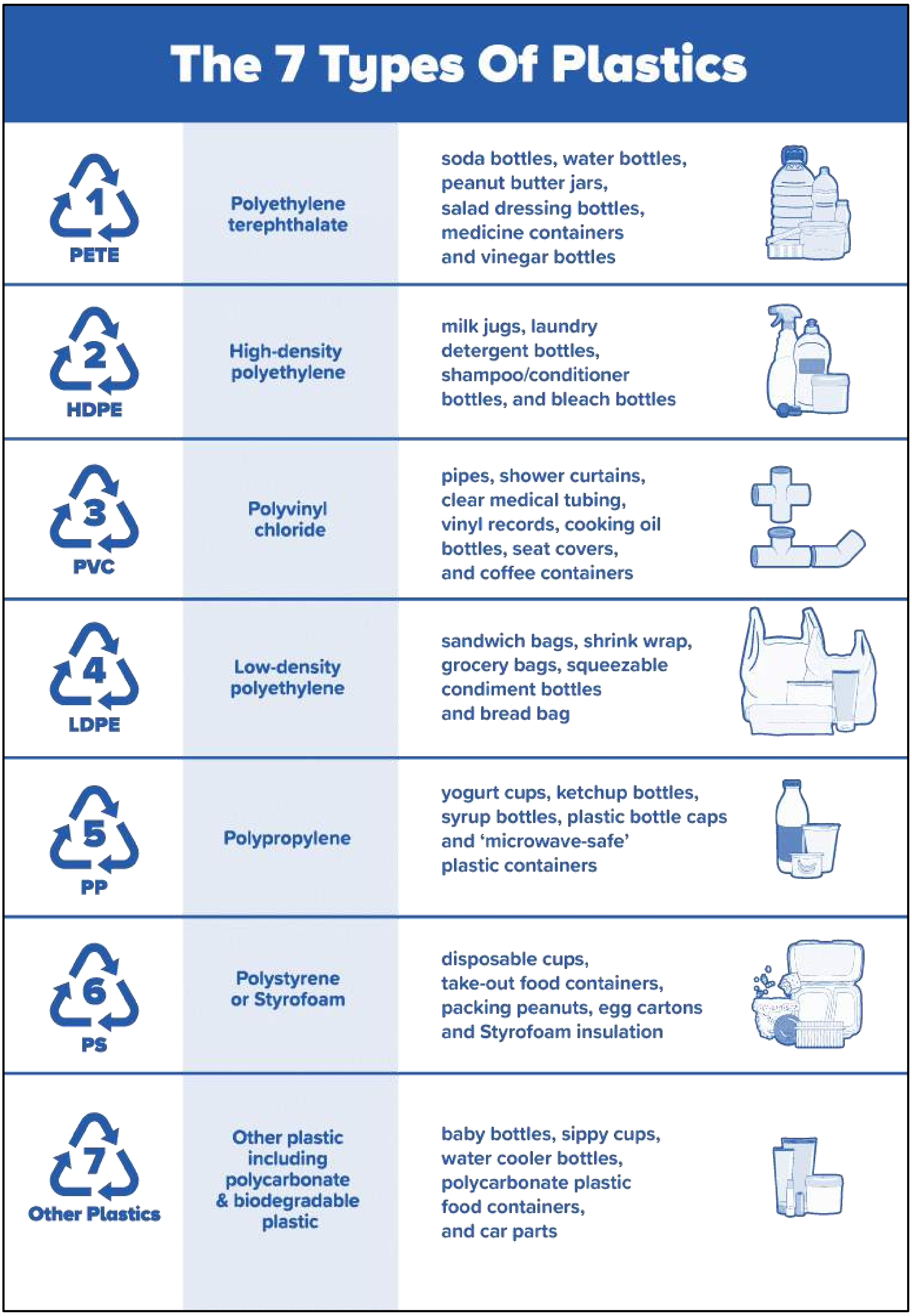


Figure 4 Type of Plastics and its Uses

Figure 5 Types of Plastic

2.2. Environmental impacts of plastic waste

- Littering of plastic waste is a major environmental issue. It makes the land infertile, choke the drains, causes death of cattle when ingested, and gives an ugly look to the area. Open burning of plastic waste is a major health and environmental issue, as it emits toxic gases such as dioxin, furan and phthalates
- Leaching impact on soil, underground water, etc. due to improper dumping of plastic waste (contains metals and phthalates).
- Release of harmful gases such as carbon monoxide, formaldehyde, etc. during product manufacturing.
- Leaching of toxic metals into underground water such as lead and cadmium pigments due to indiscriminate dumping of plastic waste on land.
- Sub-standard plastic carry bags, thin packaging films, etc. pose problem in collection, recycling and reuse.

2.3. Responsibility of waste generator (as per PWM Rules, 2022)

- Take steps to minimize generation of plastic waste and segregate plastic waste at source in accordance with the Solid Waste Management Rules, 2000 or as amended from time to time.

- Not litter the plastic waste and ensure segregated storage of waste at source and handover segregated waste to urban local body or gram panchayat or agencies appointed by them or registered waste pickers', registered recyclers or waste collection agencies.
- All institutional generators of plastic waste, shall segregate and store the waste generated by them in accordance with the Municipal Solid Waste (Management and Handling) Rules, 2000 notified vide S.O 908(E) dated the 25th September, 2000 under the Act or amendments and handover segregated wastes to authorized waste processing or disposal facilities.
- All waste generators shall pay such user fee or charge as may be specified in the bye-laws of the local bodies for plastic waste management such as waste collection or operation of the facility thereof, etc.

2.4. Banned Single Use Plastic (SUP) Items:

The following identified single use plastic items, which have low utility and high littering potential, have been prohibited, with effect from 1st July, 2022, vide Plastic Waste Management Amendment Rules, 2021:

- Ear buds with plastic sticks, plastic sticks for balloons, plastic flags, candy sticks, ice-cream sticks, polystyrene [Thermocol] for decoration;
- Plates, cups, glasses, cutlery such as forks, spoons, knives, straw, trays, wrapping or packing films around sweet boxes, invitation cards, and cigarette packets, plastic or PVC banners less than 100 micron, stirrers.
- Carry bags or recycled bags with thickness less than 120 microns. Below table 5 provides list of SUP items banned and their alternatives

Table 5 Banned SUPs items and its alternatives

Sr. no.	SUPs	Banned SUPs	Alternate to SUPs
1	Polystyrene [thermocol] for decoration		

2	Packing films around sweet boxes, invitation cards, and cigarette packets		
3	Ear buds with plastic sticks, plastic sticks for balloons, plastic flags, candy sticks, ice - cream sticks	 	
4	Plates, cups, glasses, cutlery such as forks, spoons, knives, straw, trays, wrapping, stirrers		 
5	Plastic or PVC banners less than 100 micron		
6	Carry bags or recycled bags with thickness less than 120 microns		

2.5. The 3R principle for Plastic Waste

3 Rs- Refuse, Reduce and Reuse should be practiced for plastic waste minimization. It is responsibility of the individuals in colonies and offices of DPA to practice this by limiting the use of plastics in day to day lives like carrying a cloth bag to markets, making use of stainless steel/earthen water bottles, making use of recyclable goods used in day to day lives etc. General Do's and Don'ts regarding plastic usage are as below:

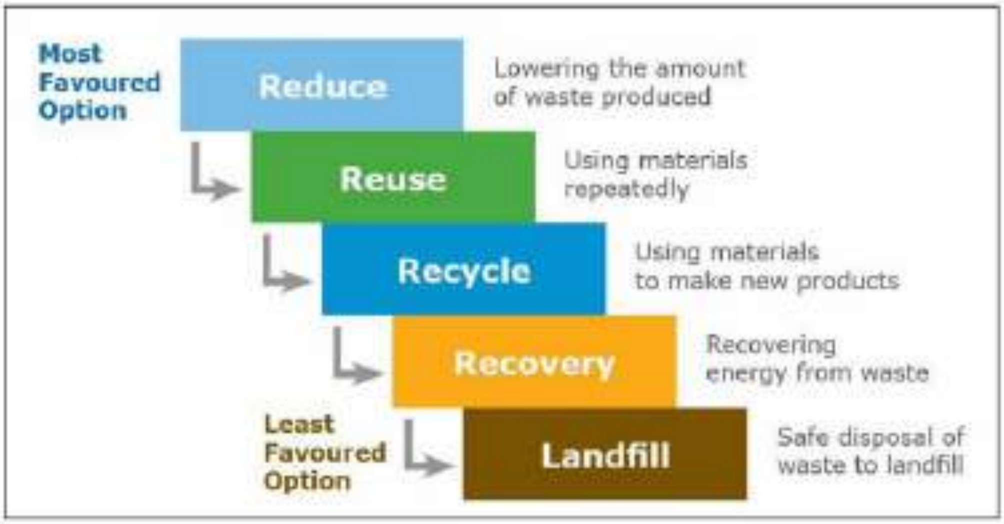


Figure 6 3 R's- Refuse, Reduce and Reuse

2.6. Compostable Plastic

2.6.1. Background and legal provisions

As per the Rule 3(e)(Definitions) of PWM Rules, 2018 "compostable plastics" mean plastic that undergoes degradation by biological processes during composting to yield CO_2, water, inorganic compounds and biomass at a rate consistent with other known compostable materials, excluding conventional Petro-based plastics, and does not leave visible, distinguishable or toxic residue.

As per the Rule 4(h) (Conditions) of PWM Rules, 2018, the manufacturers or sellers of compostable plastic carry bags/products shall obtain a certificate from the CPCB before marketing or selling compostable carry bags/products. Every compostable plastic carry bag manufacturer/seller shall comply following provisions under PWM Rules, 2018:

- **Rule 4(h) (Conditions):** The provision of minimum thickness of 50 micron shall not be applicable to carry bags made up of compostable plastic. Carry bags made from compostable material or plastics shall conform to the Indian Standard: 1S:17088 (as amended from time to time) titled as 'Specifications for Compostable Plastics'.
- **Rule 10 (Protocols for compostable plastic material):** Determination of the degree of

degradability and degree of disintegration of plastic material shall be as per the protocols of the Indian Standards 1S/ISO: 17088 (as amended time to time).

- **Rule 11 (Marking or labelling):1(c):** shall have the following information printed in

English and local **languages** namely; name and certificate number in case of carry bags made from compostable plastic. Each carry bag made from compostable plastics shall bear a label **"compostable"** and shall conform to the Indian Standard: 1S/ISO-17088 (as amended from time to time) titled as "Specifications for Compostable Plastics".

2.6.2. How to identify compostable plastic?

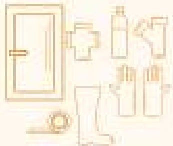
- Plastic products or materials meeting all the requirements specified in 1S/1S0:17088 may be labeled as "compostable" or "biodegradable during composting ".
- The labelling shall conform to international, national, regional or local regulations.
- The name of the country where the plastic product or material is to be marketed or recycled by composting shall be indicated.
- Each carry bag made from compostable material or plastic shall bear a label **"COMPOSTABLE" IS/1SO:17088** titled as Specifications for "Compostable Plastic" in English & regional language. Each carry bag shall also have printed code: …… and Certificate Number of **"MANUFACTURER/SELLER"**.

Figure 7 Compostable Plastic Bags

2.7. Information, Education and Communication (IEC)

- DPA should organize awareness campaigns for residents and office staff to educate them about environmental pollution, its health effects caused due to littering plastics and solutions to these problems. The residents and office staff shall be made aware of Single Use Plastics (SUPs), banned SUPs and environmental damage caused by use of SUPs.
- Segregation of PW from MSW at household and office level could substantially streamline the implementation of PW management system. Residents and office staff should make an effort at bringing a behavioral change in dumping wet and dry (plastic) waste separately at its source of generation itself.
- Efforts should be made for use of plastic free day to day items like earthen wares, cotton bags, steel bottles etc.
- Community awareness is the best means to reduce and manage plastic waste. DPA should organize activities and competitions in its school and community gatherings to engage its residents especially children to create "Best out of Waste" items.
- **Recyclable plastics:** The staff involved with segregation of PW at MRF shed shall be educated and trained about the plastics that are recyclable and non-recyclable. The image given below shows the various types of recyclable plastics and day to day items made from these plastics.

UNDERSTANDING DIFFERENT TYPES OF PLASTIC AND THEIR USES

	1 PETE	Converted back to polymer and used for making apparel
	2 HDPE	Converted to pellets and used to produce new HDPE
	3 PVC	These are used to produce new PVC or as feed for other manufacturing processes or as fuel for energy recovery
	4 LDPE	Converted to pellets and used to produce new LDPE
	5 PP	Converted to pellets and used to produce new PP
	6 PS	Not recyclable
	OTHERS	Not recyclable – However, multilayer packaging could be crushed and turned into sheets and boards for roofing, using adhesives

Awareness posters


LiFE
SAY A
BIG NO
TO
SINGLE
USE PLASTIC
CARRY BAGS!
Note : Plastic carry bags with less than thickness of 120 microns are banned w.e.f 31st December 2022


LiFE
Say No To
Single Use Plastics
कहीं भी आप पतली पॉलीथिन बैग (120 माइक्रोन से कम) का उत्पादन, भंडारण, बिक्री अथवा प्रयोग होते हुए देखें तो तुरंत SUP Grievance App पर शिकायत दर्ज करें


LiFE
Switch To
Sustainable
Lifestyle
Bring Your
Own Bags
For
Shopping
Reduce
Plastic Pollution


LiFE
Repurpose Glass, Plastic
and Cardboard Containers
Give Them A New Life


LiFE
CARRY YOUR
OWN CLOTH BAG
FOR SHOPPING
INSTEAD OF USING
PLASTIC BAGS


Turn 'Single Use'
Into 'No-Use'
Lower the environmental impact of Single Use Plastics
by avoiding products made of SUPs.


DO YOU KNOW
WHAT THESE PLASTIC SYMBOLS MEAN?
PET
HDPE
PVC
LDPE
PP
PS
OTHER


EASY WAYS TO REDUCE
PLASTIC POLLUTION
Prefer metal/ glass bottle bottles instead of plastic bottles
Use cotton/paper/jute bags in place of plastic bags
Refuse plastic decorative items for family gatherings/parties
Choose eco-friendly alternatives over single-use-plastics made products

Chapter-3
E-Waste

3.1 Introduction

3.1.1 What is E- Waste?

The E-Waste (Management) Rules, 2022 defines E-waste as any electrical and electronic equipment, whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment and repair processes.

'Bulk consumer' means bulk users of electrical and electronic equipment such as Central Government or State Government Departments, public sector undertakings, banks, educational institutions, multinational organizations, international agencies, partnership and public or private companies that are registered under the Factories Act, 1948 (63 of 1948) and the Companies Act, 2013 (18 of 2013) and health care facilities which have turnover of more than one crore or have more than twenty employees. As per this definition, AO offices and Gopalpuri colony come under bulk e-waste consumers.

This manual covers topic on environmentally sound management of the e-waste at administration, consumer and waste handling levels.

3.1.2 Characteristics of E-Waste

- Electronic waste or e -waste is any broken or unwanted electrical or electronicappliance.
- E-waste includes computers, consumer electronics, phones, medical equipments,toys and other.
- Items that have been discarded by their original users.
- E-Waste also includes waste which is generated during manufacturing or assemblingof such equipments.

3.1.3 Objective of Module

Creating awareness: People residing in colonies and working staff at offices shall be made aware regarding types of e-wastes and the nuisances created by e-waste. Efforts shall be made to educate people about e-waste potential to create positive impact if collected and attended in environmentally sound manner. This will encourage public participation in collection of e-wastes.

3.2 Background of E-Waste

3.2.1 Categories of E-waste according to E-Waste (Management) Rules, 2022

Categories of electrical and electronic equipment including their components, consumables, parts and spares covered under the rules

Figure 8 E-Waste Categories

Table 6 Categories and products of electrical and electronic equipment

Sr. No.	**Categories of electrical and electronic equipment**	**Electrical and electronic equipment code**
i.	**Information technology and telecommunication equipment**:	
	Centralized data processing: Mainframes, Minicomputers	ITEW1
	Personal Computing: Personal Computers (Central Processing unit with input and output devices)	ITEW2
	Personal Computing: Laptop Computers (Central Processing unit with input and output devices)	ITEW3
	Personal Computing: Notebook Computers	ITEW4
	Personal Computing: Notepad Computers	ITEW5
	Printers including cartridges	ITEW6
	Copying Equipment	ITEW7

	Electrical and Electronic Typewriters	ITEW8
	User terminal and Systems	ITEW9
	Facsimile	ITEW10
	Telex	ITEW11
	Telephones	ITEW12
	Pay telephones	ITEW13
	Cordless telephones	ITEW14
	Cellular telephones	ITEW15
	Answering System	ITEW16
	Products or equipment of transmitting sound, images or other information by telecommunications	ITEW17
	BTS (all components excluding structure of tower)	ITEW18
	Tablets, I-PAD	ITEW19
	Phablets	ITEW20
	Scanners	ITEW21
	Routers	ITEW22
	GPS	ITEW23
	UPS	ITEW24
	Inverter	ITEW25
	Modems	ITEW26
	Electronic data storage devices	ITEW27
ii.	Consumer Electrical and Electronics and Photovoltaic Panels:	
	Television sets (including sets based on Liquid Crystal Display and light Emitting Diode Technology)	CEEW1
	Refrigerator	CEEW2
	Washing Machine	CEEW3
	Air- Conditioners excluding centralised air conditioning plants	CEEW4
	Fluorescent and other Mercury containing lamps	CEEW5
	Screen, Electronic Photo frames, Electronic Display Panel, Monitors	CEEW6
	Radio sets	CEEW7
	Set top Boxes	CEEW8
	Video Cameras	CEEW9
	Video Recorders	CEEW10
	Hi-Fi Recorders	CEEW11
	Audio Amplifiers	CEEW12

	Other products or equipment for the purpose of recording or reproducing sound or images including signals and other technologies for the distribution of sound and image by telecommunications	CEEW13
	Solar panels/cells, solar Photovoltaic panels/cells/modules.	CEEW14
	Luminaires for fluorescent lamps with the exception of luminaires in households	CEEW15
	High intensity discharge lamps, including pressure sodium lamps and metal halide lamps	CEEW16
	Low pressure sodium lamps	CEEW17
	Other lighting or equipment for the purpose of spreading or controlling light excluding filament bulbs	CEEW18
	Digital camera	CEEW19
iii.	**Large and Small Electrical and Electronic Equipment**	
	Large cooling appliances	LSEEW1
	Freezers	LSEEW2
	Other large appliances used for refrigeration, conservation and storage of food	LSEEW3
	Clothes dryers	LSEEW4
	Dish Washing Machines	LSEEW5
	Electric cookers	LSEEW6
	Electric stoves	LSEEW7
	Electric hot plates	LSEEW8
	Microwaves, Microwave Oven	LSEEW9
	Other large appliances used for cooking and other processing of food	LSEEW10
	Electric heating appliances	LSEEW11
	Electric radiators	LSEEW12
	Other large appliances for heating rooms, beds, seating furniture	LSEEW13
	Electric fans	LSEEW14
	Other fanning, exhaust ventilation and conditioning equipment	LSEEW15
	Vacuum cleaners	LSEEW16
	Carpet sweepers	LSEEW17
	Other appliances for cleaning	LSEEW18
	Appliances used for sewing, knitting, weaving and other processing for textiles	LSEEW19
	Iron and other appliances for ironing, mangling and other care of clothing	LSEEW20

	Grinders, coffee machines and equipment for opening or sealing containers or packages	LSEEW21
	Smoke detector	LSEEW22
	Heating Regulators	LSEEW23
	Thermostats	LSEEW24
	Automatic dispensers for hot drinks	LSEEW25
	Automatic dispensers for hot or cold bottles or cans	LSEEW26
	Automatic dispensers for solid products	LSEEW27
	Automatic dispensers for money	LSEEW28
	All appliances which deliver automatically all kinds of products	LSEEW29
	Indoor air purifier	LSEEW30
	Hair dryer	LSEEW31
	Electric shaver	LSEEW32
	Electric kettle	LSEEW33
	Electronic display panels/board/visual display unit	LSEEW34
iv.	**Electrical and Electronic Tools (With the exception of large-Scale Stationary Industrial Tools)**	
	Drills	EETW1
	Saws	EETW2
	Sewing Machines	EETW3
	Equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending or similar processing of wood, metal and other materials	EETW4
	Tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses	EETW5
	Tools for welding, soldering, or similar use	EETW6
	Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substance by other means	EETW7
	Tools for mowing or other gardening activities	EETW8
v.	**Toys, Leisure and Sports Equipment**	
	Electrical trains or car racing sets	TLSEW1
	Hand-held video games consoles	TLSEW2
	Video games	TLSEW3
	Computers for biking, diving, running, rowing, etc.	TLSEW4
	Sports equipment with electric or electronic components	TLSEW5
	Coin slot machines	TLSEW6

vi.	**Medical Devices (With the Exception of All Implanted and Infected Products)**	
	Radiotherapy equipment and accessories	MDW1
	Cardiology equipment and accessories	MDW2
	Dialysis equipment and accessories	MDW3
	Pulmonary ventilators and accessories	MDW4
	Nuclear Medicine Equipment and accessories	MDW5
	Laboratory equipment for in vitro diagnosis and accessories	MDW6
	Analysers and accessories	MDW7
	Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET) Scanner, Computed Tomography (CT) Scanner, & Ultrasound Equipment along with accessories	MDW8
	Fertilization tests equipment and accessories	MDW9
	Other electric appliances/equipment/kits used for preventing, screening, detecting, monitoring, evaluating, reviewing, examining, investigating, probing, treating illness sickness, disease, disorder, affliction, infection, injury, trauma, abuse or disability including the Mobiles, Tablets or any other device with the features having the potential of sex selection and their accessories	MDW10
vii.	**Laboratory Instruments**	
	Gas analyser	LIW1
	Equipment having electrical and electronic components	LIW2

3.2.2 Resources embedded in e-waste

The electronic and electrical item consists of more than 1000 different substances which can fall under hazardous and non-hazardous categories. The resources embedded in e-waste are very diverse and contains products across different categories. As shown in the below picture, the major constituents are ferrous and non-ferrous metals, plastics, glass and plywood, printed circuit boards, concrete and ceramics, rubber and other items.

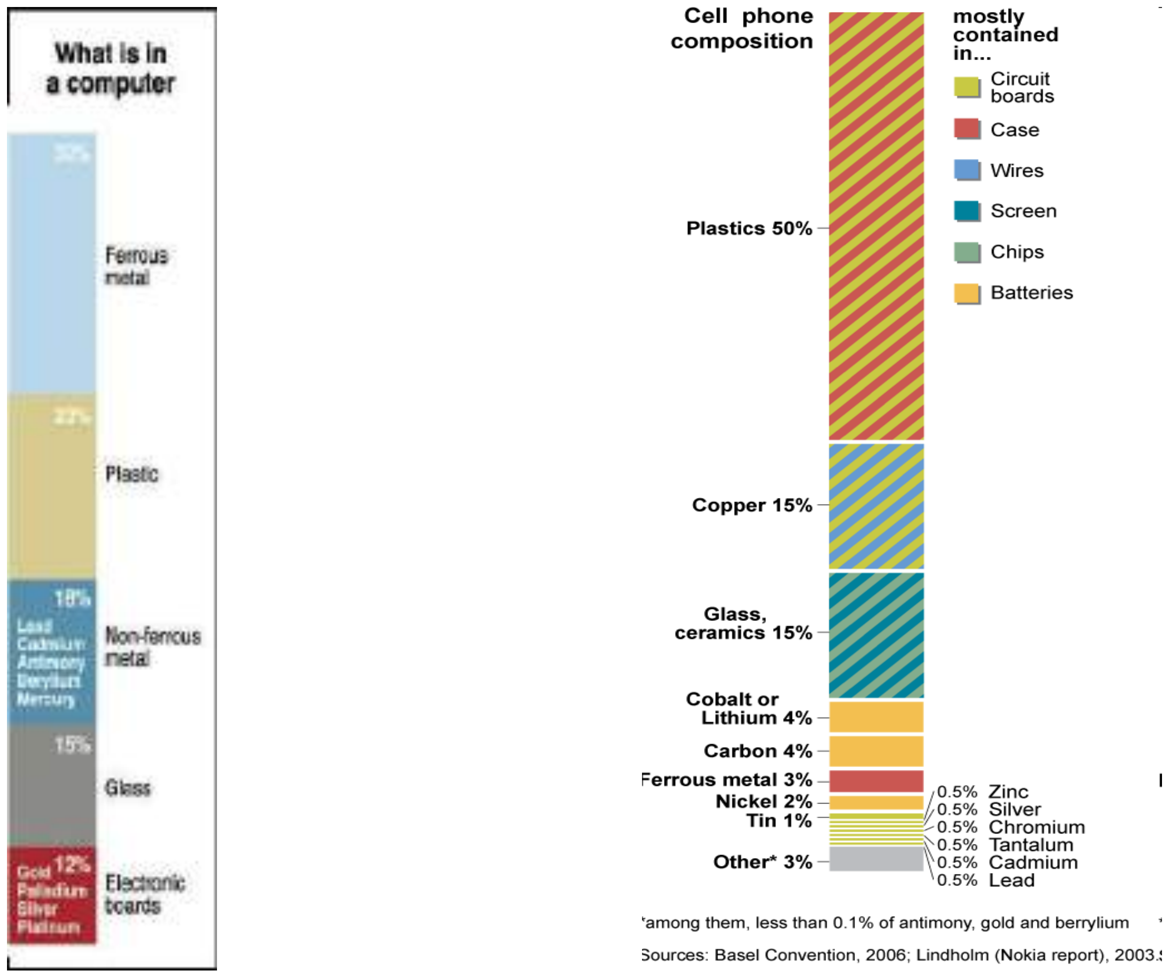


Figure 9 Resources embedded in e-waste

Source: UNEP

3.2.3 Hazards Substances in E-waste

Electronic waste is filled with a variety of toxic materials, which creates a serious risk for human health and the environment if they are released during processing, recycling or disposal. The major constituents are ferrous and non- ferrous metals, plastics, glass and plywood, printed circuit boards, concrete and ceramics, rubber and other items. Iron and steel constitute about 50% of the WEEE followed by plastics (21%), non-ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminium and precious metals like silver, gold, platinum, palladium etc. Other than these resources heavy metals and organic compounds are also found which contains in e-waste such as lead, cadmium, mercury, arsenic, beryllium, polyvinyl chloride (PVC), Brominated Flame Retardants (BFRs) and phthalates.

Table 7 Possible hazardous substances in WEEE/E-waste components

Component	Possible Hazardous Content
Metal	-
Motor/compressor	-
Cooling	ODS
Plastic	Phthalate plasticize, BFR
Insulation	Insulation ODS in foam, Asbestos, refractory ceramic fiber
Glass	-
CRT	Lead, antimony, mercury, phosphors
LCD	Mercury
Rubber	Phthalate plasticizer, BFR
Winning/electrical	Phthalate plasticizer, lead, BFR
Concrete	-
Transformer	-
Circuit Board	Lead Beryllium, antimony, BFR
Fluorescent Lamp	Mercury, Phosphorus, Flame retardants
Incandescent Lamp	-
Healing element	-
Thermostat	Mercury
BFR – containing plastic	BFRs
Batteries	Lead, lithium, Cadmium, Mercury
CFC, HCFC, HFC, HC	Ozone depleting substances
External electric cables	BFRs, plasticizers
Electrolyte capacitors (over L/D 25mm)	Glycol, other unknown substances

Source: Central Pollution Control Board

Among the substances mentioned in the table 7, of most concern are the heavy metals such as lead, mercury, cadmium and chromium (VI), halogenated substances (e.g. CFCs), polychlorinated biphenyls, plastics and circuit boards that contain brominated flame retardants (BFRs). BFR can give rise to dioxins and furans during incineration. Other materials and substances that can be present are arsenic, asbestos, nickel and copper. These substances may act as a catalyst to increase the formation of dioxins during incineration.

Many of these pollutants are embedded in e-waste and are the constituents of complex materials, e.g. flame retardants in plastics, or are hidden inside electrical components, such as mercury in switches, therefore these materials are difficult to isolate and separate from the other components. The material fusions with equipment's make the recycling of e-waste complicated and costly. Pollutants or toxins in E-waste are concentrated in circuit boards, plastics, batteries and LCDs (Liquid

crystal displays). To avoid serious environmental pollution and human exposure, adequate treatment of e-waste is crucial; particularly considering the huge amounts of e-waste we are producing globally.

Table 8 Pollutants and their occurrence in WEEE

Pollutant	Occurrence
Arsenic	Semiconductors, diodes, microwaves, LEDs (light emitting diodes), solar cells
Barium	Electron tubes, filler for plastic and rubber, lubricant additives
Brominated flame –proofing agent	Casing, circuit boards (plastic), cables and PVC cables
Cadmium	Batteries, pigments solder, alloys, circuit boards, computer batteries, monitor cathode ray tubes (CRTs)
Chrome	Dyes/pigments, switches, solar
Cobalt	Insulators
Copper	Conducted in cables, copper ribbons, coils, circuitry, pigment
Lead	Lead rechargeable batteries, solar, transistors, lithium batteries PVC (polyvinyl chloride) Stabilizers, lasers,LEDs, thermoelectric elements, circuit boards
Liquid crystal	Displays
Lithium	Mobile telephones, photographic equipment, video equipment (batteries)
Mercury	Components in copper machines and steam irons; batteries in clocks and pocket calculators, switches, LCDs
Nickel	Alloys, batteries, relays, semiconductors, pigments
PCBs (Polychlorinated biphenyls)	Transformers, capacitors, softening agent for paint, glue plastic
Selenium	Photoelectric cells, pigments, photocopiers, fax machine
Silver	Capacitors, switches (contacts), batteries, resistors
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances.

Source: Raiya Sabha Secretariat 2011

The major hazards associated with the harmful elements in the composition of WEEE are listed in the table 9. As shown in the table 9, toxic substances are found in components of the electronic or electrical products, which release highly toxic dioxins, furans and acid when burned to retrieve metals from the product. Many of these substances are toxic and carcinogenic. The materials are complex and have been found to be difficult to recycle in an environmentally sustainable manner even in developed countries.

Table 9 Hazards from E-waste substances

Metal	Danger
Lead	A neurotoxin that affects the kidneys and the reproductive system, high quantities can be fatal. It affects mental development in children. Mechanical breaking of CRTs (cathode ray tubes) and removing solder form microchips release lead as powder and fumes.
Plastic	Found in circuit boards, cabinets and cables, they contain carcinogens. BFRs or Brominated flame retardants give out carcinogenic Brominated dioxins andfurans Dioxins can harm reproductive and immune systems. Burning PVC, a component of plastics, also produces dioxins BFR can leach into landfills Even the dust on computer cabinets contains BFR.
Chromium	Used to protect metal housings and plates in a computer from corrosion, inhaling Hexavalent chromium or chromium 6 can damage liver and kidney and cause bronchial maladies including asthmatic bronchitis and lung cancer.
Mercury	Affect the central nervous system, kidneys and immune system. It impairs fetus growth and harms infants through mother's milk. It is released while breaking and burning of circuit boards and switches mercury in water bodies can form methylated mercury through microbial activity. Methylated mercury is toxic and can enter the human food chain through aquatic.
Beryllium	Found in switch boards and printed circuit boards. It is carcinogenic and causes lung diseases.
Cadmium	A carcinogen. Long-term exposure causes Itai-Itai disease, which causes severe pain in the joints and spine. It affects the kidneys and softens bones. Cadmium is released into the environment as powder while crushing and milling of plastics, CRTs and circuit boards. Cadmium may be released with dust, entering surface water and groundwater.
Acid	Sulphuric and hydrochloric acids are used to separate metals from circuit board's furnes contain chlorine and Sulphur dioxide, which cause respiratory problems. They are corrosive to the eye and skin.

E-waste typically contains complex combinations of materials and components down to microscopic levels. The wastes are broken down not just for recycling but for the recoverable materials such as plastic, iron, aluminum, copper and gold. However, since e waste also contains significant concentration of substances that are hazardous to human health and the environment, even a small amount of E-waste entering the residual waste will introduce relatively high number of heavy metals and halogenated substances. Such harmful substances leach into the surrounding soil, water and air during waste treatment or when they are dumped in landfills or left to lie around near it. Sooner or later, they would adversely affect human health and ecology.

Table 10 Typical pathways for the release of pollutants from e-waste

Heavy metals	Dioxins and Furans	Acids
• Dust generated during mechanical treatment, for example, the dismantling and crushing of WEEE. • Flue gas released during thermal treatment, for example, the release of metals from compounds during the incineration of plastic. • Vaporization where in metals are released from compounds in an acid bath	• Dioxins and furans are emitted during the thermal treatment of WEEE, for example during- • The combustion of cable insulation containing PVC in order to recycle copper wiring • The incineration of epoxy resin containing flame retardant from circuit boards in order to recycle the metal they contain	• Released in the form of vapor when metals are released from compounds. May also get disturbed throughout the surrounding area in the following ways • Factory air and dust being blown into the vicinity • Leaching through waste water and seepage • Release of flue gas into the atmosphere as a result of open incineration of furnace combustion

Table 11 Constituents of E-Waste

E-Waste Source	E-Waste Component	Environmental Hazard	Effects on Human
CRTs (used in TVs, Monitors, ATM, Video Camera, etc.) Batteries, PBC cables, Paints	Lead, barium & other heavy metals	These metals leaching into the ground water and release of toxic phosphorus	Anemia, Renal Toxicity, Insomnia
Batteries, Housing & Medical Equipment	Mercury	Air emissions as well as discharge into rivers of glass dust	Renal Toxicity, Muscle tumors, Mental retardation, Cerebral palsy
Plastic from printers, keyboard, monitors, etc.	Plasticizer bisphenol-A (or BPA), as well DEHP and DBA, plastic compounds known as phthalates	Chlorinated plastics release harmful chemical into the surrounding water resources which cause serious harm to the species that drink this water.	Risk in developing heart problems, obesity, reproductive disease
PVC & polymer, Paints inks, Electrical transformers & capacitors	Polychlorinated Biphenyls (PCBs)	Include extreme pollution from production, toxic chemical exposure during use, hazards from fires	Suppression of immune system; Damage to the liver, nervous and reproductive systems

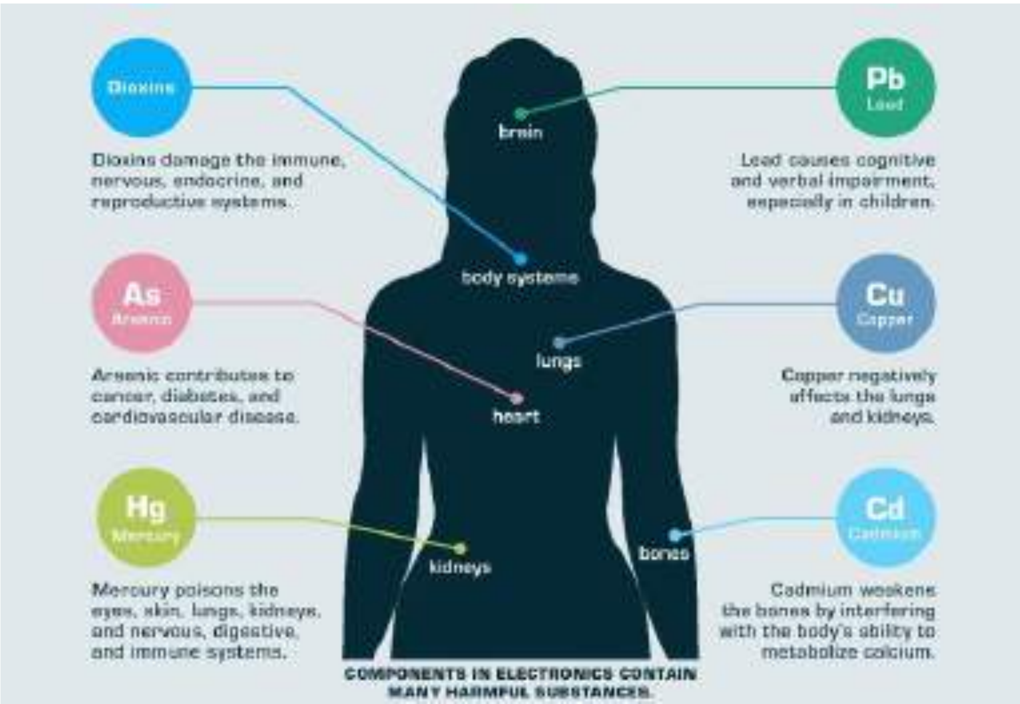


Figure 10 Adverse Impact of e-waste

3.3 Policies for E-Waste Management

3.3.1. Responsibilities of bulk consumer

Bulk consumers of electrical and electronic equipment listed in **Table 12** shall ensure that e-waste generated by them shall be handed over only to the registered producer, refurbished or recycler.

3.3.2. Formulation of a system

For channelization of e-waste from generation source to storage area until collected by authorized agency or GPCB registered e-waste recyclers/refurbishers or dismantlers. DPA shall organize e-waste collection drive once in a year at office and residencies by setting up e-waste collection booths.

The collection points/bins can be at designated places where e-waste can be collected from residential areas, office complexes, commercial complexes and educational institutions.

Mobile collection vans can be used for door-to-door collection of e-waste from and such vans shall be linked to collection booths

During the e-waste collection drive following information shall be communicated to the residents in colonies and office staff:

- Share information pertaining to e-waste collection booths like booth location, timings, etc.
- Toll free number for query resolution to be available during working hours (10 A.M. to 6 P.M.)
- Details of dealers, retailers, collection points/bins/pick up vans linked to collection booths for depositing of e-waste, if they are part of the take-back system.
- Details of any incentive scheme for consumers for returning of e- waste

Collection booth should have weighing equipment for weighing each delivery received by it and maintain a record in this regard.

Collection booths shall store e-waste products category wise.

3.3.3. Record keeping

Since the e-waste generated at Vadinar port and offices is sent to EDP store at AO, Gandhidham office, the concerned official at AO Gandhidham shall keep a record of below listed information to be furnished in Form 2 as per E-waste Management Rules, 2016.

- Name & Address: Producer /Collection Centre/Dismantler/Recycler/ Bulk consumer
- Date of Issue and Validity of Authorization

- Category, description & Quantity of e- waste handled/generated
- Category, description & Quantity of e- waste stored in storage area
- Category, description & Quantity of e- waste handed over to authorized collection center/registered recycler/ dismantler etc.
    - **If e-waste is sent to refurbished:** Name, address and contact details of the destination of refurbished materials
    - **If e-waste is sent to dismantler/recycler or for disposal:** Name, address and contact details of the destination (dismantler/recycler/ dismantling/ recycling or disposal facility)
- Category, description & Quantity of e- waste treated & disposed

3.3.4. Guideline for storage of e-waste

Every manufacturer, producer, refurbisher and recycler may store the e-waste for a period not exceeding **one hundred and eighty days (180)** and shall maintain a record of sale, transfer and storage of e-wastes and make these records available for inspection and the storage of the e-waste shall be done as per the applicable rules or guidelines for the time being in force:

Provided that the Central Pollution Control Board may extend the said period up to **three hundred and sixty-five days (365)** in case the e-waste needs to be specifically stored for development of a process for its recycling or reuse.

Storage of end-of-life products may be done in a manner which does not lead to breakage of these products and safe to workers handling such products.

The storage where refrigerator and air conditioners are also stored should have adequate facilities for managing leakage of compressor oils, coolant/refrigerant gases such as CFCs/HCFCs and mercury from end of life fluorescent and other mercury containing lamp etc. Spills involving broken fluorescent lamps, Oils spills should first be contained to prevent spread of the material to other areas. This may involve the use of dry sand, proprietary booms/absorbent pads, stabilizing chemicals etc. for subsequent transfer of hazardous waste to TSDFs.

During storage of e-waste care may be taken:

- To avoid damage to refrigerators and air-conditioner so as to prevent release of refrigerant gases such as CFC, HFS, HCFC etc. and to prevent spillage of oils (mineral or synthetic oil) and other emissions.

- To avoid damage to Cathode Ray Tube
- To avoid damage to fluorescent and other mercury containing lamps
- To avoid damage to equipment containing asbestos or ceramic fibers to avoid release of asbestos or ceramic fibers in the environment.

After collection of fluorescent and other mercury containing lamps, it should be sent only to a recycler or to a TSDF in case no recycler is available.

Loading, transportation, unloading and storage of E-Waste/ end of life products should be carried out in such a way that its end use such as re-use after refurbishing or recycling or recovery is unaffected.

The storage area should have fire protection system in place.

The storage capacity of the collection/storage area should be in accordance with volume of operations (weight and numbers) and category of E-waste. Space needed for storage of different category of e-waste is given in table 12 below:

Table 12 Space needed for storage

Sr. no	Categories of electrical and electronic equipment	EEE Code	Storage area requirement in m^3/tonne
1.	**Centralized data processing:** Mainframe Minicomputer Personal Computing: Personal Computers (Central Processing Unit with input and output devices) Laptop Computers (Central Processing Unit with input and output devices) Notebook Personal/Notepad Computers Printers including cartridges	ITEW1 to ITEW6	4.0
2.	Monitors (CRT)	Monitors (CRT)	5.0
3.	Copying equipment Electrical and electronic type writers, User terminals and systems, Facsimile	ITEW7 to ITEW10	5.0
4.	Telex Telephones Pay telephones Cordless telephones	ITEW11 to ITEW14	3.0
5.	Cellular telephones Feature phones Smart phones	ITEW15	1.0
6.	Answering systems	ITEW16	3.0
7.	Television sets (including sets based on (Liquid Crystal Display and Light Emitting Diodetechnology)	CEEW1	6.5
8.	Refrigerator	CEEW2 -	10.0

9.	Washing Machine	CEEW3	7.5
10.	Air-conditioners excluding centralized air conditioning plants	CEEW4	6.0
11.	Fluorescent and other Mercury containing lamps	CEEW5	1.0

3.3.5. Questions to Ask

What questions should you ask the manufacturers when you do bulk procurement of electrical and electronic goods? What conditions can you introduce in your tender specification to enable easy disposal of e- waste?

The questions that can be asked from the manufacturers and conditions that can be introduced in tender are:

1. Ask whether 'Extended Producer Responsibility - Authorization' is available with the manufacturer. It means a permission given by Central Pollution Control Board to a producer, for managing Extended Producer Responsibility with implementation plans and targets outlined in such authorization including detail of Producer Responsibility Organization and e-waste exchange, if applicable. This can be a mandatory condition in tender.
2. Ask if manufacturer has submitted the 'Extended Producer Responsibility Plan' means a plan submitted by a producer to Central Pollution Control Board, at the time of applying for Extended Producer Responsibility - Authorization in which a producer shall provide details of e-waste channelization system for targeted collection including detail of Producer Responsibility Organization and e-waste exchange, if applicable. This can be a mandatory condition in tender.
3. Ask if manufacturer has 'facility' or any location wherein the process incidental to the collection, reception, storage, segregation, refurbishing, dismantling, recycling, treatment and disposal of e-waste are carried out. This can be a mandatory condition in tender.
4. Ask if the manufacturer has set up 'deposit refund scheme' means a scheme whereby the producer charges an additional amount as a deposit at the time of sale of the electrical and electronic equipment and returns it to the consumer along with interest when the end-of life electrical and electronic equipment is returned. This can be a mandatory condition in tender.
5. Ask regarding tie up with dismantlers and recyclers. This can be a mandatory condition

in tender.

What questions should you ask the e-waste collector/ dismantler/ recycler when you dispose of your e-waste?

The following questions can be asked from the e-waste collector/ dismantler/ recycler:

1. Does the organization have authorization from the CPCB or SPCB for collecting, dismantling or recycling the e-waste.
2. Does it have safe working conditions, tools and equipment to ensure safe treatment and disposal of e-waste.

How can you organize a collection drive for e- waste in your organization? Which agencies can support you in organizing such a collection and awareness drive? How to set up a collection centre?

A collection drive for e-waste can be organized by contacting manufacturer or dealers who would then refer to the authorized collector, dismantler and recycler of e-waste. A record of each item collected in the drive should be maintained and provided to the collector, dismantler and recycler. The local pollution control board officer can be informed about the drive and the e-waste collected during the drive so that they can audit if safe recycling of the collected e-waste has been conducted.

All manufacturers, dealers and government's environment department could support collection and awareness drive. In addition, national, international and local environmental NGOs can be partners for such a drive.

Setting up a collection centre for e-waste:

As per the e-waste management and handling rules to set up a collection center there is a need to apply for authorization from the State Pollution Control Board or Pollution Control Committee as per FORM – 1(a). There is a need to have agreements with producers who are willing to get the e-waste covered under their EPR collected at your center as well as with dismantlers and recyclers who will be taking the e-waste from the collection center for further processing. It should be ensured that systems for record keeping and training for safe handling and storage of e-waste is provided to the people who will be managing the collection center.

Responsibilities of Collection Centres include:

1. Ensure that the facilities are in accordance with the standards or guidelines prescribed by the Central Pollution Control Board from time to time;

2. The e-waste collected by them is stored in a secured manner till it is sent to registered dismantler or recycler as the case may be;
3. Ensure that no damage is caused to the environment during storage and transportation of ewaste;
4. Maintain records of the e-waste handled in Form 2 and make such records available for scrutiny by the State Pollution Control Board or the Pollution Control Committee concerned.

3.4. Battery waste

3.4.1. What is a Battery?

Battery Waste Management Rules, 2022 defines Battery as a new or refurbished cell and/or Battery and/or their component, including accumulator, which is any source of electrical energy generated by direct conversion of chemical energy and includes disposable primary and/or secondary battery.

Many different types and shapes of batteries can occur in IT appliances. Small batteries (i.e. button cells) are used to cover the permanent low energy supply for alarm and computer system (clock, memory backup, etc.). In contrast, bigger batteries (e.g. laptop batteries) allow to run the whole device. Most modern devices do not need the small batteries anymore because the permanent energy demand for the system is reduced on the one hand. On the other hand, the remaining energy demand can be covered by the capacitors.

3.4.2. Responsibilities of User

Under Battery Waste Management Rules, 2022, DPA shall be responsible for the following:

- Ensure that the Waste Battery is collected separately from other waste streams especially from mixed waste and domestic waste streams
- Ensure the disposal of waste batteries in an environment friendly manner by handing it over to an entity engaged in its collection or refurbishment or recycling or under EPR to the entity from which batteries are purchased.

3.4.3. Toxic substances in Batteries

Heavy metals such as cadmium (Cd), nickel, (Ni), and to some extent zinc (Zn). Organic solvents, etc. are some toxins present in batteries.

3.4.4. Localization in appliance

Batteries are very diverse in terms of characteristics, composition, form, size, colour, etc. Almost every IT-equipment contain at least one battery. Rechargeable accumulators can be found in mobile phones, laptops, toothbrush or electrical razors. Appliances like torches, portable CD players, etc. can be operated using rechargeable and non-rechargeable batteries. Small (button) cell batteries are often used as a backup battery to the main battery; it provides an independent energy supply for processors, timers, security backup, etc. in computers. It is commonly located on the PWB.

3.4.5. Handling Aspect

Caution during dismantling

NEVER CRUSH OR OPEN A BATTERY

There is usually no difficulty or risk to separate the batteries from their support if they are in good condition. Use gloves, and wash hands and throw the gloves away after contact with substances from defective and leaking batteries.

3.4.6. Requirement for storage and transport

Avoid long time storing. Batteries are subject to corrosion and cell rupture, which could release reactive hazardous substances (heavy metal oxide, organic solvents, sulphuric acid).

Lithium-ion batteries can easily rupture, ignite, or explode when exposed to high temperatures, or direct sunlight.

Avoid fire risk and contact with heat sources. All batteries must be stored in acid-resistant barrels. They should be stored in a dry and sheltered place.

Batteries should be treated in an adequate plant for recovery or disposal. In any case, they should not be incinerated in an open fire or with municipal waste.

Awareness Posters

Chapter-4
Bio-Medical Waste

4.1. Introduction

The term 'Bio-medical waste' includes any waste which is generated during the diagnosis, treatment or immunization of human beings or animals or research activities pertaining thereon, or in the production or testing of biologicals or in health camps, including the categories mentioned in Schedule 1 of the Biomedical Waste Management Rules, 2016. In addition, biomedical waste includes similar kind of waste that are generated at household level, due to health care offered at household level e.g., dialysis at home, self-administration of insulin injections and restorative care.

General waste or non-hazardous waste constitutes to 75 to 90% of waste generated at health care facilities. Administrative, housekeeping, packaging, kitchen and maintenance activities of the facilities contribute to the general waste or non-hazardous waste. The remaining 10 - 25% of waste is considered hazardous and can pose threat to human and environmental health.

Figure 11 Showing Proportion of Infectious and Hazardous Waste

Bio-medical waste and its management is a comprehensive issue, encompassing occupational health and safety, environmental health and safety, and injury and incident prevention.

Training healthcare personnel to adopt 'Good Work Practices' will go a long way in Promoting the safe management of bio-medical waste so that the environment is protected

4.2. Classification of Bio-Medical Waste

Table 13 Classification of Bio-Medical Waste as Per BMW Rules 2016

Colour Coding	Type Of Waste	Examples
Yellow	. Human anatomical waste	Human tissues, organs, body parts, fetus
	. Animal anatomical waste	Experimental animal carcasses
	. Soiled waste	Cotton contaminated with blood and other body fluids, plaster casts
	. Expired or discarded medicines	Discarded tablets and capsules
	. Chemical waste	Used or discarded disinfectants, chemicals used in biologicals
	Chemical liquid waste	Laboratory reagents, X ray film developer, disinfectants, floor washings, formalin
	. Discarded linen, mattresses, beddings contaminated with blood or body fluid	Bedsheets, blankets, mattresses contaminated with blood or body fluids
	Microbiology, biotechnology and other clinical laboratory waste	Culture plates, blood bags, vaccines
Red	Contaminated waste (recyclable)	Plastic tubing, urine bags, vacutainers, gloves,catheters, Ryle's tube
White	Waste sharps including metals	Hypodermic needles, auto-disabled syringes, syringes with fixed needles, scalpels, knives, blades, lumbar puncture needles and intravenous needles.
Blue	Glassware	Used glass bottles
	Metallic body implants	Body implants, Plates and screws

4.3. Hazards of Improper Bio-Medical Waste Management

Who are at risk?

Individuals who would be at risk would include anyone working in proximity with biomedical waste, that would be,

Generators - all individuals working in health care facilities who generate biomedical waste

Handlers - who handle biomedical waste at health care facilities or at treatment and disposal facilities

Exposed group - who are exposed to hazardous biomedical waste due to consequence of careless actions of generators and handlers.

Main groups at risk are:

- Nurses, doctors, allied health care personnel (laboratory technicians)
- Patients receiving care either at hospital or at home

- visitors to health care facilities
- General public if biomedical waste is managed improperly
- Personnel in support services like; cleaners, laundry services,
- Personnel working in waste treatment/management or disposal facilities
- Personnel involved in transporting biomedical waste.

Table 14 Hazards From Various Categories of Bio-Medical Waste

Sr. No	Type Of Waste	Hazard from the Waste	Impact from the Waste
1.	Infectious waste and sharps	• Cuts • Abrasions • Infections	• Percutaneous infections with Hepatitis B, Hepatitis C, HIV
2.	Chemical and pharmaceutical waste	• Intoxication by acute or Chronic exposure • Physical injury • Chemical burns • Injury to skin • Injury to eye • Injury to mucous • membrane of airways • Respiratory disease • Skin disease	• Harmful to wildlife Evolution of antibiotic resistance in bacterial. • The chemicals can also cause contamination of water bodies and soil. When large quantities of Disinfectant are released into sewers, they can bring down the efficiency of the sewage treatment plant.
3.	Genotoxic waste	• Irritant • Dizziness • Nausea • Headache • Dermatitis	• Spontaneous abortions
4.	Radioactive waste	• Headache • Dizziness • Vomiting • Fatal	• Can expose the public as well as healthcare workers to the risk of loss of fetus in the first three months of pregnancy death
5.	Healthcare waste-treatment methods	• Flue gases from improperly • functioning waste incinerators • Physical injuries • Leachate release into water • Burning leads to heavy metal release	• Flue gases released • Water pollution • Air pollution • Release of pathogens and toxic pollutants into the environment.
6.	Public sensitivity	Sensitivity to vision of anatomical parts	• Disposal of anatomical waste inappropriately such as dumping in a landfill is unacceptable.

Figure 12 Hazards of Healthcare Waste

4.4. Training Manual for Bio-Medical Waste (BMW)

First five steps: Segregation, Collection, Pre-treatment, Intramural Transportation and Storage is the exclusive responsibility of Health Care Facility. To ascertain a systematic implementation of these steps following is recommended for identified target audiences.

4.4.1. Target audience: Nursing and BMW handling staff

- **Mandatory use of PPEs**: The Nursing and BMW staff at DPA HCFs shall make use of below listed PPEs while dealing with or handling BMW.

Personal Protective Equipment (PPE)includes:

- Heavy Duty Gloves (Workman's Gloves)
- Gum Boots or safety shoes for waste collectors
- Face mask
- Head Cap
- Splash Proof Gowns or aprons etc.
- Disposal gloves for waste handlers

Follow Good practices for Segregation of BMW:

Bio- medical waste generated from a HCF is required to be segregated at the point of generation as per the color coding stipulated under Schedule-I of BMWM Rules, 2016 presented in Table 15.

Collection of BMW:

- Bio-medical waste should be collected on daily basis from each ward of the hospital at a fixed interval of time depending upon the waste quantum generated in each ward.
- In an IPD ward where the morning routine begins with the changing of dressings, infectious waste could be collected mid-morning to prevent soiled bandages remaining in the area for longer than necessary
- General waste collection, must be done immediately after the visiting hours of the HCFs, as visitors coming to facility generate a lot of general waste and in order to avoid accumulation of such general waste in the HCF. The collection timings must enable the HCF to minimize or nullify the use of interim storage of waste in the departments

- The collection timeline should be such that the disposal of human anatomical waste, animal anatomical waste, soiled waste and biotechnology waste is done within 48 hours of its generation.

Packaging:

- Bio-medical waste bags and sharps containers should be filled to no more than three quarters full.
- Plastic bags should be tied or sealed with a plastic tag or tie and not stapled.
- Replacement bags or containers should be readily available at each waste-collection location so that full ones could immediately be replaced.

Table 15 Color coding and type of containers for BMW

Sr. No.	Category	Type of waste	Colour & Type of storage container
1.	Yellow	Human Anatomical Waste Animal Anatomical Waste Soiled Waste Discarded or Expired Medicine Microbiology, Biotechnology and other clinical laboratory waste Chemical Waste Chemical Liquid Waste	Yellow coloured non-chlorinated Plastic Bags  Note: Chemical waste (yellow-e)comprising of un-used, residual or expired liquid chemicals including spent hypo of X-Ray, should be stored in yellow container
2.	Red	Contaminated Waste (Recyclable)	Red Colored Non-Chlorinated Plastic Bags (having thickness equal to more than 50 µ) and Containers 
3.	White	Waste Sharps including metals	White Coloured translucent, puncture proof, leak proof, Temper Proof containers

			
4.	Blue	Glassware Metallic Body Implants	Puncture proof, leak proof boxes or containers with blue colored marking  

Labelling

All the bags/ containers/ bins used for collection and storage of bio-medical waste, must be labelled with the Symbol of Bio Hazard or Cytotoxic Hazard as the case may be in accordance with the BMWM Rules, 2016.

Bio-Hazard Label

Cyto-Toxic Label

Bio-medical waste bags / containers are required to be provided with bar code labels in accordance with CPCB guidelines for "Guidelines for barcode System for Effective Management of Biomedical Waste".

QR Code		Bar Code
Sl No. 000xxxxxxxxxx **ALLIN110029DHBH00578**	**OR**	**Sl No. 000xxxxxxxxxx** **ALLIN110029DHBH00578**

Intramural transportation:

In house transportation of BMW from wards to central waste collection room, within the premises of the hospital must be done in closed trolleys / containers preferably fitted with wheels for easy maneuverability.

- Patient trolleys must not be used for BMW transportation.
- Size of such waste transport trolleys should be as per the volume of waste generated from the HCFs.

The route selection for intramural transportation should be in accordance with the below listed points:

- Transportation does not occur through high-risk areas.
- Supplies and waste are transported through separate routes.
- Waste is not transported through areas having high traffic of patients and visitors.
- Central Waste collection area can be easy accessed through this route.
- Safe transportation of waste is undertaken to avoid spillage and scattering of waste.

Storage:

- Exhaust fans should be provided in the waste collection room for ventilation.
- It is to be ensured by the health care facility that such central storage room is safety inspected for potential fire hazard and based on such inspection preventive measure has to be taken by the health care facility like installation of fire extinguisher, smoke detector etc.
- There should also be provision for water supply adjacent to central waste storage area for cleaning and washing of this station and the containers. The drainage from the storage and washing area should be routed to the Effluent Treatment Plant.
- Sign boards indicating relevant details such as contact person and the telephone number should be provided.
- The entrance of this station must be labelled with "Entry for Authorized Personal Only".

4.5. Training manual for HCF Administration

Following criteria pertaining to BMW management shall be put in place by the administration of HCFs at Gopalpuri, Gandhidham, Port area, clinic in Adipur and HCF in Vadinar. The nursing and other BMW management staff shall be educated and trained in systematic implementation of BMW management system.

Training of BMW staff and its record keeping:

As per Bio Medical Waste Management Rules, 2016, it is mandatory for all the employee of the healthcare facility to be trained on handling of biomedical waste management and handling.

- The HCF administration shall formulate a Training Plan and a Training calendar comprising of two parts:
- Induction training to new joinees
- Annual training to Nursing and BMW management staff.
- The 'Guidelines for Management of Healthcare Waste as per Biomedical Waste Management Rules, 2016'', can be used as a training manual. The guidelines have been attached at Annexure X
- The HCF administration shall maintain training records and furnish them to GPCB on or before 30th June, every FY. The Training records shall mandatorily include following details.
- Total Number of trainings conducted along with the date of imparting the training
- Total number of participants of each training
- Attendance Record
- Total Number of staff trained on BMW Handling
- Total number of staff trained on BMW handling at the time of Induction
- Total number of staff, not undergone any sought of training on BMW Handling

Regulatory requirements

i. Authorization as mandated under BMW rules, 2016 and its timely renewal

The DPA HCFs at Kandla and Vadinar have obtained the authorization from GPCB for operation of HCFs at Kandla, Vadinar and Adipur. Its amendment and renewal from time to time is to be taken under consideration. Also, if any Hospital is converted to a dispensary, its amendment is to be done as per defined procedure under BMW rules.

ii. Information requirements for making a fresh application for amendment

- Particulars of Health Care Facility: Name, Address, Contact Details etc.
- Validity of Consents under Water (Prevention and Control of Pollution) Act, 1974 and Air (Prevention and Control of Pollution) Act, 1981 (in case of bedded HCFs)
- Detail of HCF: Number of beds, Average number of patients treated per month
- Category wise Quantity of Waste Generated or disposed by the health care facility

- Detail of any treatment facility available in the premises of health care facility

iii. Information requirements for making a renewal application

- Name of the Applicant
- Name of the health care facility (HCF)
- Address for correspondence
- Activity for which authorization is sought (Generation, segregation, Collection, Storage packaging Reception Transportation Treatment or processing or conversion Recycling Disposal or destruction use offering for sale, transfer Any other form of handling)
- Previous authorization number and date:
- Address of the health care facility (HCF) mentioning GPS coordinates of the facility
- Number of beds of HCF
- Number of patients treated per month by HCF
- Quantity of Biomedical waste handled, treated or disposed as per below format

Table 16 Details of waste

Category	Type of Waste	Quantity Generated kg/day	Method of Treatment and Disposal
Yellow	(a) Human Anatomical Waste:		
	(b)Animal Anatomical Waste:		
	(c) Soiled Waste:		
	(d) Expired or Discarded Medicines:		
	(e) Chemical Solid Waste:		
	(f) Chemical Liquid Waste:		
	(g) Discarded linen, mattresses, beddings contaminated with blood or body fluid.		
	(h) Microbiology, Biotechnology and Other clinical laboratory waste:		
Red	Contaminated Waste (Recyclable)		
White (Translucent)	Waste sharps including Metals:		
Blue	Glassware:		
	Metallic Body Implants		

- Brief description of arrangements for handling of biomedical waste

i. Mode of transportation (if any) of bio-medical waste:

ii. Details of treatment equipment as per table 17

Table 17 Details of treatment equipment

Treatment equipment	No. of units	Capacity of unit
Incinerators		
Needle tip cutter		
Plasma pyrolysis		
Microwave:		
Autoclaves:		
Hydroclave:		
Shredder:		
Sharps encapsulation or concrete pit:		
Deep burial pits:		
Chemical disinfection		
Any other treatment equipment		

- Details of directions or notices or legal actions if any during the period of earlier authorization

iv. Reporting to Gujarat Pollution Control Board

Annual Reporting as per the Form IV, BMWM, Rules, 2016

HCF is required to submit the Annual Report to the GPCB on or before 30th June every year, for the period from January to December of the preceding calendar year.

- The information list for filling Annual return is detailed below:
- Particulars of HCF
- Quantity of waste generated in kg/annum
- Details of storage, treatment, transportation, processing and disposal facility
- Details of training conducted on Bio Medical Waste Management
- Details of accident Occurred
- Details Emission and Effluent testing
- Training imparted to the Health Care Workers involved in handling of bio-medical waste
- Minutes of Meeting of BMW Management Committee
- Details of Accident Occurred during one year, along with the remedial steps taken
- Records of testing of Emission of DG Sets / boilers
- Records of Effluent generated and its characteristics from health care facility

- Records of pre-treatment of specified waste categories Record of recyclable waste handed over to the authorized recycler in kg/annum (where captive treatment facility is allowed by the GP)
- Records of health status of the Health Care Workers involved in handling of bio- medical waste
- Records of immunization of Health Care Workers involved in handling of bio- medical waste
- Each healthcare facility must also ensure that the annual report submitted to the GPCB is also published in its website

Table 18 Format for Bio Medical Waste Register/Record

NAME & ADDRESS OF HEALTH CARE FACILITY BIO MEDICAL WASTE REGISTER/ RECORD FORMAT										
Sr.no.	**Date of Generation**	**Quantity of BMW Generated (in KG) Color Coding and Category**					**Date of collection by Waste Collection Agency**	**Time (in AM/ PM)**	**Name & Signature of Waste Collector**	**Name & Signature of HCF Staff**
		Yellow (1)	**Red (2)**	**White (3)**	**Blue (4)**	**Total**				
1.										
2.										
3.										
4.										
5.										

Format for Accident reporting as per Form I BMWM, Rules, 2016

HCF shall report major accidents including accidents caused by fire hazards, blasts during handling of biomedical waste and the remedial action taken and the records relevant thereto. In the manner described below

The list of information required for filing Accident reporting form is as below:

1. Date and time of accident

2. Type of Accident

3. Sequence of events leading to accident

4. Has the Authority been informed immediately

5. The type of waste involved in accident

6. Assessment of the effects of the accidents on human health and the environment:

7. Emergency measures taken

8. Steps taken to alleviate the effects of accidents

9. Steps taken to prevent the recurrence of such an accident

10. Does facility have an Emergency Control policy? If yes give details:

Awareness Posters


CPCB
Segregate the hospital waste in
designated colored dustbins
Grey bin
Metal sharps
Blue bin
Recyclable
General waste
Red bin
Contaminated
plastic waste
Black bin
Hazardous and
Other waste
Green bin
Biodegradable
General waste
Blue bin
Glass waste and
metallic implants
Yellow bin
Anatomical waste, chemical waste,
soiled waste, chemotherapy waste,
discarded linen & medicines
and laboratory waste
#Biomedical
Waste Management
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Chapter-5
Construction and Demolition (C&D) Waste

5.1. Introduction

5.1.1 Objective

The objective of the training manual is to educate and inform the DPA on the severity of problem caused by Construction and Demolition (C&D) waste on the environment and serve as a reference manual providing detailed information towards management of C&D waste in an environmentally sustainable manner. It is intended that the manual be used for the purpose of training various DPA staff involved with civil construction and management of C&D waste. The sections of the training manual can be formed as training modules for providing necessary knowledge that an individual DPA staff will require to effectively and efficiently perform their respective duties with regards to implementation of C & D waste management rules (2016).

5.2. Background on Construction and Demolition (C&D) waste

5.2.1 Objective of the section

Management of Construction and Demolition waste is a relatively new term in India and so is the need for it. The urbanizing trend leading to lack of availability of land and resource shortage in construction sector has led to the notice, importance of C&D waste management in India which has brought about policy changes which specifies that all local governing bodies manage their C&D waste and also all polluters are responsible for the waste they generate.

Upon successful completion of the session, the participants should:

- Have an insight on what is C&D waste and what is it composed of
- Knowledge on estimation of C&D waste quantities in Indian cities
- Understanding on the flow of C&D waste in India
- What C&D waste can be recycled / reused for?
- Be familiar with the process of collection and transport of C&D waste

5.2.2 What is C&D waste?

Construction and demolition (C&D) waste is generated from construction, renovation, repair, and demolition of houses, large building structures, roads, bridges and dams.

C&D waste is made up of:

- Concrete
- Soil
- Steel, Wood and Plastics

- Other materials – bricks and mortar

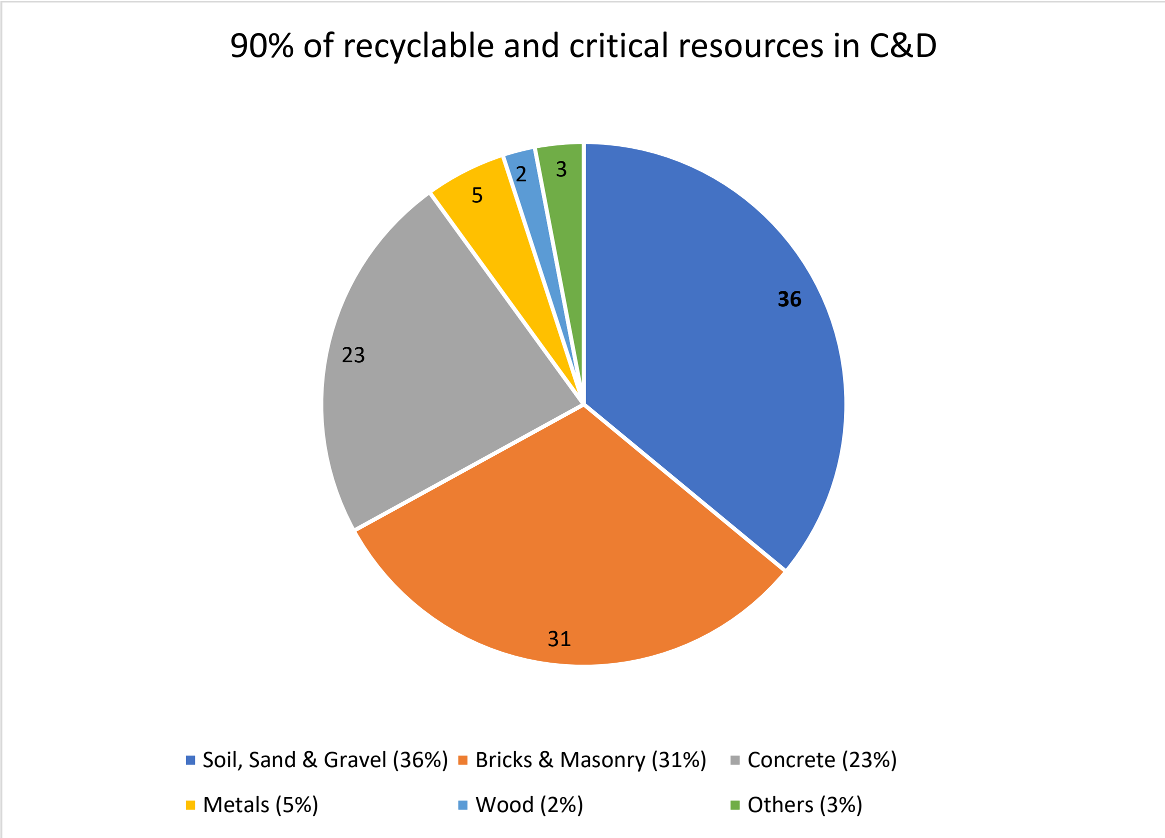


Figure 13 Typical composition of C&D waste (Source: TIFAC,2001)

Figure 14 Components of C&D waste

5.2.3 Why does C&D waste need to be managed?

The importance of C&D waste management is not lost among the stakeholders especially in large cities, where impacts have already been felt. But still effective management of C&D waste is hampered by several challenges and implementation is far from ideal.

The improperly managed and waste heaps impact the system and the environment in multiple aspects which could broadly be classified into the following aspects

Social

- Huge heaps of C&D waste on footpaths, carriage ways, alleys is a common scene in Indian cities turning the surrounding unaesthetic.
- The C&D debris usually could not be removed by normal street sweeping or household waste collection staff as they usually do not carry the equipment neither enough capacity in the collection vehicle nor enough manpower.
- Usually, the polluters tend to dump other municipal solid waste on the heap making it a mix of waste further creating an unsanitary situation.
- The C&D waste is also stealthily dumped in open drains, water channels, and even riverbeds. The debris clog the drains and create water logging. Reports of water logging of drains turning to source for spread of epidemics is common in India
- Clearing drain silts is a major challenging activity for local governing bodies and a major percentage is consisted of by C&D.
- The C&D waste also consists of several kinds of materials which include sharps, broken glasses, boulders, broken wooden logs, rusted metal, broken ceramics etc. which create a hazardous environment when dumped on unfenced open places.

Figure 15 Unauthorized Dumping

Environmental

- C&D waste is also a source of environmental pollution: The C&D debris over course of time forms fine dust creating air pollution, and reducing visibility.
- The leachate and fine chemical particles degrade the soil leading to land pollution and in addition materials like paints, oil and asbestos sheets are common components of C&D waste which are bio-hazardous in nature having potential to endanger health of workers handling the waste, civilians and any living organism
- Formation of silt deposits when dumped in wetlands and water bodies damaging the water ecosystem

Economic

- C&D waste usually gets mixed up with other municipal solid waste also during the process of transfer or at the collection site.
- C&D waste is very difficult to segregate. Separate labor has to be employed for manual segregation or it has to be performed using earth moving machine, in addition the processing efficiency also get reduced due to the presence of C&D waste which is mostly inert.
- The huge mass and volume of C&D waste results in occupying a large volume oflandfills and dump-yards resulting in governing bodies to find alternate space and creation of more landfills, again leading to economic inefficiency in the system.

Figure 16 Mixing with municipal solid waste

Resource shortage - India is witnessing a boom in construction industry due to the urbanization which leadsto over exploitation of primary resource to match the demands. For instance, almost 100% in case of cement and bricks, 40-60% of steel, 85% of paint and 70% ofglass produced in India goes into the construction sector. The anticipated growth of the sector in the near future exerts added pressure on limited stocks of resources especially sand, soil, stone and limestone which have been identified as most critical resources. Therefore, use of secondary materials needs to be promoted to supplement the use of primary materials and recycled C&D waste is one of the best available option available as secondary raw material.

Secondary Raw Material

A secondary raw material can be raw material waste from another industry or an alternate building material available in nature that can be used in place of critical primary resources. The material could partially or completely be replaced in a product

5.2.4 C&D waste management Rules in India

The Ministry for Environment and Forests notified Construction & Demolition waste management rules in 2016 to regulate the handling of C&D waste being generated. According to the new rules, the various stakeholders involved in C&D waste management have been assigned a specific role to be played in the process. Salient features of Construction & Demolition Waste Management Rules, 2016 are covered in detail as separate chapters.

5.2.5 How to implement a proper C&D waste management system?

A cradle to grave approach has to be adopted for proper management of C&D waste according to the national standards (C&D Waste Management Rules, 2016) where a properly implemented system exists. The system should contain proper collection of segregated C&D waste from the polluter, proper transportation of waste, storage of waste occurs at designated transfer stations or collection points followed by proper processing of waste into recycled or reusable products that have market value and where minimal rejects are produced which get deposited in designated landfills. A properly implemented management system also needs to contain proper quantification and classification system for C&D waste at different stages of handling and a properly implemented monitoring system with a neat documentation process.

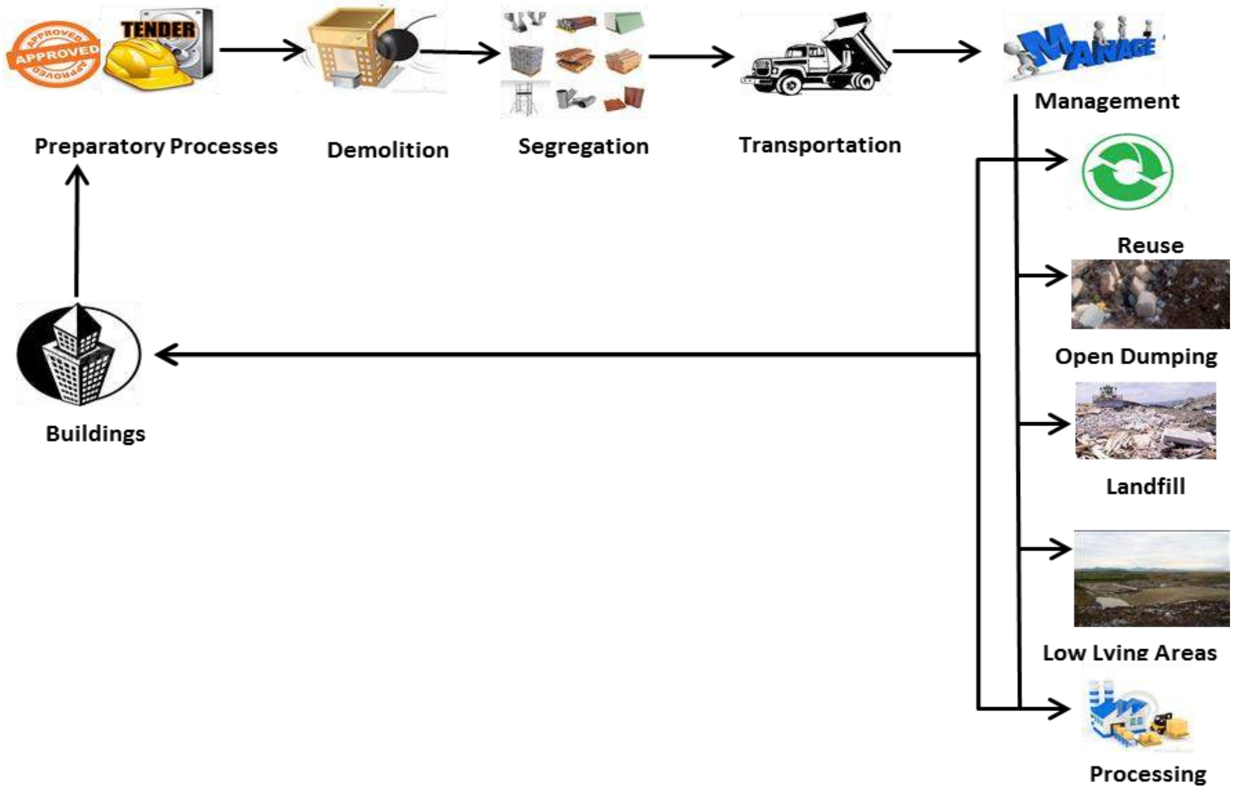


Figure 17 Schematic of current C&D Waste Management Processes in India

5.2.6 What can C&D waste be recycled / reused for?

C&D waste could be recycled and reused for multiple purposes depending on the composition and characteristics of the waste. The major applications of C&D waste which is practiced is listed below:

- **Granular Sub Base (GSB) –** Crushed C&D waste could be used as GSB layer for road constructions, regardless of the type of construction. The granular sub-base layer is formed by piling and compacting C&D aggregates of different sizes one over the other directly below the pavement surface. This acts as the load bearing and strengthening component of the pavement structure, in addition it provides drainage for the pavement structure and protects the structure from frost.
- **Recycled Concrete Aggregates (RCA)** – Concrete waste could be recycled to make aggregates of different standard sizes to replace natural aggregates in construction processes. According to Indian standards RCA could be used in any kind of structural and non-structural applications
- **Recycled Aggregates (RA)** – Crushed aggregates of standard size made from a mix of different C&D waste materials is termed as Recycled Aggregates. RA could be used for partial replacement of natural aggregates for construction of non-load bearing structures.

According to Indian standards, it could replace 20% in plain cement concrete and upto 30% replacement in road construction but only if backed up by proven laboratory test results. RA could also be used for construction of prefabricated molded structures like paver blocks, kerb stones, concrete pots and RCC Sculptures.

Table 19 C&D waste and its potential use

Material	Process	End Use
Plain Concrete	Crushed	Aggregate
Fresh Concrete	Washed to removecement & recover aggregate	Aggregate
Reinforced Concrete	Crushed & Steel bars removed Steel recycled	Crushed Concrete reused as aggregate
Brick	Cleaned & crushed	Aggregate & Filling material

- **Manufactured Sand (M-Sand)** – Manufactured sand is also produced by crushing of C&D waste, but is much finer materials which could replace natural sand in construction activities of non-load bearing structures. According to Indian standards only materials of sieve size between 0.075mm – 4.750mm is considered classified as M-sand and much finer particles are classified as dust particles, suitable only for daily cover for MSW.
- **Backfilling** – The most common reuse practice for C&D waste in India is as a backfilling material. The C&D was as such can be dumped in pits, trenches etc and compacted for backfilling or used to increase elevation or to make top layer of surface even for construction
- **Reusing** – Materials of reuse value like wood, unbroken bricks and ceramics are being used and could be used in secondary market for construction of temporary structures or if treated properly could be used for permanent structures as well
- **Other applications** – C&D waste is also applicable in other minor applications like carrier material in preparing fertilizers, filler material in roofing constructions, wall decorative chips etc.

Table 20 Demand for soil and sand and potential generation from C&D waste

Soil	Stone (Aggregates)
Demand for soil in brick making - **884** million tons/annum	Demand for stone as coarse aggregates in concrete – **1.1 billion** tons/annum Demand for stone as coarse aggregates inroads – **5 million** tons/annum
Soil waste generated from C&D waste - **213** million tons/annum	Aggregates generated from C&D waste - **254** million tons

5.2.7 Importance of Recycling of C&D Waste

a. Re-use and recycling 'wastes' has been promoted in all the waste rules.

b. With the increasing demand for built spaces and scarcity of land, a trend of re-development projects is expected. With increased urbanization and increased housing demands, there will be a shortage of aggregates to the extent of 55,000 million cu.m in housing sector, whereas the road sector requires an additional 750 million cu.m. of aggregates. This emphasizes the need of C & D waste management in India. The cost of construction materials is increasing enormously. In India, the cost of cement during 1995 was Rs. 125/kg and in 2012 the price increased to Rs. 330/bag. In case of bricks, the price was Rs. 0.66 per brick in 1995 and the present rate is Rs. 6 per brick in 2012. With the environmental hazards caused by excessive and illegal extraction of river sand, the mining of river sand was banned since April 1, 2012 (Ref. Report (May 2008) report on practices in C & D waste management in some Asian (includes India) by AIT Thailand).

c. Recycling of C & D waste is important as it helps to reduce the dependence on natural resources and eliminates adverse environmental impacts ex. mining which is energy intensive activity. Recycling of C & D wastes has the additional advantage of controlling the quantum of C & D waste destined for disposal at landfills besides reducing transportation costs.

d. When opportunities for reuse or salvage are exhausted, recycling is the next level. C & D waste materials that can be recycled include acoustical ceiling tiles, asphalt, asphalt shingles, carpets, concrete, drywall, fluorescent lights, land clearing debris (vegetation, stumpage, dirt), metals and metal alloys, structural steel, plastic film (sheeting, packaging), glass, wood etc.

e. The list of reuse and salvage materials include appliances, bathroom fixtures, bricks, blocks, masonry stone, structural steel, cabinets, carpeting, ceiling tiles, timber and timber based boards, door and window frames and shutters, flooring tiles, stone tiles/platforms, insulation, landscaping materials, lighting fixtures, metal framing including for partitions and ceiling, paneling, pipes, antique moldings, accessories and hardware of furniture, PVC water tanks, roofing sheets used for garages, outdoor areas, fabric of tensile structures etc.

f. From recyclability, building materials can be specified which will encourage recycling of building materials. The list of recycled content building materials include carpet, floor mats, flooring, cellulose insulation, ceiling tile, ceramic/porcelain tile, concrete masonry units, countertop, ductwork, fences/posts, fibre board, fiberglass, insulation, pilings, roofing, structural steel, wallboard, asphalt, concrete, drainage or backfill aggregate.

g. C & D and other inert waste may be utilized for making bricks, pavement blocks, construction materials such as aggregates etc. There are several plants of various capacities in India to make bricks, paver blocks, aggregates, etc. out of such waste material.

h. The Hon'ble Court's intervention on the controversy over sand mining in some states has focused the need to explore options for recycle, reuse and substitute naturally sourced building material (example sand) hence the spotlight on C & D waste management.

i. See **ANNEXURE I**: Potential uses of C & D wastes

5.3. C & D Waste Management Rules, 2016

5.3.1 Why separate rules for Construction and Demolition (C&D)

Government of India in the erstwhile Ministry of Environment and Forest published Municipal Solid Wastes (Management and Handling) rules, 2000 which was amended from time to time. However, the central government after reviewing the existing rules considered it necessary to make separate rules for management of construction and demolition waste due following reasons,

- To give thrust to segregation, recovery, reuse and recycle
- To emphasis roles and accountability of waste generators and other stakeholdersrelated to waste management

5.3.2 Definitions in the Rules

The rules specifically define terms relevant to implementation of its implementation. The important elements of the definitions are highlighted for better understanding of the reader.

Construction

Process of erecting or alternation of building or built facility or other structure, or building of infrastructure

Construction and Demolition Waste

Waste comprising of building materials, debris and rubble resulting from construction, remodeling, repair and demolition of any civil structure

De-construction

Planned selective demolition in which salvage, re-use and recycling of the demolished structure is maximized.

Demolition

Breaking down or tearing down building and other structures either manually or using mechanical force (by various equipment) or by implosion using explosives

Local Authority

Urban local authority such as municipal corporation, municipality, nagar palika, nagar Nigam, nagar panchayat, municipal council including notified area committee, gram panchayat

Waste Generator

Person or association of persons or institution, residential and commercial establishments including Indian Railway, Airport, Port and Harbour and Defence establishments who undertakes construction or demolition

5.3.3 The Rules promote C & D waste utilization

The Construction and Demolition (C & D) Waste Management Rules, 2016 promotes C & D waste utilization.

Under Rule (6) under Duties of Local Authority, the following sub-rules states:

i. sub-rule (9) 'shall device appropriate measures in consultation with expert institutions for management of construction and demolition waste generated including processing facility and for using the recycled products in the best possible manner';

ii. sub-rule (10) 'shall create a sustained system of information, education and communication (IEC) for construction and demolition waste through collaboration with expert institutions and civil societies and also disseminate through their own website';

iii. sub-rule (11) 'shall make provision for giving incentives for use of material made out of construction and demolition waste in the construction activity including in non-structural concrete, paving blocks, lower layers of road pavements, colony and rural roads.

Under Rule (7) mentions the 'Criteria for storage, processing or recycling facilities for construction and demolition (C & D) waste and application of construction and demolition waste and its products'.

Under Schedule I (Rule (7) (1)): 'Construction and demolition waste shall be utilized in sanitary landfill for municipal solid waste of the city or region as mentioned under Schedule I'.

a. The Rule (7) sub-rule (3) gives Application of materials made from construction and demolition waste in operation of sanitary landfill shall be as per the criteria given in Schedule II.

b. The Rule (9) sub-rule (4) mentions that the 'Procurement of materials made from construction and demolition waste shall be made mandatory to a certain percentage (say 10-20%) in municipal and Government contracts subject to strict quality control'.

c. Rule (11) under Duties of Bureau of Indian Standards (BIS) and Indian Roads Congress (IRC) 'The Bureau of Indian Standards and Indian Roads Congress shall be responsible for preparation of code of practices and standards for use of recycled materials and products of construction and demolition waste in respect of construction activities and the role of Indian Road Congress shall be specific to the standards and practices pertaining to construction of roads.

5.3.4 Type of C & D wastes products proposed under Rules

The C & D wastes products suggested under the Construction and Demolition (C & D) Waste Management Rules, 2016 are as follows:

i. Under Rule (6) under Duties of Local Authority: sub-rule (11) 'shall make provision for giving incentives for use of material made out of construction and demolition waste in the construction activity including in non-structural concrete, paving blocks, lower layers of road pavements, colony and rural roads.

ii. Under Schedule I (Rule (7) (1)): 'Construction and demolition waste shall be utilized in sanitary landfill for municipal solid waste of the city or region as mentioned under Schedule I'. The Rule (7) sub-rule (3) gives Application of materials made from construction and demolition waste in operation of sanitary landfill shall be as per the criteria given in Schedule II.

iii. The Rule (9) sub-rule (4) mentions that the ‘Procurement of materials made from construction and demolition waste shall be made mandatory to a certain percentage (say 10-20%) in municipal and Government contracts subject to strict quality control’.

5.3.5 Duties of stakeholders

Stakeholders mentioned and defined in the rules are,

- Waste Generator
- Service providers and their contractors
- Local authority

The rules define duties each of the above-mentioned stakeholders.

Duties of waste generator

- Waste generators as defined in the rules are responsible for,
  - Collection
  - Storage of C&D waste generated within their premises
- Ensure Solid waste does not get mixed with C&D waste
- **Deposit C&D waste to collection centers OR processing facilities** as designatedand authorized by local body.
- Ensure that there is **no littering or deposition of C&D waste** to prevent obstruction of traffic, public and the drains

1. Concrete **2. Soil** **3. Steel** **4. Wood and Plastics** **5. Bricks & Mortar**

Figure18 Segregate waste into 5 streams

- Waste generators who generate **more than 20 tons per day** OR **300 tons per project in a month** shall,
  - Submit **waste management plan and approval from local authority** beforestarting construction, demolition or remodeling work.
  - **Pay relevant charges** for collection transportation, processing and disposal asnotified by local authority.

Duties of service providers and their contractors

- Prepare **comprehensive C&D waste management plan** for area within their jurisdiction
- **Clean C&D waste** in the work area every day in a reasonable timeframe depending on the duration of work and quantity and type of waste generated. This should be done in consultation with local authority.
- **Tie up with authorized agencies** for cleaning of C&D waste if logistics support is not available.

Duties of local authority

- **Issue direction for management of C&D waste** as per the rules within their jurisdiction and seek detailed plan or undertaking as applicable from generator of C&D waste.
- **Chalk out stages, methodology, equipment required, material** involved in the activities required after Construction and Demolition.
- **Safely dispose C&D waste contaminated with hazardous, toxic or nuclear material**
- after consultation with concerned authority.
- **Make arrangement for collection of C&D waste** and ensure that clean-up is done at regular intervals.
- Get the collected C&D waste transported to appropriate sites for disposal or processing.
- **Give incentives to generator** for salvaging, processing and or recycling C&D waste preferably in-situ.
- **Examine and sanction waste management plan of generators** within one month or within date of submission and approval of building plan, whichever is earlier.
- **Establish C&D waste generation database** and update once a year.
- **Device appropriate measures for management of C&D waste and use of recycled products** in best possible manner.in consultation with expert institutions,
- **Create sustained system of IEC activities for C&D waste management** through collaboration with expert institutes and civil society organizations and also disseminate through their own website.
- **Give incentive for use of products made with recycled C&D waste** in construction activities

5.4. Inventorization of C&D waste in the DPA

5.4.1 Why to do Inventorization of C&D waste?

Inventorization of C&D waste is crucial for following purposes:

- Decision making on capacity and technology of C&D waste processing plant that should be installed.
- Decision making on products that can be made from C&D waste
- Decision making on amount of funds that need to allocated for management of C&D waste
- Decision making on management practices to be adopted for C&D waste

5.4.2 How to estimate the generation of C&D waste in the DPA

The first step towards management of Construction and Demolition (C&D) waste is to determine and quantify the amount of C&D waste generated. Waste quantification models which have been utilized all over the world and other models available from literature review are presented here for better understanding and implementation for quantifying C&D waste. However, the accurate estimation of C&D waste depends on the availability and accessibility of data.

Site visit method

This methodology requires investigators to visit the construction or demolition sites for a realistic survey. Measurements are conducted through weighing C&D waste directly on site where onsite interviews are conducted with professionals for fine tuning the estimated generation. Although this method is very practical and suitable for measuring waste produced from all of the waste generation activities, it not appropriates for estimating the C&D waste generation at a regional level because of the high requirement of time, labor and money.

Per-capita multiplier

Per-capita multiplier is one of the earliest methodologies developed from methodologies that were used to quantify municipal solid waste (MSW). Per-capita multiplier is an easy way to quantify C&D waste as this method is based on population statistics of the region. This type of estimation is less reliable as it often leads to more than 10 folds' variation in the quantity estimated.

Waste Generation rate model

Waste generation rate model is widely used by researchers around the world to estimate the quantity of waste generated in the city. In this method, the amount of construction and demolition activity happening in the sector has to be estimated and an appropriate activity specific waste generation rate has to be multiplied with the quantum of activity to get the total estimate. Statistical data such as number and the area of waste generation has to be collected for estimation in this model.

Estimation based on waste generation model

$$Q = \sum_{K=1}^{m} \sum_{j=1}^{l} \sum_{i=1} A_i * q_{jk} * p_k$$

Where,

Q is the total quantity of demolition waste generated in a region (in kg);

$\mathbf{A_i}$ refers to the total amount of demolition activity in the i^{th} part of the region;

l is the number of parts or zones in the region;

$\mathbf{q_{jk}}$ is the waste generation rate of j^{th} type of major material from K^{th} type of building;

m is the number of major materials

$\mathbf{p_k}$ refers to the proportion of the k^{th} type of building in the region; and

n is the number of different types of building in the region

Quantification of Construction and Demolition waste is regarded as a pre-requisite for successful implementation of C&D waste management in a city. The selection of most appropriate method is recommended based on the quantification objectives and region-specific conditions.

According to the Technology Information, Forecasting and Assessment Council's, or TIFAC's, thumb rule, a new construction generates 40-60 kg of C&D waste per sq m, then taking an average of 50 kg per sq m. The waste produced per sq m of demolition is 10 times that generated during construction and for building repair/renovation TIFAC estimated that it produces 40-50 kg per sq m of waste. Therefore, the estimates of waste generation can be calculated depending on the type of activity such as Construction, Demolition and renovation.

5.5. Collection, Transportation and Disposal of C&D waste

5.5.1 How to Collect and transport C&D waste?

Collection

Weighbridge

Weighbridge is a device in form of a platform used to weigh very heavy objects like trucks. The weight of trucks is mostly weighed on a loaded and unloaded situation in order to measure the load it carried

Existing Practices – C&D waste in most ULBs is not collected or transported in an orderly manner. The waste is either collected by a random transportation contractor and used for backfilling elsewhere or dumped on unfenced land which is mostly illegal. Some municipalities have designated landfills for disposal, where the polluter has to dump waste at his own arrangements which in most cases isnot practiced since it is either far away on outskirts of city or the designated area is not known to the polluter due to improper communication by the ULB. Among the ULBs which have a collection yard a few have a proper tracking system by means of weigh bridges.

Changes to be adopted - As per the national standards C&D waste need to be kept in the generator's compound and then transported to designated disposal site prescribed by the local governing body.

Transportation

The C&D waste need to be stored in a segregated manner and transported to the designated location on self-arrangements or through local governing bodies system, which ever exist in the ULB. Either way both the generator and the transporting body needs to maintain records of the quantum of waste transported to the dumping area. The local governing body could also provide fenced transfer stations as designated dumping units to facilitate easy transport of waste for the generator. The waste reaching the designated transfer stations of the ULB needs to be recorded and from transfer stations, the waste needs to be transported by the governing body to the dumping site or processing site.

C&D waste is transported from the site by trucks or tractors to disposal sites by paying a minimal fee to the transporters. These transporters can be private or empaneled with the ULB. The ULB transports the waste to the disposal site from these points or contracts with private contractors to do so. The transport of C&D waste needs to be in a covered truck (or any vehicle) to avoid dust, air pollution and spilling of debris on roads. Large scale waste quantum (more than 2 Tons) should be transported only by empaneled trucks which to be registered with the ULB and the registered trucks need to be available to the public to utilize. The trucks empaneled for transportation of generated waste can be enabled with GPS devices for tracking of waste flow from the collection points or demolishing site to the waste processing facilities. The waste needs to be quantified at disposal or processing site also by proper weighing of trucks.

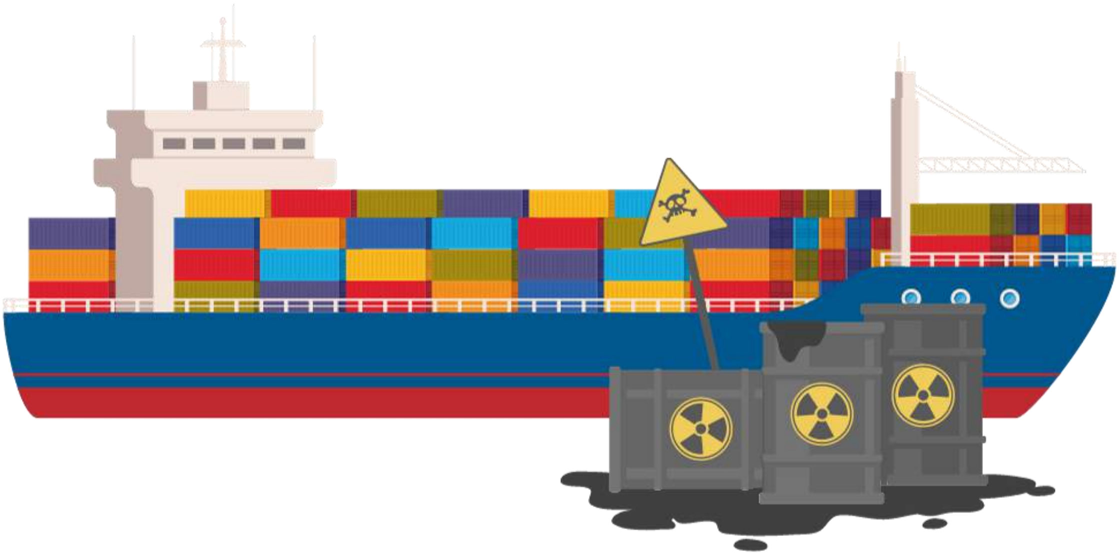
Disposal

Existing practices – C&D waste is mostly being disposed in on plain land, but it is also used as daily cover in MSW landfills. In many Municipalities it is also filled inside MSW landfill, in which case it occupies huge spaces and reduces capacity of the landfill.

Changes to be adopted – The C&D waste that comes out as a waste product after processing need to dumped into a separate sanitary landfill and should not be mixed with other MSW. The hazardous C&D waste need to be dumped in a hazardous waste landfill.

C&D waste should not be allowed to be dumped in the landfills before recovering useful materials from the waste stream.

Even for cities which do not have dedicated recycling facilities, the C&D waste debris should be disposed at designated dumping sites which provides an opportunity for recycling them in the future.



Chapter-6
Shipping Waste

6.1 Introduction of Shipping waste

6.1.1 What is shipping waste

Shipping waste means all types of waste, including sewage, and residues other than cargo residues, which are generated during the service of a ship, and fall under the scope of Annexes I, IV and V to MARPOL 73/78, and cargo associated waste, which is (not limited to): spillage during loading/ unloading, separation materials, fastening pallets, packing and casing materials, plywood, paper, cardboard, wires and steel bands (as defined in the Guidelines for the implementation of Annex V to MARPOL 73/78);

6.1.2 Objective of Manual

Target audience: Deputy Conservator Office and Marine Department, DPA

1. Creating awareness on Ocean pollution

The awareness shall be made amongst all stakeholders regarding the adverse impacts of oil spills and dumping of other wastes into the ocean. Below image in brief states the type of wastes that pollute oceans and adversely impacts Ocean ecosystems.

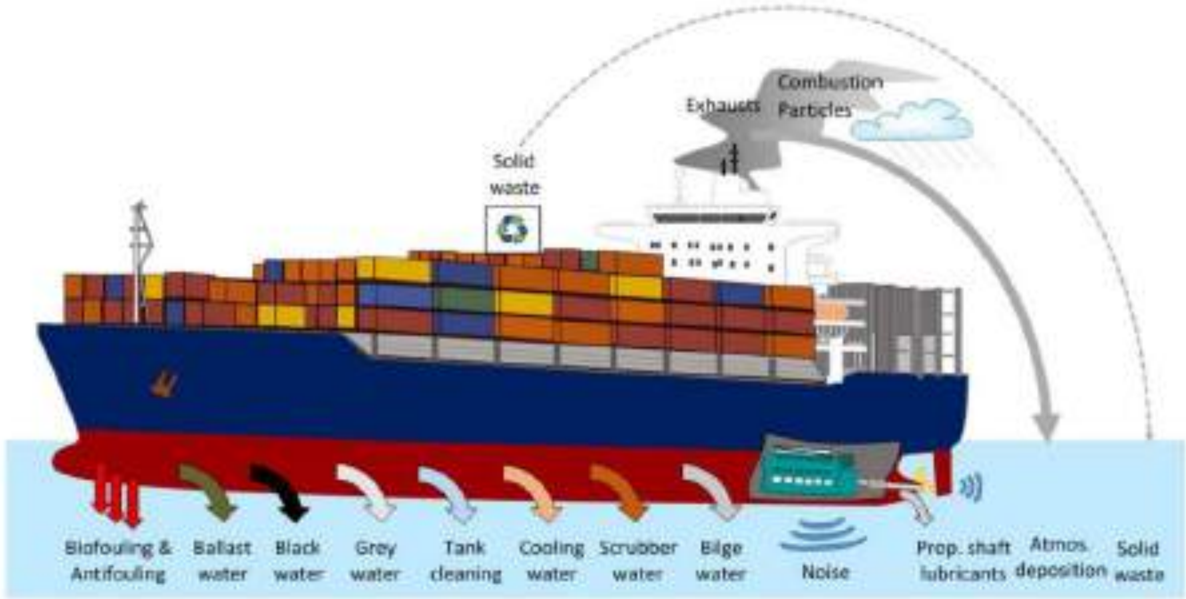


Figure 19 Effect of shipping waste on Ocean

6.2 Legal requirement

As per **Hazardous and Other Wastes (Management and Transboundary) Rules, 2016** DPA shall adhere to the provisions made for waste received from ships calling at the DPA ports as per MARPOL and Hazardous Waste Handling and Management Rules, 2016.

6.2.1 Maintaining records

The standard format for maintaining records of Hazardous and other wastes received at the ports from various ships as per Form 3

List of details required for filling up this format are:

- Name and address of the facility
- Date of issuance of Authorization from GPCB and its reference number
- Description of hazardous and other wastes handled (Generated or Received)

Record keeping format tabulated in Table 21 could be followed for systematic compilation of Waste generated and received from ships calling at the ports.

Table 21 Inventory of waste generated/received at Port

Waste reception date	Received from	Received at (Berth no.)	Waste category as per HWM rules	Waste category as per MARPOL	Total quantity (Metric Tons)	Method of Storage	Destined to
dd/mm/yy	Name of the ship generating waste	Give details of berth receiving the shipping waste	As specified under HWM rules	Whether waste falls under purview of Annex I, II, IV or V		Details of any on-site waste storage if applicable	Details of agency assigned for waste collection

6.2.2 Annual return

Annual return is to be submitted to Gujarat Pollution Control Board by 30th June every year for the preceding period April to March

List of information required for filling the annual return are:

- Name and address of the facility:
- GPCB Authorization No. and Date of issue:
- Name of the authorized person and full address with telephone, fax number and e-mail
- Total quantity of waste generated category wise to be maintained as per format indicated in Table 22
- Date wise description of management of hazardous and other wastes including products sent and to whom in case of recyclers or pre-processor or utilizer. The record keeping of the movement of waste from port to Waste Managing Agency (WMA) either for processing/reuse or disposal shall be facilitated by the record keeping format shown in Table 22

Quantity dispatched

1. To disposal facility
2. To recycler or co-processors or pre-processor
3. Others

based on frequency of collection of waste by the agency

Table 12 Details of waste collection by agency

Date	Type of waste	Total quantity (Metric Tons)	Details of Agency	Method of disposal
Date of waste collection by agency	Details of waste collected: Name of waste Category of waste	Quantity collected by agency	Name, address and contact details of agency collecting the waste	Mention if waste is Recycled or Reused or Reprocessed and used as raw material or Disposed if disposed; mention the method of disposal i.e Landfilled, incinerated etc.

Quantity in storage at the end of the year

Waste quantity if not collected by agencies due to any circumstances has to be placed in a designated storage area that is protected from sunlight, wind or rain and in an environmentally sound manner. The record keeping of wastes under storage could be done as per format tabulated below in Table 23.

Table 23 Format for waste under storage

Name and type of waste	Quantum of waste (per year)	Reason for non-disposal	Method of storage
		Give brief detail on the reason for non-arrangement of disposal of the stated waste	Mention whether stored in storage room or shed or any other provision ensuring environmentally sound conditions

6.3 Adequacy of Port Reception Facilities

Through its Annexes MARPOL states the requirement for a Port Reception Facility (PRF) to be adequate to meet the needs of ships normally visiting the port and cause not any undue delay.

In the Guidelines for ensuring the adequacy of port waste reception facilities (resolution MEPC.83(44)) "adequate" is described as: "To achieve adequacy the port should have regard to the operational needs of users and provide reception facilities for the types and quantities of wastes from ships normally visiting the port".

"Adequate facilities" are described as those which:

- Mariner's use;
- Fully meet the need of ships regularly using them;
- Do not provide mariners with a disincentive to use them; and
- Contribute to the improvement of the marine environment.

The provided PRF must meet the needs of the ships normally using the port and allow for the ultimate disposal of ship-generated wastes and residues to take place in an environmentally appropriate way.

According to the 2017 Guidelines for the implementation of MARPOL Annex V (resolution MEPC.295(71)) the methodology for determining the adequacy of a reception facility should be based on:

- The number and types of ship calling at the port,
- The waste management requirements of each type of ship
- As well as the size and location of a port.

When selecting the most appropriate type of reception facility for a particular port, attention should be given to alternative methods available:

- Mobile facilities, such as trucks, can enhance a cost-efficient way of collecting ships' wastes.
- Floating facilities, such as barges, might be considered more effective, in particular where access by road is not practicable.

Timely assessment of the need for updating the Port Waste Management Plan (PWMP) shall be done by following:

- Assessing the demand for expanding Port Reception facility, based on waste categories and its quantities being received and requested by users
- Ensure whether information regarding waste categories for which reception facilities like Name of contact person/contractors/fees to be charged on port web-site/ Swachh Sagar Portal or by any other means are readily available to visiting ships prior their arrival
- Address the complaints registered on IMO GISIS Web-site
- Ensuring that the reception facilities provided fully meet the need of ships visiting the ports
- Ensuring that a fee charged to avail the port reception facilities does not act as a dis-incentive to use the facilities
- Ensure whether categorization and separation of ship waste into hazardous and non-

hazardous waste in accordance with hazardous and other waste rules, 2016 is practiced.

- Ensuring whether disposal of hazardous and non-hazardous waste is in accordance with hazardous waste Rules 2016 and port procedures. Also ensure whether waste not defined under hazardous waste rules is disposed in accordance with relevant rules like Plastic Waste in accordance with Plastic Waste Management Rules, e-waste in accordance with E-waste Management Rules and likewise.

6.4 Segregation of wastes on the ship

Target audience: Staff handling waste

PRF and/or port authorities might promote or (financially) incentivize the onboard separation of wastes for its environmentally sound management. The captain of the ship could be educated for waste segregation of ship generated wastes on the ship itself to avoid undue delay.

Table 24 Components of waste

Waste components	
Non-recyclable plastics and plastics mixed with non-plastic garbage	Wood
Rags	Metal
Recyclable wastes	Plastics (including extruded polystyrene or other similar plastic material)
Cooking oil	E-wastes such as electronic cards, equipment, computers, printer cartridges, etc.
Glass	Garbage that might present a hazard to the ship or crew (e.g. Oily rags, light bulbs, acids, chemicals, batteries, etc.)
Aluminum cans	Damaged/unwanted fishing gear
Paper, cardboard, corrugated board	

6.4.1 Segregation of ship generated waste

Segregation of waste generated or received at the ports from the ships calling at ports shall be encouraged as segregation is the building block of waste management system. The wastes shall be segregated into below listed components.

Table 25 Components of waste to be segregated

Waste components	Waste items
Food wastes	E.g. Animal-derived products and by-products because of risk of animal diseases
Cooking oil	Animal-derived products and by-products because of risk of animal diseases
Plastics	All typed of day-to day plastics in use like cutlery, bottles etc.
Domestic waste, operational waste and recyclable or reusable material	Paper, cardboards etc.
Special items like medical waste, outdated pyrotechnics and fumigation remnants	Medicines, drugs etc.
Animal wastes, including used bedding from the transport of live animals (due to risk of disease) but excluding drainage from spaces containing living animals	Animal-derived wastes
Cargo residues	Packaging etc.
E-waste	Such as electronic cards, gadgets, equipment, computers, printer cartridges, etc.

Chapter-7
References

1. Annual Report of Deendayal Port Authority, 2021-22.
2. Solid Waste Management Rules, 2016, Ministry of Environment, Forest and Climate Change, April 2016.
3. A step-by-step Guidance for Bulk waste generators for Waste Management, Ministry of Housing and Urban Affairs, November 2017.
4. Municipal Solid Waste Management Manual – Part II, Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, Government of India, 2016.
5. Overview of Plastic Waste Management, CPCB, June 2013.
6. Plastic Waste Management Rules, 2016, Ministry of Environment, Forest and Climate Change, March 2016 and its Amendments.
7. Plastic Waste Management (Amendment) Rules, 2022 Ministry of Environment, Forest and Climate Change, February 2022.
8. Manual: Plastic Waste Management, July 2021, Department of Drinking Water and Sanitation, Ministry of Jal Shakti.
9. Toolkit: Plastic Waste Management, June 2021, Department of Drinking Water and Sanitation, Ministry of Jal Shakti.
10. Consolidated Guidelines for Segregation, Collection and Disposal of Plastic Waste, September 2017, Central Pollution Control Board.
11. E- Waste Management Rules, 2022.
12. Manual: E Waste Awareness for Government Official, 2016, Ministry of Electronics & Information Technology.
13. Battery Waste Management Rules, 2022, Ministry of Environment, Forest and Climate Change, August 2022.
14. Manual: E – Waste Training, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.
15. Guidelines on Implementation of E-Waste (Management) Rules, CPCB, 2016.
16. Bio-Medical Waste (Management and Handling) Rules and its Amendment thereof , Ministry of Environment, Forest and Climate Change, March 2016.
17. Guidelines for Management of Healthcare Waste as per Biomedical Waste Management Rules, 2016.
18. Toolkit: Bio-Medical Waste Management Rules, 2016.
19. Construction & Demolition Waste Rule, 2016, Ministry of Environment, Forest and Climate Change, March 2016.

20. Manual: Construction and Demolition Waste Management in India for Cities and Towns, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.
21. Guidelines on Environmental Management of Construction & Demolition (C&D) wastes, CPCB, March 2017.
22. Draft circular on Port Reception Facilities, Director General of Shipping, Government of India.
23. Consolidated Guidance for Port Reception Facility providers and users, international maritime organization (IMO).
24. Draft circular on Port Reception Facilities, Director General of Shipping, Government of India.
25. Consolidated Guidance for Port Reception Facility providers and users, international maritime organization (IMO).

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ANNEXURE F
Mitigation Measure

Subject: Compliance of mitigation measures suggested in EIA report of "Developing Integrated Facilities (Stage I) within the existing Kandla Port at Kandla"

Reference: Point No. XX of Environmental and CRZ Clearance granted by MoEF&CC, GoI vide letter F. No. 11-82/2011-IA-III dated 19/12/2016.

Brief Status of work

The compliance report submitted by the Concessionaire M/s KOTPL of project at Sr. no. 1 is attached as **Annexure-A** with EC compliance report. Wherein, the Concessionaire has mentioned "Point Noted" in compliance with the Point No. XX of EC&CRZ Clearance accorded vide MoEF&CC, GoI letter dated 19/12/2016.

S.No.	Particulars	Location	Quantification	Proposed Measures	Compliance
1.	Generation of Particulates	Applicable to the proposed projects and surrounding	Not quantified	Spraying of water	DPA has already installed continuous water sprinkling system in coal stack yard in DPA (40 ha. area) to prevent dust pollution. For the newly developed area of 34 hectares for coal storage, the work of installation of sprinkling system is also completed Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done. DPA has installed Mist Canon at the Port area to minimize the dust.
				Reducing speed of vehicles	DPA has issued Circular No. TF/SH/Circulars/2022/1341 dated 04/11/2022 considering the safety norms provided for smooth and continuous operation. Further, DPA has issued Circular No. TF/SH/Circulars/2019/1256 dated 10/10/2019 for the trucks, dumpers loaded for delivery of coal while moving from plot to weighbridge or weighbridge to plot and moving out to be covered by tarpaulin.
				Deploying vehicles with PUC certificate	DPA has issued Circular regarding Implementation of RFID enabled access control system (e-Drishti); wherein, PUC certificate has been made mandatory for vehicle registration in e-Drishti portal to obtain valid permit for entry in the port premises.

2	Generation Noise	Along proposed projects	Not quantified	Restricted operation in the night time Selection of machinery generating noise less than 72 db(A) Fitting on noise attenuation devices	DPA has issued Circular No. TF/SH/Circulars/2022/1341 dated 04/11/2022 considering the safety norms provided for smooth and continuous operation. For monitoring of environmental parameters, DPA has been appointing NABL Accredited laboratory and reports are being submitted from time to time to the GPCB, IRO, MoEF&CC, GoI, Gandhinagar. Recently, DPA appointed GEMI, Gandhinagar for regular monitoring of environmental parameters vide Work Order dated 15/02/2023. The work is in progress and the latest Environmental Monitoring report submitted by GEMI is enclosed with the EC compliance. Further, routine maintenance is being carried out to keep check on the efficiency and noise.
Soil & Geology					
3	Soil erosion	Applicable to the proposed projects	Not quantified; initiates a chain of impacts	Water bars; stabilization of slopes Controlled discharge of water Conducting construction activities in non-monsoon season Oil spill prevention measures	Topography at the site location is generally flat with average ground level of about 6.5 m CD with marshy topsoil. Kindly refer Section 3.4.1 Topography of the EIA report. Point noted The area falls under arid/semi-arid region, thus the rainfall is very scanty. DPA has Oil Spill Contingency Plan in place. Copy of the same has already been communicated with the earlier EC compliance report submitted.
Hydrology					
4	Surface water contamination	At the proposed projects Soil erosion prone area	Not quantified	Soil erosion control measures	For mitigating soil erosion, DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed. DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005 Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for “Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-I)” vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. Copy of the final report

	Spillage and sanitary wastes			Waste management and spill control	submitted by GUIDE, Bhuj is enclosed with the EC compliance report. Further DPA has accorded the work of "Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The same is in process For waste management, companies authorized by State Pollution Control Board (SPCB) have been awarded the work of collection, transporting and disposal of solid waste by the DPA. DPA has entered into 'Selling Agency' agreement with M/s. MSTC (Govt. of India Enterprise), Vadodara on 04/01/2022 for collection, transporting and disposal of scrap, surplus items, unserviceable equipment etc. Further, DPA has assigned M/s Gujarat Environment Management Institute (GEMI) vide letter EG/WK/4751/Waste Management-1/217 dated 24/01/2023 for "Preparation of Plan for Management of Plastic Waste, Solid Waste, C&D Waste, E-waste, Hazardous Waste including Bio-medical Waste and Non-hazardous waste in the Deendayal Port Authority Area" DPA has Oil Spill Contingency Plan in place. Copy of the same has already been communicated with the last compliance report submitted.
5	Ground water contamination	Not expected			
Land Use and Aesthetics					
6	Land use and Aesthetics	At project site At campsites At other utilities like scraper stations	Not quantifiable	Contouring of the affected areas Cleaning the stretch immediately after the construction activities are over	Topography at the site location is generally flat with average ground level of about 6.5 m CD with marshy topsoil. Kindly refer Section 3.4.1 Topography of the EIA report. DPA has included clause in tender/ Concession agreement for the contractor to undertake Clearance of site on completion and environmental protection measures. Copy of the relevant page of the tender has already been communicated with the last compliance report submitted.

				Restoration and re-vegetation to the best possible extent	DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. Copy of the final report submitted by GUIDE, Bhuj is enclosed with the EC compliance report. Further DPA has accorded the work of "Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The same is in process DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005.
Biological Environment: Flora and Vegetation					
7	Due to dusting on floral cover	At project site & approach road	Limited	Sprinkling of water for dust suppression.	– DPA has installed Mist Canon at the Port area to minimize the dust. – DPA has already installed continuous water sprinkling system in coal stack yard in DPA (40 ha. area) for to prevent dust pollution. Further, to control dust pollution in other area, regular sprinkling through tankers on roads and other staking yards is being done.
8	Removal of vegetation	At project site	Limited	Restoration and re-vegetation and plantation;	DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The copy of the final report submitted by GUIDE, Bhuj is attached with the EC compliance

					report. Further DPA has accorded the work of "Green belt development in DPA and its surrounding area (Phase II) to Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The same is in process
				Compensatory vegetation	DPA has undertaken Mangrove Plantation in an area of 1600 Hectares since the year 2005 The copy of the details has already been communicated with the earlier compliance reports submitted.
9	Due to Piling activity	At project site	Limited	Piling should be done in closed vessels to minimize the impact.	DPA has included clause in tender/ Concession agreement for the contractor to undertake piling installation in accordance with IS 2911. Copy of the relevant page of the tender has already been submitted with the last compliance report.
10	Due to dredging	At project site in Sea	Not quantified	Silt curtain should be used to minimize the impact.	The possibility of providing silt curtains to minimize the impacts while dredging activities in a study for "Comprehensive study for the Deepening of Navigational channel to increase the draught of Navigational channel at Deendayal Port Trust including Capital & Maintenance dredging requirements and Preparation of Technical & Commercial Feasibility Report" has been awarded to IIT, Madras.
11	Oil spillage & waste disposal from ships	Sea & creeks	Unlimited	Oily wastes and sewage should not be discharged directly; MARPOL norms should be followed.	DPA issued Grant of License/Permission to carry out the work of collection and disposal of "Hazardous Waste/Sludge/ Waste Oil" from Vessels calling at Deendayal Port" through DPA contractors. Further, it is to state that, all ships are required to follow DG Shipping circulars in line with MARPOL norm regarding the reception facilities at Swachch Sagar portal.
12	Fishes & Fishery	In project area	Limited	No legal fishery is in study area, major fish landing site is far from project site.	Since Kandla Port is one of the major port in India and major portion of the study area is occupied by the Kandla port, and other industrial activities, fishing activities are very limited in the study area. Kindly refer Section 3.9.4 Fisheries of the EIA Report.
Fauna and Wildlife					
13	Loss of wildlife	No wildlife habitation in proximity	Not applicable	Strictly prohibiting hunting and similar activities	It is a custom bonded area, therefore, no hunting or similar activities are permitted in the port area. Moreover, In the study area of the KPT no National park, wildlife sanctuary or biosphere reserve is present. Kindly refer Section 3.5.5.4 Occurrence of National Park/ Sanctuary/ Biosphere Reserve etc. of the EIA report.
				Restricting the speed of	DPA has issued Circular No. TF/SH/Circulars/2022/1341 dated

				movement of vehicles Keeping "trench plugs" at strategic locations Shifting the nests, wherever possible	04/11/2022 considering the safety norms provided for smooth and continuous operation. Point noted There is no considerable habitat of fauna in vicinity of the project site. Kindly refer 3rd paragraph of Section 5.3.1 Noise Generation During Construction Phase of EIA report.
Socio-Economic and Cultural Environmental					
14	Human habitations affected	No habitation falling within the project site	Not quantified, but critical locations are identified	Villagers in the proximity will kept informed on the project activities	Deendayal Port Authority had already given advertisement regarding grant of Environmental & CRZ Clearance of the project in two newspapers, i.e., in KUTCHMITRA (Gujarati) & in The Indian Express (Ahmedabad Edition) (English) dated 20/12/2016. Further, DPA forwarded the copies to the Regional Office, MoEF&CC, GoI, Gandhinagar vide letter dated 22/12/2016.
15	Economic implications	Along the project site	Not quantified. The implications with regard to loss of seasonal crops and plantations are identified	Compensation to the affected people Employment, wherever possible, to the unskilled local people	The law of land will be followed by the BOT operator. Further, the commitments made during the Public Hearing are being complied with letter & spirit. In this regard, the details of CSR Activities implemented as well as proposed are enclosed with EC compliance report.
16	Agriculture lands	At project site	No agriculture land involved	Restoration of the land; Management of topsoil	No agriculture land is involved. For topsoil management, DPA entrusted work of green belt development in and around the Port area to the Forest Department, Gujarat at Rs. 352 lakhs (Area 32 hectares) and the work is already completed. Further, DPA has appointed the Gujarat Institute of Desert Ecology (GUIDE) for "Green belt development in Deendayal Port Authority and its Surrounding Areas, Charcoal site' (Phase-l)" vide Work Order No.EG/WK/4757/Part [Greenbelt GUIDE, dated 31st May 2022. The copy of the final report submitted by GUIDE, Bhuj is submitted along with the compliance report submitted on 12/09/2023. Further DPA has accorded the work of "Green belt development in DPA and its surrounding area (Phase II) to

					Gujarat Institute of Desert Ecology (GUIDE), Bhuj for the plantation of 10000 saplings of suitable species vide work order dated 23/06/2023. The same is in process
17	Infrastructure	Near human habitations Road and railway crossings	Not quantified	Rehabilitation of the affected infrastructure components; Leaving behind the infrastructure facilities like approach roads and facilities at the campsites for the local inhabitants	N/A
18	Social conflicts	Surrounding the proposed project.	Not quantifiable	Keeping good relationship with the local people; Keeping them informed on the project and project development.	The commitments made during the Public Hearing are being complied with letter & spirit. In this regard, the details of CSR Activities implemented as well as proposed are enclosed herewith with the EC&CRZ compliance report. Deendayal Port Authority had already given advertisement regarding grant of Environmental & CRZ Clearance of the project in two newspapers, i.e., in KUTCHMITRA (Gujarati) & in The Indian Express (Ahmedabad Edition) (English) dated 20/12/2016. Further, DPA forwarded the copies to the Regional Office, MoEF&CC, GoI, Gandhinagar vide letter dated 22/12/2016. Moreover, Public Hearing was conducted on 18.12.2013 to inform about the project.
19	Political conflicts	-	Not quantifiable	Keeping the key players informed on the pros and cons of the project.	The key players shall be informed on the pros and cons of the project.
20	Historic and archaeological importance	Surrounding the 15.0 Km. radius from the proposed project.	No structure on the surface possibilities are there of sub-surface structure	Inform the concerned authority in case of coming across any structure of archaeological significance.	Point noted

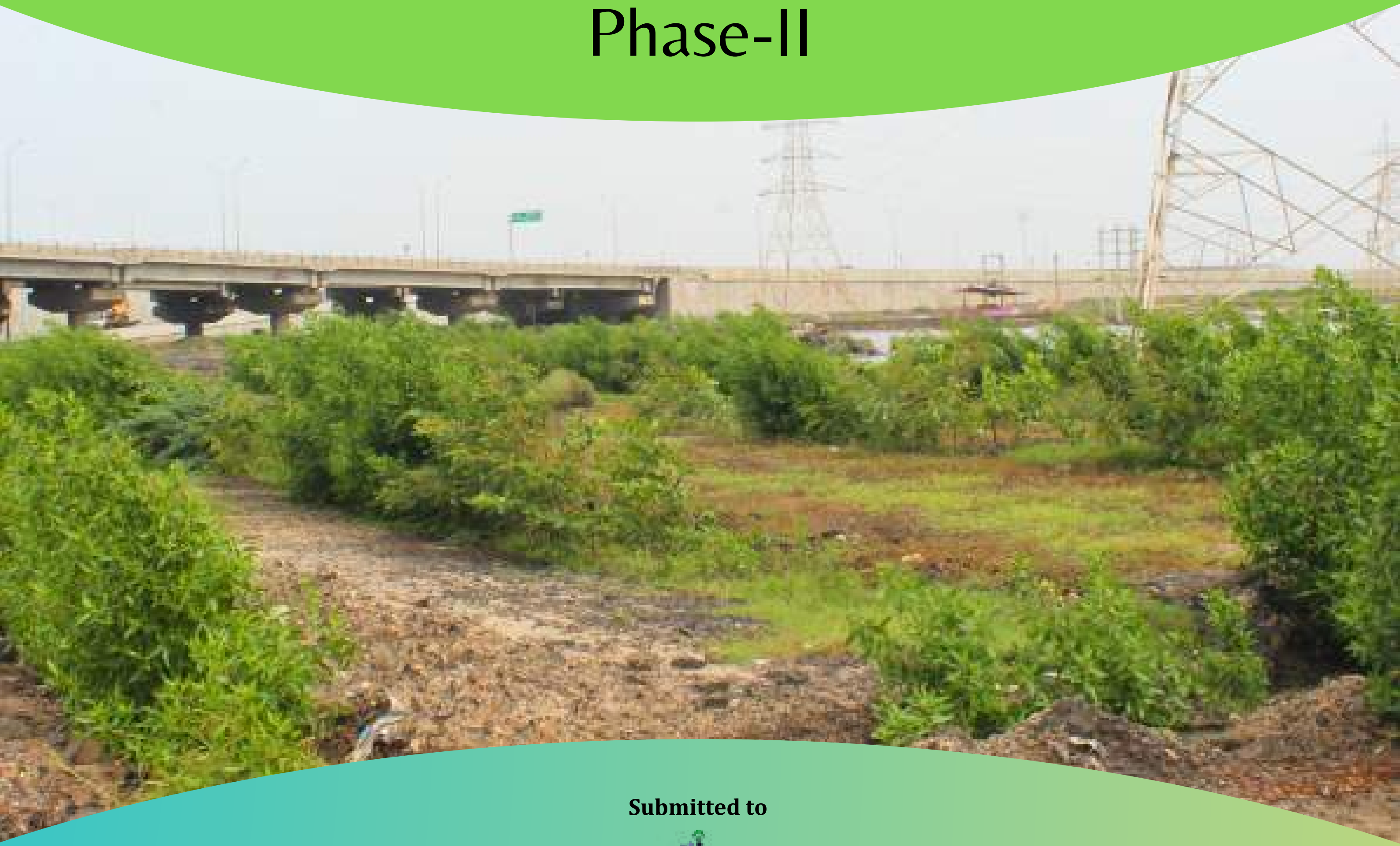
ANNEXURE G
Final Report of Green Belt Development II

Final Report

on

Greenbelt Development in Deendayal Port Authority and its surrounding areas, Kandla Port

Phase-II



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Final Report

on

Greenbelt Development in Deendayal Port Authority and its surrounding areas (Phase-II) Kandla Port

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Content

Introduction

The Greenbelt cover/forest has been the utmost necessity for the survival of human as well as for the wildlife with the current scenario of human explosion, industrial development and climate change. The greenbelt cover provides ecological services such as purifying air, reduce soil erosion, improving ground water table, reduce salinity. In addition, it also caters the services such as food, fodder and medicine, etc. along with playing a very vital role in providing habitats for wildlife and maintaining ecological balance, climate regulation, biodiversity conservation and maintaining pleasant micro climate of the region. Thus, green belt offers a number of benefits for population. Moreover, vegetation absorbs various pollutants from the environment and thus helps in effective pollution control. However, due to the various types and extent of economic development like industrialization, mining, infrastructural development, etc. has exerted pressure in reducing and fragmenting natural vegetation cover day-by day all over the world.

The infrastructural and industrial development leads to influence the life of all the living organisms in two directions: either upwards or downwards. In the upward mode, human being gets opportunities for luxuriant life with easy accessibility to the resources while in downward, the quality of ecosystem services gets affected. Most of the industrial and infra-structural developmental activities generate pollution of one or other types with varying magnitudes, which makes susceptible to all the organisms, nevertheless, the pre-eminence of resistance of each of the organisms helps themselves to overcome the hazards caused by such pollutants.

Therefore, the general concept of green belt has evolved in recent years to develop vegetations or green spaces alongside of industries, mines, thermal power station, roadsides, and other development units is an effective mechanism to rejuvenate the environment through vital vegetation cover that safeguard the health of human and other living organisms. Green belts in and around urban and industrial areas are important to the ecological health of any given region. Greenbelt is the plantation of trees along the industrial units, mines, roadside for reducing the pollution originating from these operations (Flemming, 1967; Hanson and Throne, 1970; Warren, 1973; Ganguly, 1976). Greenbelt has been developed in view of the following factors; (i) physical characteristics of the green belt eg. Distance from the source, width, and height and leaf surface area density (ii) aerodynamic properties eg. Wind speed through greenbelt and effective height of the incident air stream (iii) deposition velocity of the pollutant and (iv) atmospheric stability conditions (CPCB, 2000).

As per the National Forest Policy (NFP-1988), it is necessary to encourage the planting of trees alongside of roads, railway lines, rivers and streams and canals, and on other unutilized lands under state/corporate, institutional or private ownership. NFP give emphasis on the green belt developments. It says – Green belts should be raised in urban/industrial areas as well as in arid tracts. Such a programme will help to check erosion and desertification as well as improve the microclimate.

Green infrastructure serves to provide on ecological framework for social, economic and environmental health of the surroundings. The main components of this approach include storm water management, climate adaptation, less heat stress, more biodiversity, food production, better air quality, sustainable energy production, clean water and healthy soils, as well as the more anthropocentric functions such as increased quality of life through recreation and providing shade and shelter in and around infrastructure and industrial areas. Green infrastructure is thought to be effective in such scenarios, where green plants from a surface capable of absorbing air pollutants and act as a sink for pollutants. Leaves with their vast leaf area in the tree canopy, absorbs pollutants on their surface. Thus, effectively reduce their concentrations in the ambient air. Often the absorbed pollutants are incorporated in metallic streams and thus the air is purified. Plants grown in such a way as to function as pollutant sinks are collectively referred to as green infrastructure or green belts. Apart from functioning as a pollutant sink, green belts would also provide other benefits like aesthetic improvement and providing possible habitats for birds and animals along with maintain the soil moisture regime with the soil microorganisms and improve the Soil quality and ground water recharge. The greenbelts have helps in improving the ecology, maintenance of biodiversity, mitigation of dust pollution and fugitive emission, control of noise pollution, provide fresh air, increasing aesthetic values of an area and overall improvement of the landscape.

Rationale

Deendayal Port in Kachchh District of Gujarat State (formerly Kandla Port Trust), operated by Deendayal Port Authority (DPA), is a gateway Port to the hinterland in the western and northern states of India. It is one of the 11 major Ports of India situated at 22°59'39.77'' N latitude and; 70°13'20.14'' E longitude on Kandla creek at Gulf of Kachchh. The inclusion of Karachi Port in Pakistan after India's partition and heavy traffic congestion at the then Bombay Port gave impetus for promoting Deendayal Port during the year 1950s. In 1955, Deendayal Port acquired the status of a major Port in India. Because of its proximity to the Gulf countries, large quantities of crude petroleum and other assorted cargo are imported through Deendayal Port. The Port presently has 14 jetties, six oil terminals, and several allied facilities for handling dry and liquid cargo. Regular expansion/developmental activities such as the addition of jetties, allied Special Economic Zones (SEZ hereafter), industrial parks and ship bunkering facilities are underway to cope with the increasing cargo handling demands. Shri Mansukh Mandaviya, Minister of State for Ports, Shipping and Waterways (I/C) appreciated the efforts taken by Deendayal Port and added that it is indeed the major achievements in the challenging (COVID) times and it is significant indication that economy is bouncing back to achieve pre-COVID times.

Major commodities handled by the Deendayal Port are Crude Oil, Petroleum product, Coal, Salt, Edible Oil, Fertilizer, Sugar, Timber, Soya bean, Wheat. This major achievement can be attributed to the user-friendly approach of port with the Shipping fraternity / stakeholders and constant consultations with them to improve ease of doing business. An assortment of liquid and dry cargo is being handled at Deendayal Port. The dry cargo includes fertilizers, iron crap, steel, food grain, metal products, ores, cement, coal, machinery, sugar, wooden logs, salt extractions, etc. The liquid cargo includes edible oil, crude oil and other petroleum products. DPA created a new record by handling 127.10 million metric tons of cargo during FY 2021-22 compared to 117.566 MMT in FY 2020-21, with a growth of 8.11%. Incidentally, DPA is the only major Indian Port to handle more than 127 MMT cargo throughput, and it has also registered as the highest cargo throughput in its history. The Port has handled 3151 vessels during FY 2021-22 compared to 3095 vessels in FY 2019-20. While the Port has flagged off several projects related to infrastructure creation, DPA has successfully awarded the work of augmentation of Liquid cargo handling capacity by revamping the existing pipeline network at the oil jetty area in September 2021. Deendayal Port is a natural harbour located on the eastern bank of North-South trending Kandla creek at an aerial distance of 145 km from the Gulf's mouth.

Being located at the inner end of the Gulf of Kachchh (GoK), Deendayal Port has a marine ecosystem with a vast expanse of mangroves, creek systems and allied biota. The Port location is marked by a network of major and minor mangrove-lined creek systems. The coastal belt in and around the Port has an irregular and dissected configuration.

There are no perennial or seasonal rivers in Gandhidham taluka where the part is located. Total rainy days during the monsoon season is limited to only 15-20 days and used to be erratic. Freshwater input into the near coastal waters is relatively meagre and appears to have less influence on the ambient coastal water quality except during monsoon months, during which freshwater through flash floods get discharged in the near coastal waters. The annual average humidity is 60%, which increases to 80% during the southwest monsoon (June to September) and decreases to 50% during the months of November and December. The drought phenomenon is common with two drought years in a cycle of 5 years.

The coastal belt in and around the Kandla region is characterized by a network of creek systems and covered by sparse halophytic vegetation, creek water and salt-encrusted land mass, which forms the major land forms. The surrounding environment in a radius of 10 km from the Port is mostly built-up areas consisting of salt works, human habitations and Port related structures on the west and north, creek system, mangrove formations on the east and south. The Deendayal Port and its surroundings have mangroves and creek systems as major ecological entities.

DPA is committed towards environment protection since its establishment and has taken many initiatives towards increasing green cover and greenbelt development in various areas under DPA through intensive plantation activities and developing greenbelt around its established port and jetty areas and human habitations.

In order to enhance and strengthen Greenbelt Development, the DPA has approached GUIDE to develop the greenbelt area within the port area in phase wise manner and raised 5000 plants at a suitable site during the first phase (2022-23). In continuation, 10,000 plants have been finalized during the 2nd phase 2023-24 and 800 plants as a deficient of first phase.

GUIDE team has visited the proposed Greenbelt development site at Kandla port with the officials from Kandla Port as part of selection of suitable and available locations for green belt development. Based on the observation of the project site and its landscape, environment and ecology of the area, suitable plant species for such area was worked out in order to improve the local environment and for the Greenbelt development at the port area.

Project Site

Based on observation made by the GUIDE Team and Officials from Deendayal Port Authority, a site at RoB and another site opposite to 15-16th Birth along the wall have been selected on the peripheral boundary of two sites.

Fig. 1 Map of Plantation Area RoB

The area proposed for green development of Deendayal Port is barren land without any vegetation. The soil of the area is black muddy and is high saline soil and with saline ground water. The area is very dry and hot during the summer. The highest temperature in Kandla is used to be recorded in this area.

Fig. 2 Map of Plantation Area 15-16 Birth Opp: Wall

Fig. 3 Map of Plantation Area 15-16 Birth Opp: Wall

Scope of Works

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

1. To make an inventory of suitable sites for greenbelt development in and around the Deendayal Port at Kandla.
2. To carryout Soil and Moisture Conservation (SMC) of the selected sites.
3. Identification of suitable species of plants as per site scenario for the greenbelt plantation.
4. Adopting plantation technique and soil/manure amendments.
5. Regular monitoring (survival and growth) of the plantation.
6. Suggest measures for management and improvement of the greenbelt.

Approach and Methodology for Greenbelt Development

Following steps have been adopted for greenbelt development:

- Removal of exotic/unwanted plants plant species from the entire area demarcated for green belt development: The entire selected site has been cleared by removing unwanted weeds and material such as stones, plastics etc.by JCB and also with the help of labor forces.
- Landscaping of the area and land preparation Trench line of 2.5x 2.5 ft. have been dig out through JCB at RoB site and another site opposite to 15-16th Birth along the wall.
- Soil and moisture conservation work since the port area is highly saline, SMC work was very much essential for better survival of the plants. Agriculture fertile soil have been added in appropriate quantity.
- Identification of native species of plants for plantation in greenbelt as per the site suitability the site was very challenging for greenbelt development since the water and soil is highly saline with the extreme climatic condition, the selection of plant species for plantation has been made very carefully. 40 % of plants have been selected as native species for plantation where as 60% species of *Conocarpus* depends on high salinity level of the soil of the area.

- Procurement of sapling of identified species or Nursery management or seeding of tree/shrub species all the saplings were procured where of 3-4 ft. in height from reliable nursery. All saplings were of tree species.

- Installation of drip irrigation facilities was not feasible therefore activity was planned preferably through tankers. The watering of the plantation has been scheduled as per the seasons which is given in table. Regular watering as per the scheduled have been provided by the water tanker under the supervision of team expert

- Use of Manure, preferably organic fertilizer for enhancing soil fertility best quality organic manure have been provided to the saplings for better growth and survival. Weed management and trench repairing have been carried out periodically also as and when it required.

- Regular monitoring and management of the saplings by a qualified team from GUIDE the selected. The regular visit to the site has been made for monitoring and clearing the road for water tanker for irrigation. Gap fillings was also made during the period.

Plantation Techniques:

- Site development for a plantation includes clearance for weeds and it involves, bush cutting, soil and moisture conservation works and marking of pits for planting of saplings etc.

- After clearing the land sites for digging of pits, plantation have been marked on ground using a measuring tape to ensure the desired spacing.

- Pits of the size 45 cm x 45 cm and 45 cm depth have been dug for tree plantation. Pits have been deep enough to ensure that the roots of the plants do not curl up once the planting material is placed in it.

- Since the soil is highly saline, a fertile soil around 10 dumpers have been added for better survival of plants

- Organic manure has been added for better growth and survival.

- The pit has been filled a little above the ground level so that after the earth settles the upper surface of the pit is level to the ground thus avoiding any water logging.

- The plantation has been carried out in two phases

- Around 4000 saplings have been planted during the first phase at available plantation area at RoB site.
- Around 4500 saplings have been planted during the first phase at available plantation area at opposite 15-16th Birth along the wall.
- The remaining 2500 saplings have been planted at opposite 15-16th Birth along the wall. Thus, a total of 11000 plantations have been completed at the end of the project.
- Along with the above, gap filling of 2500 plants were carried out in both the sites, thus covering a total of 13,500 plants have been planted to achieve the target of 11,000 plants.
- The assessment on survival of plants have been carried out during the 2nd week of August 2024 which shows the deficient of around 1000 plants hence the gap filling of 1200 plants have been made during 3rd to 7th September 2024.
- The verification of plantation has been made with the officials of Deendayal Port Authority on 22nd October 2024 and it has been verified and confirmed that 90% survival of plants for the plantation carried out during the 2nd Phase under the project.

Selection of Plant Species for Plantation:

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

Number of Sapling:

Approximate numbers of saplings to be required for the greenbelt are as follows;
Total plantations of 11,000 saplings were planted at RoB & 15-16 Birth (Opposite wall both sides) along with additional gap filling in the areas.

Management and Monitoring of Greenbelt:

The plantation within the identified site have been managed and monitored for a minimum period of one year from June 2023 to September 2024. The management of plantation includes appropriate irrigation of the plantation in regular intervals, during summer and winter periods along with dry spells during the monsoon.

The plants are growing very well and reached more than 4-6 ft. height. The survival of plants has been noted very high as 90% during September 2024. Watering have been made through tanker service at given schedule during the different seasons. (Table. 1)



Table-1 Time Schedule for Watering

Sr. No.	Month & Year	Number of Time
1	October 2023	7 times/ month
2	November 2023	7 times/ month
3	December 2023	7 times/ month
4	January 2024	7 times/ month
5	February 2024	7 times/ month
6	March 2024	9 times/ month
7	April 2024	10 times/ month
8	May 2024	10 times/ month
9	June 2024	8 times/ month
10	July 2024	8 times/ month
11	August 2024	3 times/ month
12	September 2024	5 times/ month

Annexure I
List of Plants for Plantation at site for Greenbelt Development
Site: Road Over Bridge

Sr. No.	Scientific Name	Local Name	No. of Plants
1	*Conocarpus*	Conocarpus	2500
2	*Peltophorum pterocarpum*	Peltofoum	200
3	*Millettia pinnata*	Karanj	100
4	*Delonix regia*	Gulmahor	200
5	*Alstromia schollaris*	Saptparni	100
6	*Terminalia catapa*	Badam	100
7	*Plumaria obtusa*	Chmapo	100
8	*Ceaslpinia pulcherima*	Galtoro	100
9	*Bauhinia racemosa*	Kachnar	200
10	*Tabubia rosea*	tabubia	100
11	*Terminalia arjuna*	Arjun	100
12	*Cassia fistula*	Garmalo	200
	Gap Fillings		2050

Site: Opposite 15-16th Berth

Sr. No.	Scientific Name	Local Name	No. of Plants
1	*Conocarpus*	Conocarpus	4000
2	*Peltophorum pterocarpum*	Peltofoum	450
3	*Millettia pinnata*	Karanj	400
4	*Delonix regia*	Gulmahor	400
5	*Mimusops elengi*	Borssalii	300
6	*Ceaslpinia pulcherima*	Galtoro	450
7	*Tabubia rosea*	tabubia	400
8	*Cassia fistula*	Garmalo	300
9	*Bauhinia racemosa*	Kachnar	300
	Gap fillings		1650

Fig. 4 Digging Out Trench for Plantation

Fig. 5 Transportation of Plants to Site

Fig. 6 Fertile Soil for Better Survival of Plants

Fig. 7 Soil Filling in Plantation Pits

Fig. 8 Organic Manure for Better Growth and Survival

Fig. 9 Regular Watering of the Plants by Tanker

Gap Filling (September 2024)

Current Status of plantation at RoB site

Current Status of plantation opp: 15-16 Berth

ANNEXURE H
Form V

DEENDAYAL PORT AUTHORITY
(Erstwhile: DEENDAYAL PORT TRUST)

दीनदयाल पत्तन प्राधिकरण
DEENDAYAL PORT AUTHORITY

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

www.deendayalport.gov.in

EG/WK/4751 (CCA Renewal)/ 92

Date: 19/07/2024

To,
The Member Secretary
Gujarat Pollution Control Board
Paryavaran Bhavan,
Sector 10A, Gandhinagar - 382010

Sub: Submission of Environmental statement in format form V for the financial year 2022-23 reg. (Detailed Consent Order issued by GPCB vide letter no. GPCB/CCA-Kutch-812/(5)/ID - 28494/581914 dated 22/01/2021 – Consent no. AWH – 110594 & CCA amendment Order – WH-130995).

Ref.: 1) KPT letter no. MR/GN/1527(Part I)/535 dated 16/6/2012
2) KPT letter no. MR/GN/1527(Part I)/2011 dated 20/5/2013
3) KPT letter no. MR/GN/1527(Part I)/337 dated 17/05/2014
4) KPT letter no. MR/GN/1527/ (Part I)/dated 27/04/2015
5) KPT letter no. EG/WK/EMC/CCA (Part II)/218 dated 27/6/2016
6) KPT letter no. EG/WK/EMC/CCA (Part II)/214 dated 19/6/2017
7) DPT letter no. EG/WK/EMC/CCA (Part II)/294 dated 13/6/2018
8) DPT letter no. EG/WK/EMC/CCA (Part II) dated 27/5/2019
9) DPT letter no. EG/WK/4751 (CCA Renewal) dated 22/5/2020
10) DPT letter no. EG/WK/4751 (CCA Renewal)/14 dated (30)04/(4)5/2021
11) DPA letter no. EG/WK/4751 (CCA Renewal)/132 dated 06/07/2022
12) DPA letter no. EG/WK/4751 (CCA Renewal)/326 dated 19/06/2023

Sir,

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

In this connection, it is to state that, the Deendayal Port Authority had obtained Renewal of Consolidated Consent & Authorization from the GPCB vide order no. AWH – 110594 dated 22/01/2021 valid up to 21/07/2025 for Port Area of Deendayal Port Authority and subsequently, the GPCB had issued correction in consent vide order dated 09/04/2021. Afterward, DPA has also obtained amendment in Consent Order from the GPCB vide order dated 11/01/2024 (CCA Amendment – WH-130995) **(Copy attached as Annexure I).**

In this regard, as per statutory requirement, the DPA has regularly submitted Annual Returns (as mentioned in reference above) in format Form V to the GPCB.

Now please find the enclosed herewith Environmental Statement in Form V for the year 2023-24 as **Annexure II**.

This is for kind information and record please.

Encl : As above

Yours faithfully
19/7/24

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

AnyScanner

Annexure I

GUJARAT POLLUTION CONTROL BOARD

GPCB

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

CCA-Amendment
[WH-130995]

No. PC/CCA-KUTCH- 612(6)/ GPCB ID-28494/ **Date: /01/2024**

To,

M/s. Kandla Port Trust,
At Kandla, A.O Building Gandhidham,
Tal: Gandhidham,
Dist: Kutch – 370 201.

SUB: Amendment in the consolidated consent & Authorization of the Board.

REF. 1) CCA issued by this office vide order no- **AWH- 110594 dated** 22/01/2021 valid up to 21/07/2025.

2) Your CCA Amendment Application Inward ID **No.277270** dated **23/05/2023.**

In exercise of the power conferred under section-25 of the Water (Prevention and Control of Pollution) Act-1974, under section-21 of the Air (Prevention and Control of Pollution)-1981 and Authorization under rule 6(2) of the Hazardous And Other Waste (Management and Transboundary) Rules, 2016 & framed under the Environment (Protection) Act-1986, The Board has granted CCA vide order No. **AWH- 110594** issued vide order dated 22/01/2021 valid up to 21/07/2025.

The Board has right to review and amend the conditions of the said CCA and its amendment orders. Now, considering your application for CCA amendment inward ID **No.277270** dated 23/05/2023, **the said CCA order is amended as below:**

1. **The order shall be read as CCA amendment Order No.: WH- 130995 Date of issue: 14/12/2023, valid up to 21/07/2025.**

SUBJECT TO THE FOLLOWING SPECIFIC CONDITIONS:

1. There shall be no change in existing production and its capacity, raw materials consumption, fuel consumption, flue gas emission & process gas emission. due to CCA Amendment.
2. Industry shall not carry out any activity which may attract the applicability of EIA notification-2006 & its amendment
3. No ground water shall be withdrawal without prior permission from CGWA as per Hon'ble NGT order.
4. Unit shall obtain fresh water from valid source have permission of the competent authority.
5. Industry shall manage Solid Wastes generated from industrial activities as per Solid Waste Management Rules-2016 (solid waste as defined in Rule-3(46)).
6. Industry shall renew Public Liability Insurance Policy time to time & submit a copy of the same to this office.
7. Industry shall comply with circular of the Board dated 27/08/2021 regarding retrofitting of emission control/ equipment in D.G. Set of capacity 125 KVA and above as per system & procedure for emission compliance testing of Retrofit Emission Control Devices (RECD) for D.G. Set issued by CPCB dated 01/02/2022 at the earliest and submit compliance.

Outward No:781072 31/01/2024

2. **The condition no. 3 of the said CCA is amended as below:**

3. CONDITION UNDER THE WATER ACT:

3.1 Water Source: - GWIL

3.2 There shall be no industrial water consumption & waste water generation from manufacturing process & other ancillary operation.

3.3 The quantity of domestic water consumption shall be decreased from 1300 KL/Day to 3000 KL/Day, due to CCA-Amendment.

3.4 The quantity of domestic waste water shall not exceed 800 KL/Day.

3.5 Sewage shall be treated separately to conform to the following standards as per Hon.ble NGT order in the matter of OA No.1069/2018 dated 30/04/2019

PARAMETERS	GPCB NORMS
pH	5.5-9.0
Biochemical Oxygen Demand (BOD)	10 mg/L
Total suspended solids (TSS)	20 mg/L
Chemical Oxygen Demand (COD)	50 mg/L
Nitrogen –Total	10 mg/L
Phosphorous-Total (for discharge into Ponds, Lakes)	1.0 mg/L
Fecal Coliform	Desirable-100 MPN/100ml Permissible -230 MPN/100 ml

3.6 Treated domestic effluent conforming to above standard shall be discharged on land for gardening and plantation purpose within premises.

3.7 Industry shall provide fixed pipeline network with flow meter for even distribution of treated domestic effluent and maintain its record

3.8 Disposal system for storm water shall be provided separately. In no circumstances storm water shall be mixed with the industrial effluent

3. **The condition no. 5.1 & 5.2 of the said CCA is amended as below:**

5.1 Authorization order no. **WH-130995** Date of issue. 14/12/2023.

5.2 **M/s. Kandla Port Trust** is hereby granted an authorization based on the enclosed signed inspection report for generation, collection treatment, storage, transport of hazardous waste on the premises situated at Kandla, A.O Building Gandhidham, Tal: Gandhidham, Dist. Kutch;

Sr. No.	Waste	Quantity per Annum Existing	Quantity per Annum After CCA-Amendment	Schedule &Category	Facility
1	Used or Spent Oil	1125 MT	4250 MT	I-5.1	Collection, storage, transportation and disposal by selling out to registered recycler

Outward No:781072 24/01/2024

2.	Residue Containing Oil	3444 43 MT	8500 MT	I-5.2	Collection, storage, transportation and disposal by selling out to registered recycler.

4. Rest of conditions of Consolidated Consent & Authorization (CC&A) order No: AWH-110594 issued vide this office letter no. GPCB/CCA-KUTCH-812(5)/ID: 28494/581914 dated 22/01/2021 shall remain unchanged and industry shall comply with the same judicially.

For and on behalf of
GUJARAT POLLUTION CONTROL BOARD

(T. C. Patel)
Unit Head

Outward No:781072,11/01/2024

Annexure II

Environmental Statement (Form V)
For Deendayal Port Authority, Kandla
For the FY @ 2023-2024

"FORM-V"
(See rule -14)

From:
Deendayal Port Authority,
Administrative Office Building,
Post Box No.: 50, Gandhidham,
Dist.: Kutch – 370 207. Gujarat State.
Tel No.: O: 02836-220038
Fax No.: 02836-220050

To,
The Member Secretary,
Gujarat Pollution Control Board,
Paryavaran Bhavan, Sector - 10A,
Gandhinagar – 382043

Environmental statement for the financial year ending the 31st March, 2024

"PART-A"

1) Name and Address of the owner/occupier of the industry or process		
➢ NAME	:	Shree V Raveendra Reddy Chief Engineer
➢ ADDRESS	:	**Deendayal Port Authority** Administrative Office Building, Post Box No.: 50, Gandhidham, Dist.: Kutch – 370 207. Gujarat State. Tel No.: O: 02836-220038 Fax No.: 02836-220050
➢ Industry Category Primary – (STC code) Secondary – (STC code)	:	Major port Authority under the administrative control of Ministry of Ministry of Ports, Shipping and waterways, GOI
➢ Year of Establishment	:	8th April 1955
➢ Date of the last Environment audit report submitted	:	27th June, 2016

<u>"PART-B"</u>

<u>WATER AND RAW MATERIAL CONSUMPTION</u>

Sr.No.	WATER CONSUMPTION	KLD
1.	Process	**1573**
2.	Cooling	
3.	Domestic Purpose	
Total water consumption for the period from April 2023 to March 2024 was **574086 KL** hence, average water consumption for per day – **1573 KLD**		

I. Water Consumption

Sr. No.	Name of Products	Process Water Consumption per unit of products output	
		During the current financial year 2022-23	During the current financial year 2023-24
01.	Dry Cargo Handling	**137.5 MT**	**132.37 MT**
02.	Liquid Cargo Handling		

Deendayal Port Authority has only loading & unloading activities for dry cargo and liquid cargo. Hence consumption of process water consumption per unit of output with respective to production is not applicable.

During FY 2023-24 Total Cargo Handled is **132.37** MMTPA

However, Details of the Domestic water consumption for the financial year 2023-24 please refer **Annexure-A**

II. Raw material Consumption

Sr.No.	Name of Raw Material	Name of Products	Consumption of Raw material per unit of output	
			During the current financial year 2022-23	During the current financial year 2023-24
1.	Deendayal Port Authority has only loading & unloading activities for dry cargo and liquid cargo. Hence consumption of raw material per unit of output with respective to production is not applicable			

"PART-C"

POLLUTION DISCHARGED TO ENVIRONMENT/UNIT OF OUTPUT (PARAMETERS AS SPECIFIED IN THE CONSENT)

Pollutant	Quantity of Pollutant Discharged (mass/day)	Concentration of Pollution in Discharge (mass/volume)	% of Variation from prescribed standard with reasons
Please Refer **Annexure -B** for Environmental Monitoring Reports of • Ambient Air Quality Monitoring • Drinking Water Quality Monitoring • Marine Water Monitoring • Noise Level Monitoring			

"PART-D"

HAZARDOUS WASTE

[AS SPECIFIED UNDER HAZARDOUS WASTE (MANAGEMNET AND HANDLING) RULES -1989 & AMENDMENT RULES -2008]

Sr.No.	Hazardous Waste	Total Quantity in MT/Year	
		During the current financial year 2022-23	**During the current financial year 2023-24**
1.	5.1- Used Spent Oil	4578.79	2431.39
2.	5.2- Waste Residue Containing Oil	9157.58	7294.17
• Details of Hazardous Waste generated during the financial year 2022-23 please refer **Annexure-C**			
a. From Process: NA b. From Pollution Control facility: NA			

“PART-E”
SOLID WASTE

Sr.No.	Solid Waste	Total Quantity in MT/year	
		During the current financial year 2022-23	**During the current financial year 2023-24**
1.	From Process	Nil	Nil
2.	From pollution Control Facility	Nil	Nil
a.	Quantity Recycled or Reutilized within the unit	Nil	Nil
b.	Sold	Nil	Nil
c.	Disposed Off	**2473.19 MT**	**2572.94**
Details of Solid Waste (Non-Hazardous Waste) generated during the financial year 2023-24 please refer **Annexure-C**			

“PART-F”

PLEASE SPECIFY THE CHARACTERISTICS (IN TERMS OF CONCENTRATION AND QUANTUM) OF HAZARDOUS AS WELL AS SOLID WASTES AND INDICATE DISPOSAL PRACTICE ADOPTED FOR BOTH THESE CATEGORIES OF WASTES.

Hazardous Waste:
Companies authorized by Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) have been awarded the work of collection, transporting and disposal of hazardous Waste by the Deendayal Port Authority. The same will be hand over to authorize parties for further Treatment & disposal.

Solid Waste:
Garbage facility is provided as per MARPOL Act 73/78 to the vessel berthed at Deendayal Port Authority. Companies authorized by Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB) have been awarded the work of collection, transporting and disposal of solid waste by the Deendayal Port Authority. The same will be hand over to authorize parties for further treatment and disposal.

“PART-G”

IMPACT OF THE POLLUTION ABATEMENT MEASURES TAKEN ON CONSERVATION OF NATURAL RESOURCES AND ON THE COST OF PRODUCTION.

DPA has awarded the work of “Preparing and Monitoring of Environmental monitoring and management plan for Deendayal Port Authority Kandla and Vadinar to Gujarat Environment Management Institute (GEMI), Gandhinagar (An autonomous Institute of Government of Gujarat).

Further for Pollution Abatement measures taken for Conservation of Natural Resources DPA appointed renowned agency i.e M/s. GUIDE, Bhuj for the following work.

1. Regular Monitoring of Mangrove Plantation.

2. Preparation of detailed marine Biodiversity management plan for the impact of the project activities as per the requirement of EC & CRZ Clearance accorded by the MoEF&CC, GOI 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”

3. Regular monitoring of marine ecology in and around the Deendayal Port Authority area and continuous monitoring programme covering all season on various aspects of the coastal environ covering physico-chemical parameters of marine sediments samples coupled with biological indices, as per the requirement of EC & CRZ clearance accorded by the MoEF&CC,GOI to the various projects of the Deendayal port Authority.

4. Study on dredged material for presence of contaminant as per EC and CRZ clearance accorded by the MoEF&CC, GOI dated 19/12/2016 – specific condition vii

“PART-H”

ADDITIONAL MEASURES / INVESTMENT PROPOSAL FOR ENVIRONMENTAL PROTECTION INCLUDING ABATEMENT OF POLLUTION, PREVENTION OF POLLUTION

The allocation made under the scheme of “Environmental Services & Clearance there of other related Expenditure” during BE 2024-2025 is Rs. 657 Lakhs

“PART-I”

ANY OTHER PARTICULAR FOR IMPROVING THE QUALITY OF THE ENVIRONMENT

1. DPA is ISO 14001:2015 certified port for “Providing port facility and related maritime services for vessel and Cargo handling including storage
2. DPA has appointed M/s GEMI, Gandhinagar for the work “Making Deendayal Port a Green Port– Intended Sustainable Development under the Green Port Initiatives”. M/s GEMI, Gandhinagar had submitted the Final Report on 10/03/2021
3. DPA has accorded the work of Afforestation project in Deendayal Port Area to Forest Department, GoG which includes plantation and maintenance work of 1100 plants per ha.
4. DPA has accorded the work of green belt development in Deendayal port Authority and its Surrounding areas charcoal site to GUIDE for the plantation of 5000 saplings of suitable species.
5. DPA has planted 7500 trees in Deendayal port trust area during the year 2014-15 6000 trees during financial year 2016-17 and the same has been regularly maintained.
6. DPA has planted 4000 trees at A.O building, Gopalpuri residential colony and along the road side at Kandla. Further, approximately 885 no. of trees have been planted since September 2015 onwards.
7. Continuous water sprinkling has been carried out on the top of the heap of coal, at regular intervals to prevent dusting, fire and smoke. DPA already installed sprinkling system inside Cargo Jetty area for coal dust suppression in coal yard (40 Ha. Area) at the cost of Rs. 14.44 crores.
8. DPA has installed Mist Canon at the Port area to minimize the coal dust.
9. Deendayal port Authority (traffic department) issued a Circular (SOP) to the trade with regard to control of dust pollution arising out of coal handling and ensuring safety in coal handling. In case of any violations of SOP, provision of impose of penalty of Rs. 10000/- has been made and if violation is repeated thrice, the same will lead to ban of concerned party into port area. The DPA is taking all the measures to reduce coal dust by implementing the coal handling guidelines through port users.
10. All trucks before leaving the storage yard have been covered with tarpaulin and also trucks are also not over loaded as well as there is no spillage during transportation and there is adequate space for movement of vehicles at the surrounding area.
11. DPA has constantly improving the house keeping in the dry cargo storage yard and nearby approved areas leading to roads. Adequate steps under the

provisions of air prevention and control of pollution Act 1981, Environmental Protection Act 1986 are taken.

12. DPA commissioned STP of capacity 1.5 MLD for treatment of domestic waste water for entire DPA area. (Details of domestic waste water generation is attached herewith as **Annexure D**)
13. Deendayal Port Authority had carried out mangrove plantation in an area of 1600 ha. through various government agencies like Gujarat Ecology Commission, State Forest Department.
14. It is also relevant to mention here that, DPA entrusted work to Forest Department, GoG (Social Forestry Division, Bhuj) during August, 2019 for green belt development in and around port area 31.942 hectares (approx. 35200 plants at various locations) at a cost of Rs. 352.32 lakhs.
15. DPA is involved in various CER activities like providing the proper sanitation and development of better roads for connectivity
16. DPA is managing its plastic waste as per Plastic Waste Management Rules – 2016 and amendments made therein. In order to strictly implement the said rules, DPT had issued a circular regarding plastic waste minimization, source segregation, recycling etc. vide its Circular no. EG/WK/4751/Part 243(A) dated 03/09/2021
17. DPA has entrusted the work to GEMI, Gandhinagar for "Preparation of Plan for Management of Plastic Waste, Solid Waste, C&D Waste, E-waste, Hazardous Waste including Bio-medical Waste and Non-hazardous waste in the Deendayal Port Authority Area
18. DPA has assigned the work to TERI, New Delhi for "Transition of Business Operations to Water Neutrality – Water Neutrality of Deendayal Port, Kandla (Phase I- Study and assessment)
19. Recently, DPA has entrusted the work to GEMI, Gandhinagar for "Study of CO_2 Emission Estimation and Reduction Strategy under Maritime India Vision 2030.
20. Initiative for Installation of Continuous Ambient Air Quality Monitoring System (CAAQMS) for monitoring of Air quality is under process.

Annexure A

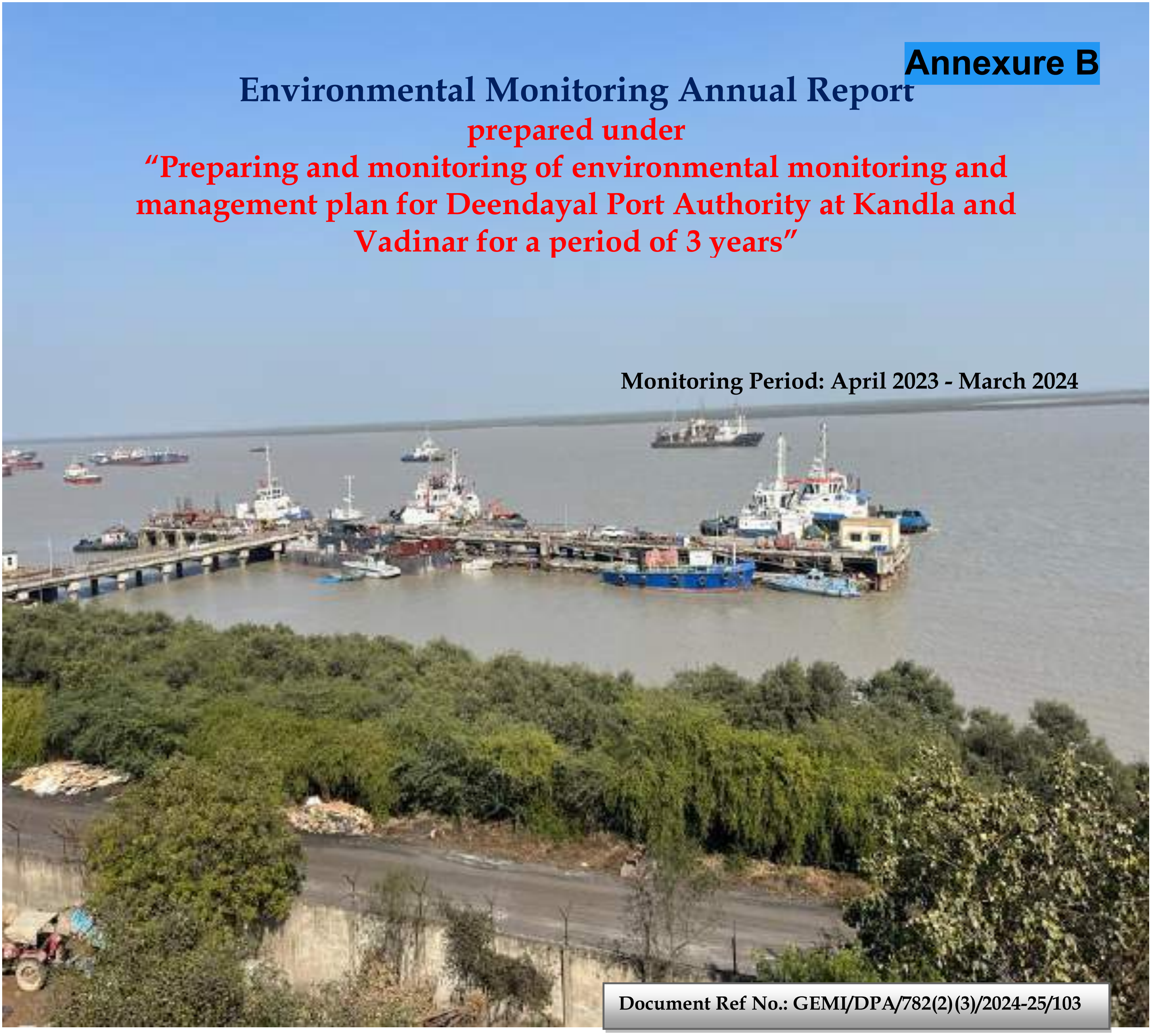
Statement Showing the quantity of water consumed from GWSSB from April 2023 to March 2024

Sr.No.	Month	Total Quantity Consumed in KL
1.	April 2023	47342.47
2.	May 2023	48920.55
3.	June 2023	47342.00
4.	July 2023	48920.55
5.	August 2023	48920.55
6.	September 2023	59980.00
7.	October 2023	48680.00
8.	November 2023	57820.00
9.	December 2023	52100.00
10.	January 2024	45566.00
11.	February 2024	30884.00
12.	March 2024	37610.00
Total		**574086.12**

XEN (PL)

AnyScanner

Annexure B



Environmental Monitoring Annual Report

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: April 2023 - March 2024

Document Ref No.: GEMI/DPA/782(2)(3)/2024-25/103

Submitted to:

Deendayal Port Authority (DPA), Kandla

Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

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

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About this Document

Gujarat Environment Management Institute (GEMI) has been assigned with the work of "Preparing and monitoring of Environmental monitoring and Management plan for Deendayal Port Authority (DPA) at Kandla and Vadinar for a period of 3 years" by DPA, Kandla. Under the said project the report titled *"Environment Monitoring Annual Report (Monitoring Period: April 2023 - March 2024)"* is prepared.

- **Name of the Report:** *Environment Monitoring Report (Monitoring Period April 2023-March 2024)*
- **Date of Issue:** 26/06/2024
- **Version:** 1.0
- **Report Ref.:** GEMI/DPA/782(2)(3)/2024-25/103

Table of Contents

List of Tables

List of Maps

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

1.2 Green Ports Initiative

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

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

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

1.3 Importance of Environmental monitoring and management plan (EMMP)

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

1. Air pollutant emissions due to ship emissions, loading and unloading activities, construction emission and emissions due to vehicular movement.

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

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

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

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

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

This document presents the Environmental Monitoring Report (EMR) for Kandla and Vadinar for the environmental monitoring done during the period from April 2023-March 2024.

1.4 Objectives and scope of the Study

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

The scope of work includes not limited to following:

1. To review the locations/stations of Ambient Air, Ambient Noise, drinking water, and Marine Water, Soil and Sediments monitoring within the impacted region in-and-around DPA establishment, in view of the developmental projects.
2. To assess the Ambient Air quality, quality at 6 stations at Kandla and 2 at Vadinar in terms of gases and particulate matter.
3. To assess the DG stack emissions (gases and particulate matter).
4. To assess Drinking water quality at twenty locations (18 at Kandla and 2 at Vadinar) in terms of Physical, Chemical and Biological parameters viz., Color, Odor, turbidity, conductivity, pH, Total Dissolved Solids, chlorides, Hardness, total iron, sulphate, NH_4, PO_4, and bacterial count on a monthly basis.
5. To assess the Marine water quality in terms of aquatic Flora and Fauna and Sediment quality in terms of benthic flora and fauna.
6. To assess Marine Water Quality and sediment in term of physical and chemical parameter.
7. To assess the trends of water quality in terms of Marine ecology by comparing the data collected over a specified time period.
8. Weekly sample collection and analysis of inlet & Outlet points of the Sewage Treatment Plant (STP) to check the water quality being discharged by DPA as per the CC&A.
9. Carrying out monthly Noise monitoring; twice a day at the representative stations for a period of 24 hours.
10. Meteorological parameters are very important from air pollution point of view, hence precise and continuous data collection is of utmost importance. Meteorological data on wind speed, wind direction, temperature, relative humidity, solar radiation and rainfall shall be collected from one permanent station at DPA, Kandla and one permanent station at Vadinar.
11. To suggest mitigation measures, based on the findings of this study and also check compliance with Environmental quality standards, Green Port Initiatives, MIV 2030, and any applicable Statutory Compliance.
12. To recommend Environment Management Plans based on Monitoring programme and findings of the study.

CHAPTER 2: METHODOLOGY

2.1 Study Area

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

a. Kandla

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

- **Climatic conditions of Kandla**

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

b. Vadinar

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

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

- **Climatic conditions of Vadinar**

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

The Kandla and Vadinar port have been depicted in the **Map 1 & 2** as follows:

ss

Map 1: Locations of Kandla and Vadinar Port

Map 2: Locations of Kandla Port

Map 3: Locations of Vadinar Port

2.2 Environmental Monitoring at Kandla and Vadinar

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

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

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

Methodology adopted for the study

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

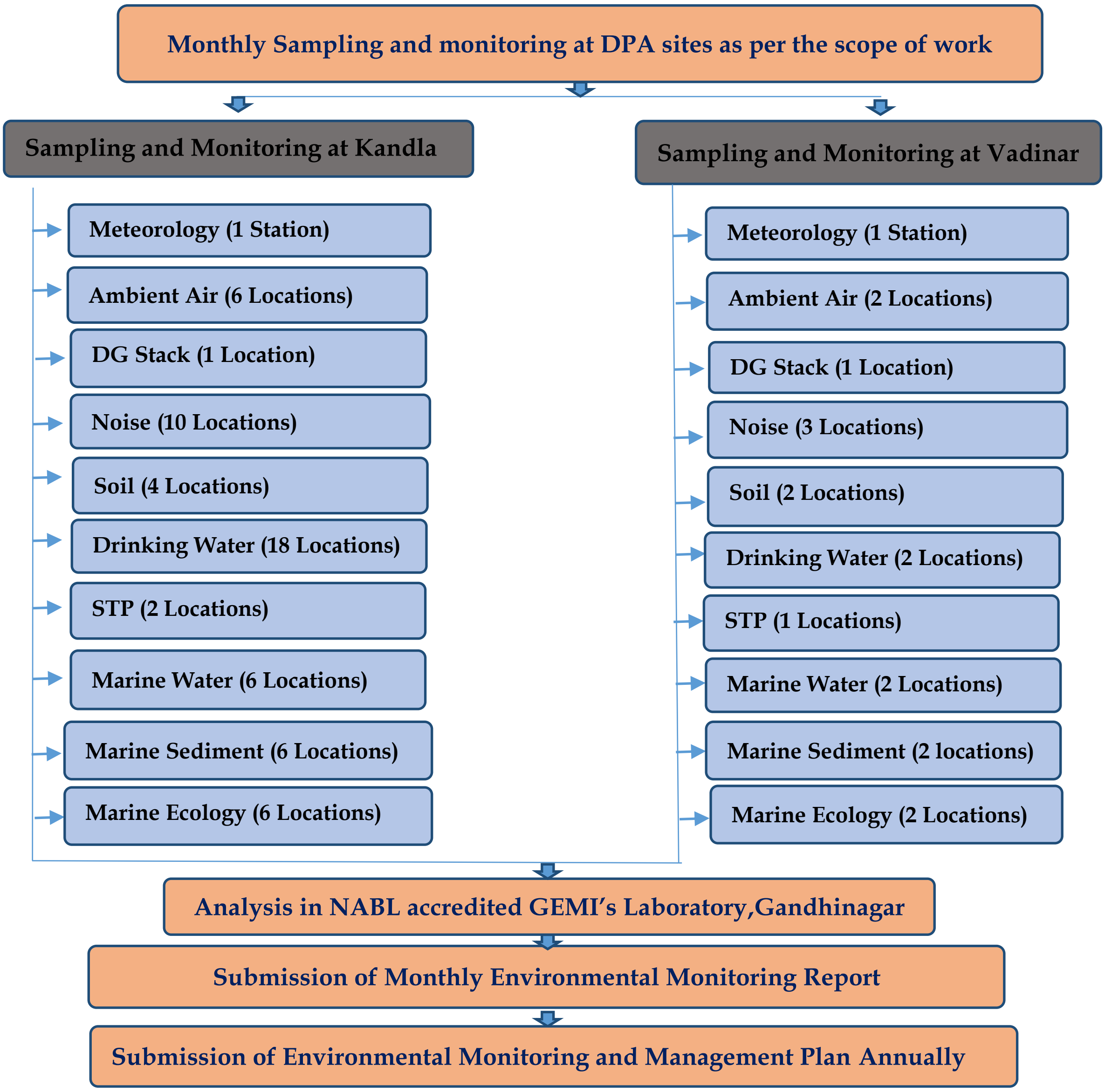


Figure 1: Methodology flow chart

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

CHAPTER 3: METEOROLOGY MONITORING

3.1 Meteorology Monitoring

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

Table 1: Details of Automatic Weather Station

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

Methodology:

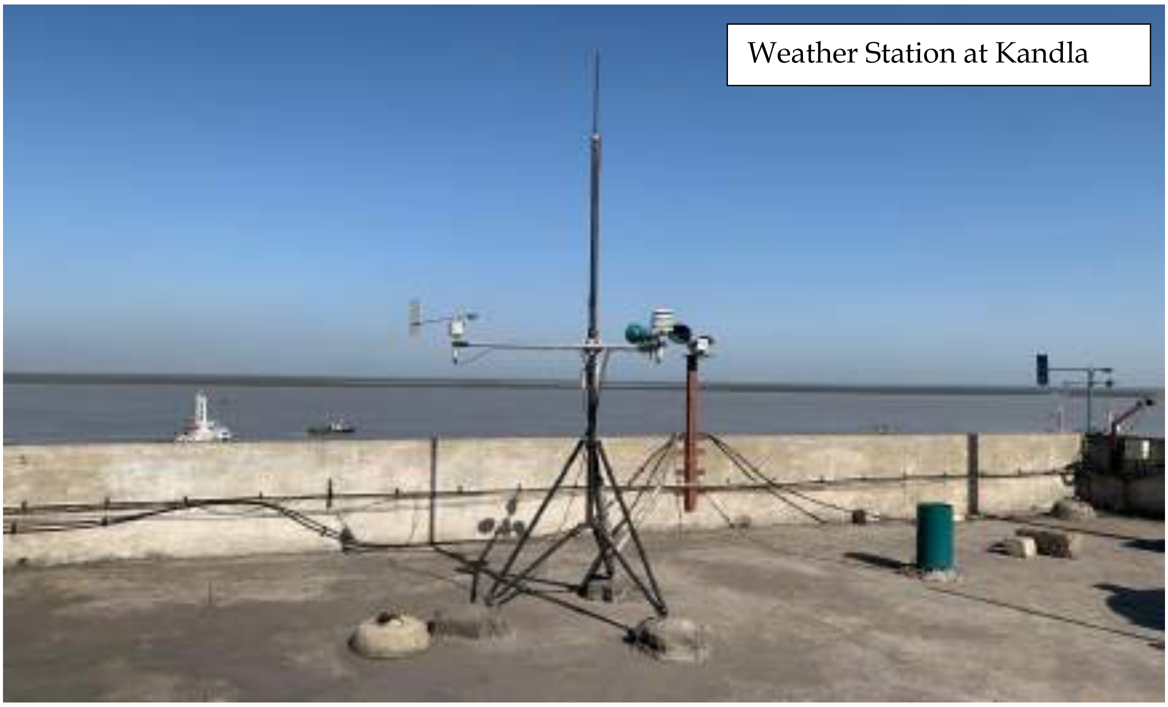
During the study, a continuous automatic weather monitoring station was installed at both the sites to record climatological parameters such as Wind speed, Wind Direction, Relative Humidity, Solar Radiation, Rainfall and Temperature to establish general meteorological regime of the study area. The methodology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

Table 2: Automatic Weather Monitoring Station details

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

Monitoring Frequency:

The Meteorological parameters were recorded at an interval of 1 hour in a day for the period of April 2023 to March 2024 and the average value for all the Meteorological parameters were summarized for the sampling period of at both the observatory site.



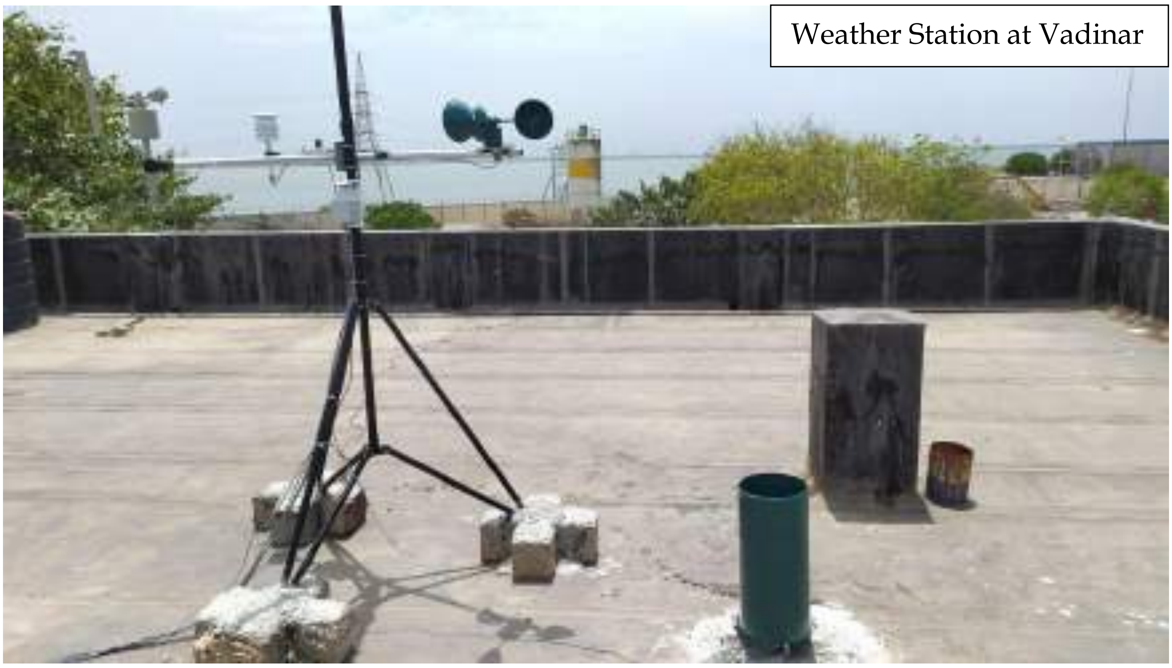


Figure 2: Photographs of Automatic Weather Monitoring Station at Kandla and Vadinar

3.2 Results and discussion

The summary of hourly climatological observations recorded at Kandla and Vadinar during the monitoring period of **April 2023 to March 2024,** with respect to significant parameters has been mentioned in **Table 3** as follows:

Table 3: Meteorological data for Kandla and Vadinar

Details of Micro-meteorological data at Kandla Observatory												
Monitoring Period	**Wind Speed (Km/h)**			**Temperature (°C)**			**Relative humidity (%)**			**Solar Radiation (W/m²)**	**Wind Direction (°)**	**Rainfall (mm)**
	Max.	**Min**	**Avg.**	**Max.**	**Min**	**Avg.**	**Max.**	**Min**	**Avg.**			
April-May 23	27.02	1.54	8.78	32.21	30.4	31.31	64.12	61.07	57.76	105.42	S.S.E	0.05
May-June 23	48.85	3.07	12.94	32.64	31.23	31.93	70.33	65.93	68.17	90.14	N & N.N.W	0.37
June- July 23	38.99	1.23	9.71	31.54	30.27	30.89	76.32	72.43	74.47	67.76	E.W.E & W.S.W	3.56
July-Aug 23	35.4	1.47	7.67	30.51	29.32	29.91	77.72	73.87	75.78	57.4	W.S.W	14.94
Aug-Sep 23	37.52	0.63	6.55	48.44	30.33	38.43	84.57	69.18	75.59	73.28	W.S.W	21.89
Sep- Oct 23	20.36	0.16	4.75	31.01	29.66	30.32	71.62	66.85	69.32	74.08	W.S.W	2.87
Oct- Nov 23	9.85	0.025	1.15	31.24	29.63	30.41	55.4	49.02	52.18	65.11	North	0.012
Nov- Dec 23	14.72	0	2.09	25.76	24.32	25.03	59.69	54.6	57.1	54.28	N.E	0.96
Dec- Jan 24	15.75	0	1.87	23.22	21.68	22.44	56.5	51.11	53.78	60.66	North	0
Jan- Feb 24	15.29	0.131	3.147	24.83	23.18	24	56	50.51	53.19	65.32	North	0
Feb- Mar 24	22.41	0.44	5.12	26.7	25.06	25.86	51.55	45.91	48.64	78.46	North	0.04
Mar- Apr 24	33.09	0.025	5.43	48.44	26.87	30.08	73.25	30.59	55.06	89.43	W.S.W	0

Details of Micro-meteorological data at Vadinar Observatory												
Monitoring Period	**Wind Speed (Km/h)**			**Temperature (°C)**			**Relative humidity (%)**			**Solar Radiation (W/m²)**	**Wind Direction (°)**	**Rainfall (mm)**
	Max.	**Min**	**Avg.**	**Max.**	**Min**	**Avg.**	**Mean**	**Max.**	**Min**			
April-May 23	26.33	7.78	13.24	28.74	28.04	28.17	73.47	70	71.08	110.76	W & South	0.02
May-June 23	34.08	7.63	16.76	29.96	29.22	29.34	71.77	69.03	69.83	102.95	S.S.E	0.19
June- July 23	12.31	1.62	5.19	29.51	28.86	28.94	77.68	75.42	75.95	78.26	South	0.27
July-Aug 23	31.69	5.39	13.12	28.62	27.99	28.06	79.51	77.31	77.77	60.86	South	0.22
Aug-Sep 23	28.07	5.2	12.96	27.75	27.18	27.22	75.13	72.87	73.42	88.14	South & S.W	0
Sep- Oct 23	21.82	4.64	9.59	28.12	27.5	27.56	77.12	74.66	75.32	87.51	South	0.06
Oct- Nov 23	13.8	1.77	4.17	27.89	27.1	27.28	63.61	59.58	61.15	81.61	N.E	0.18
Nov- Dec 23	19.37	3	4.84	24.79	24.11	24.24	64.12	60.47	61.79	70.68	S.S.E	0.03
Dec- Jan 24	16.76	1	4.18	22.94	22.14	22.34	63.13	59.25	60.71	73.37	South	0
Jan- Feb 24	10.62	1.99	3.94	23.24	22.92	22.7	65.66	64.19	64.9	87.29	South	0
Feb- Mar 24	16.92	5.36	8.55	24.16	23.6	23.82	62.34	60.91	61.51	101.99	N.N.W	0
Mar- Apr 24	29.61	0.31	11.63	29.8	24.96	26.5	82.36	57.41	71.08	114.77	N.N.W	0

3.3 Data Interpretation and Conclusion

1) Kandla:

a. The ambient temperature for the summer season varies in the range of **21.68** to **48.44** °C; in the monsoon season, the temperature varies between **29.32** and **33.38** °C; and in the winter season, the temperature varies between **21.68** and **31.24** °C. The yearly average temperature at Kandla is observed to be around **29.217** °C, with a standard deviation of 4.31.

b. The relative humidity for the summer season was recorded in the range of **30.59%** to **76.32%**; in the monsoon season, relative humidity was recorded in the range of **66.85%** to **84.57%**; and in the winter season, relative humidity was recorded in the range of **49.02** to **59.69%**; the yearly average humidity at Kandla was **61.75%** with a standard deviation of **10.635**.

c. The maximum rainfall at Kandla was observed at **21.89** mm for the monitoring period of August to September 2023; the yearly average rainfall was found to be **3.72** mm.

d. Wind speed and direction play a significant role in transporting pollutants and thus determining the air quality. In the summer season, wind blew from the North and North North West directions; in the monsoon season, wind blew from the West South West; and in the winter season, wind blew from the North direction.

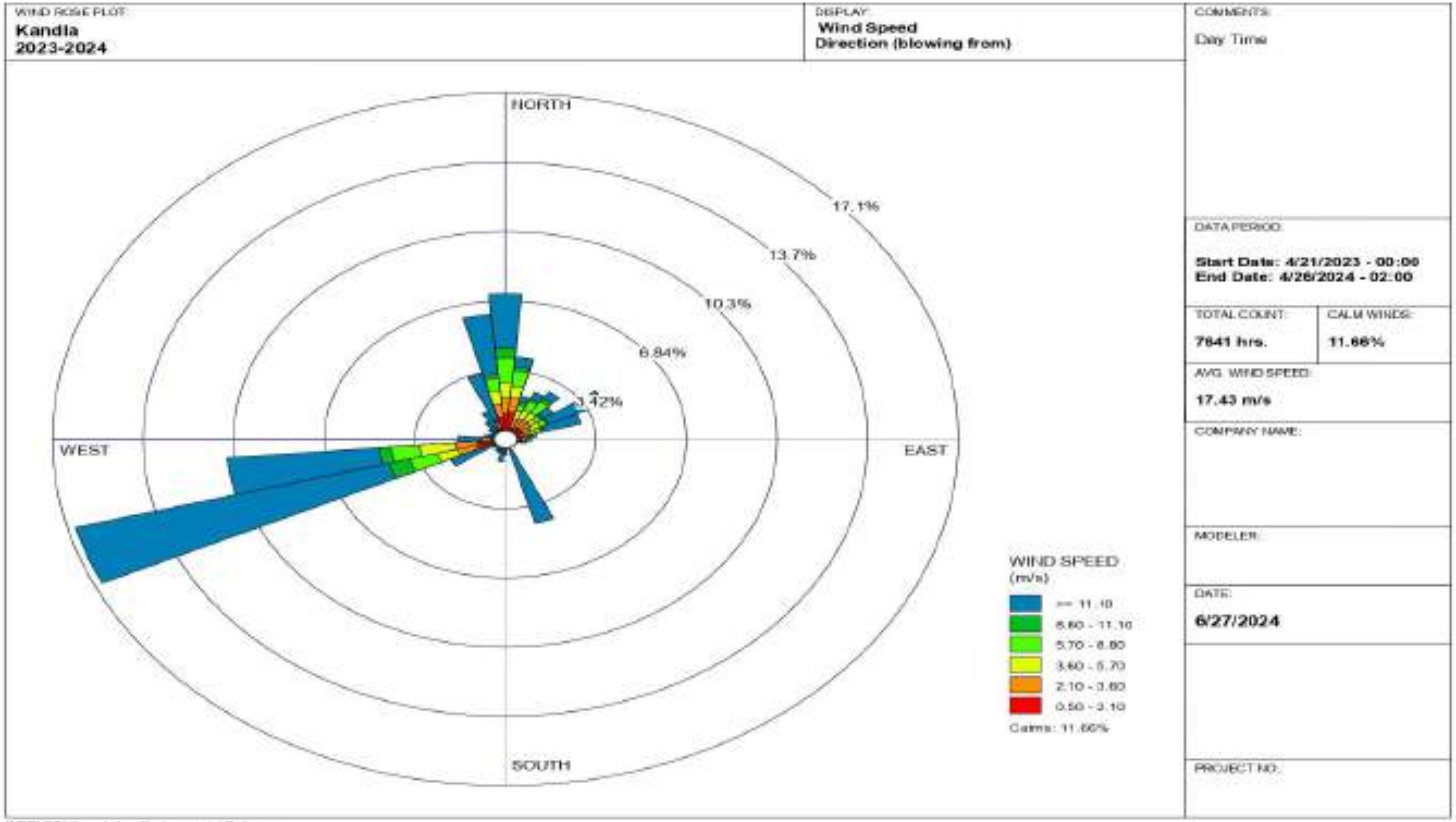
e. The wind speed recorded ranges from **0.025** to **48.85** km/h in the summer season; in the monsoon season, the wind speed recorded ranges from **0.16** to **37.52** km/h; and in the winter season, the wind speed recorded ranges from **0** to **15.75** km/h. The yearly average wind speed at Kandla is **5.77** km/h, with a standard deviation of 3.55.

f. The **maximum** solar radiation at Kandla was observed at 105.**42** W/m^2 during the monitoring period **April to May 2023**; the **minimum** solar radiation at Kandla was observed at 54.**28** W/m^2 for the monitoring period **November to December 2023; and** the yearly **average** solar radiation was found to be **73.445** W/m2 with a standard deviation of 15.19.

Wind rose diagram:

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

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



WRPLOT View - Lakes Environmental Software

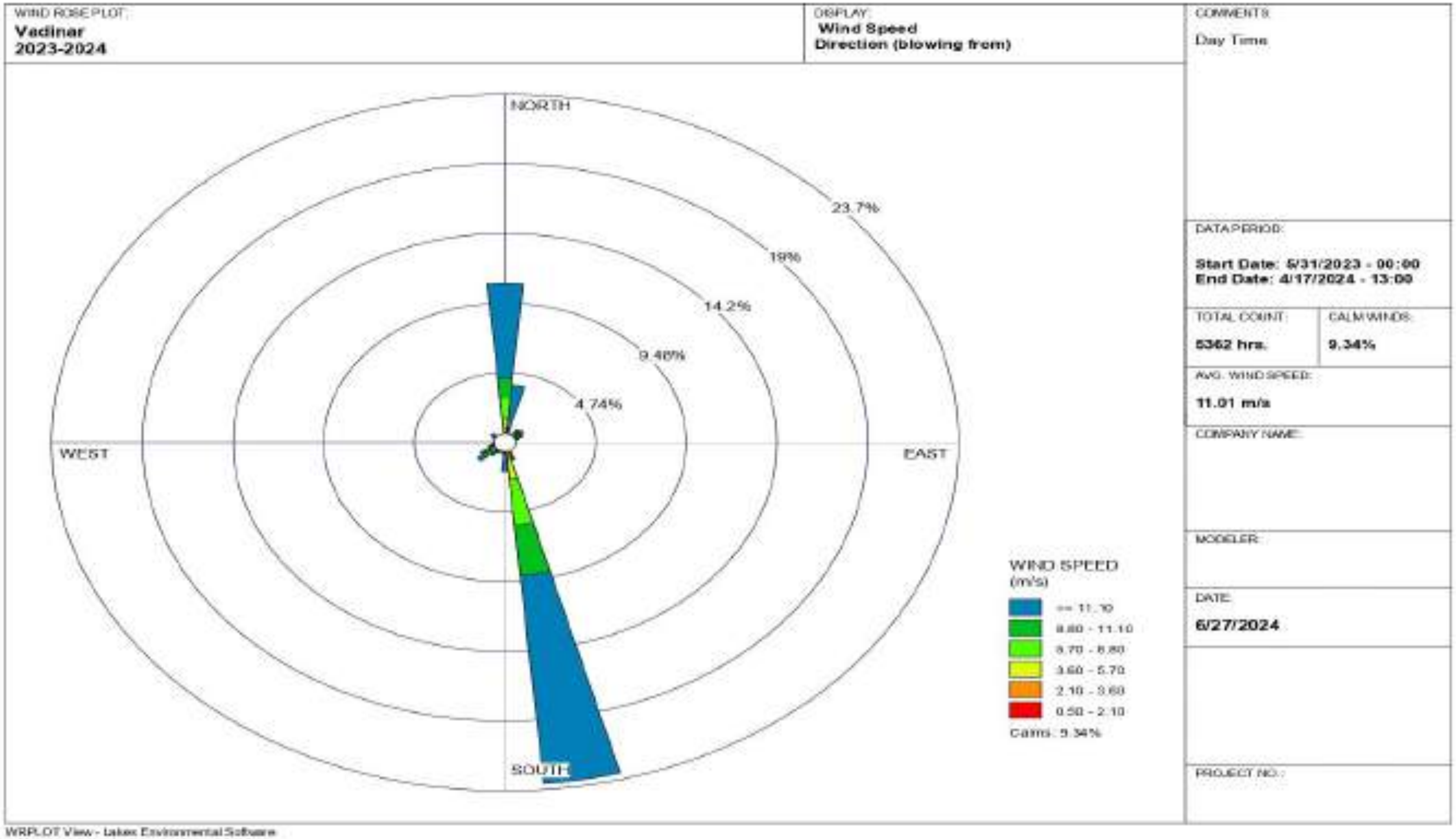
2) Vadinar:

a. The ambient temperature for the summer season varies between **23.6** and **29.96** °C; in the monsoon season, it varies between **27.18** and **28.62** °C; and in the winter season, it varies between **22.14** and **27.89** °C. The yearly average temperature at Vadinar is **2.347** °C with standard deviation of **2.4**.
b. The relative humidity for the summer season was recorded in the range of **57.41**% to **82.36**%; in the monsoon season, relative humidity was recorded in the range of **72.87**% to **79.51**%; and in the winter season, relative humidity was recorded in the range of **59.25**% to **65.66**%; the yearly average humidity at Vadinar was **68.7**% with a standard deviation of 6.38.
c. The **maximum** rainfall at Vadinar was observed at **0.27** mm for the monitoring period from **June to July 2023**; the yearly **average** rainfall was found to be **0.08** mm.
d. In Summer Season wind blew from South Direction, in Monsoon season wind blew from South and in Winter Season wind blew from South and South West direction. The recorded wind speed ranges from **0.31** to **34.08** km/hr in the summer season, **4.64** to **31.69** km/hr, and in the monsoon season, the recorded wind speed ranges from **1** to **19.37** km/hr. The yearly average wind speed at Vadinar is 9.014 km/h with a standard deviation of **4.49**.
e. The maximum solar radiation at Vadinar was observed at **114.77** W/m2 for the monitoring period April to May 2024; the minimum solar radiation at Vadinar was observed at **60.86** W/m2 for the monitoring period July to August 2023; and the yearly average solar radiation was found to be **88.182** W/m2.

Wind rose diagram:

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

At Vadinar, the winds were observed to blow from Souths direction.


WIND ROSE PLOT:
Vadinar
2023-2024
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Day Time
NORTH
SOUTH
WEST
EAST
23.7%
19%
14.2%
9.48%
4.74%
DATA PERIOD:
Start Date: 5/31/2023 - 00:00
End Date: 4/17/2024 - 13:00
TOTAL COUNT:
5362 hrs.
CALM WINDS:
9.34%
AVG. WIND SPEED:
11.01 m/s
COMPANY NAME:
MODELER:
DATE:
6/27/2024
PROJECT NO.:
WIND SPEED
(m/s)
>= 11.10
8.80 - 11.10
5.70 - 8.80
3.60 - 5.70
2.10 - 3.60
0.50 - 2.10
Calms: 9.34%
WRPLOT View - Lakes Environmental Software

CHAPTER 4: AMBIENT AIR QUALITY MONITORING

4.1 Ambient Air Quality

It is necessary to monitor the ambient air quality of the study area, in order to determine the impact of the shipping activities and port operations on the ambient air quality. The prime objective of ambient air quality monitoring is to assess the present air quality and its conformity to National Ambient Air Quality Standards i.e. NAAQS, 2009[(1)].

Methodology

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

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

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

Table 4: Details of Ambient Air monitoring locations

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

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

Ambient Air monitoring photos

Kandla


A-1: Oil Jetty No. 1


A-2: Oil Jetty No. 7


A-3: Kandla Port Colony

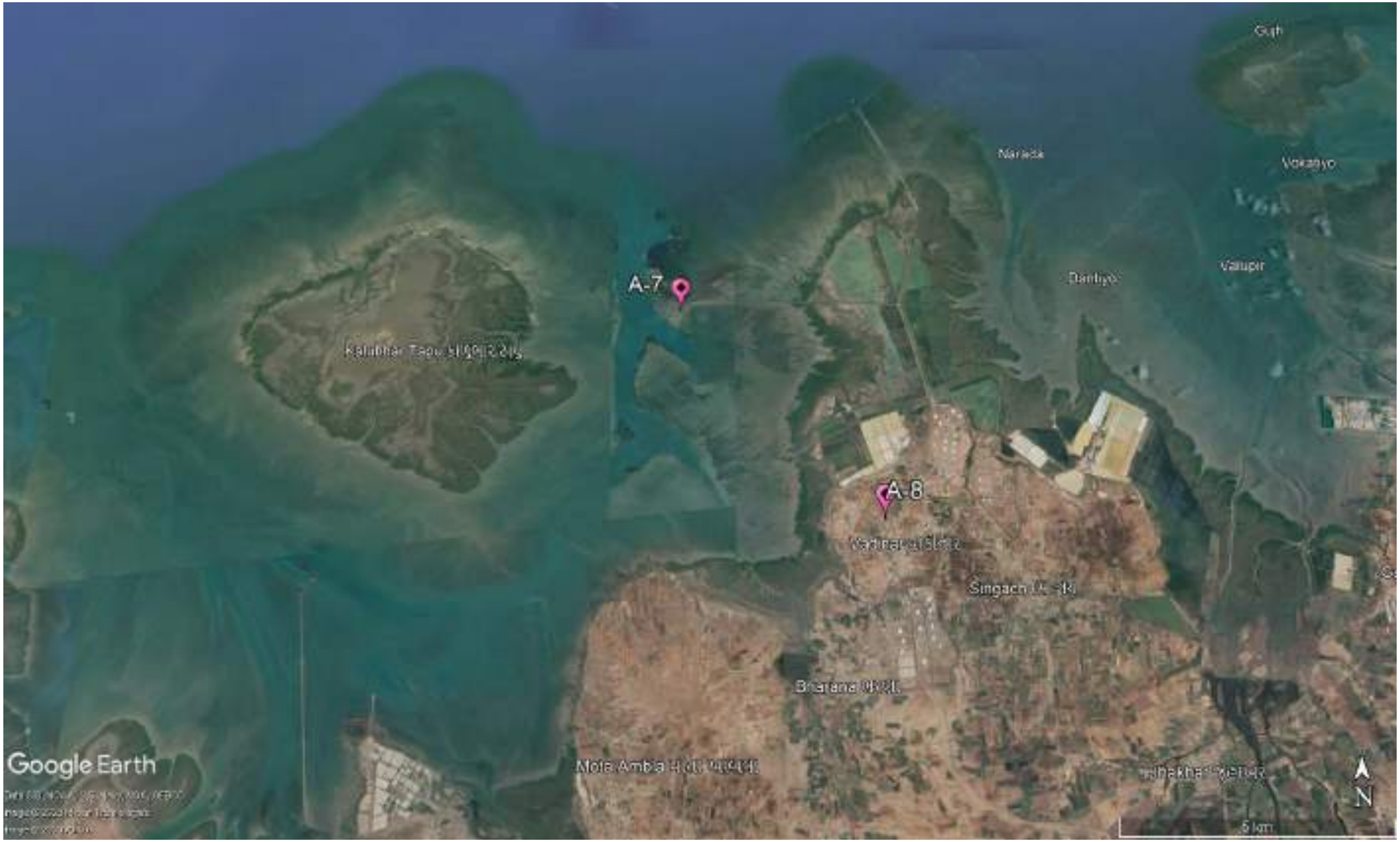

A-4: Marine Bhavan


A-5: Coal Storage Area


A-6: Gopalpuri Hospital

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

Map 4: Ambient Air Monitoring locations at Kandla



Map 5: Ambient Air Monitoring locations at Vadinar

Monitoring Frequency

The sampling for Particulate matter, i.e., PM_{10} and $PM_{2.5}$, and gaseous components like SO_x, NO_x, and CO, as well as the total VOCs, was monitored twice a week for a period of 24 hours a day. Whereas, the sampling for the components of PAH, benzene, and non-methane VOCs was conducted on a monthly basis. The monitoring period for this study is from April 15, 2023, to April 15, 2024. During this period, 95 air samples were taken from six locations in Kandla, and 97 samples were taken from two locations in Vadinar.

Sampling and Analysis

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

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

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

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

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

Table 5: Parameters for Ambient Air Quality Monitoring

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

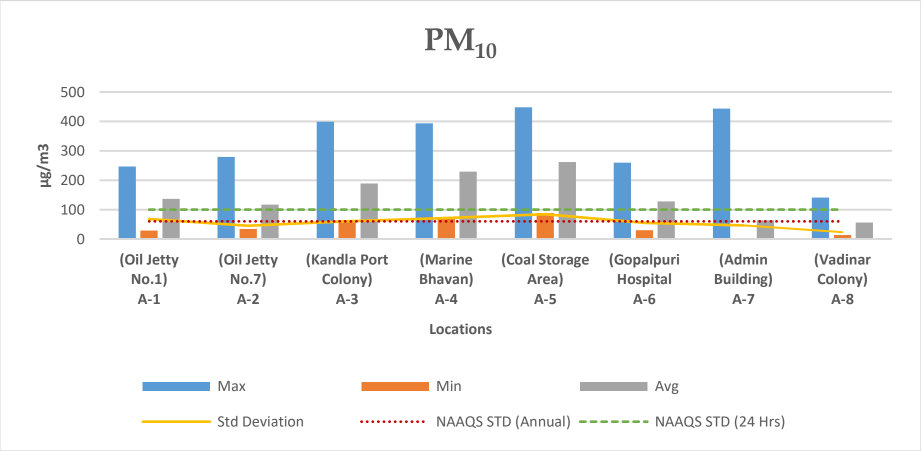
4.2 Result and Discussion

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

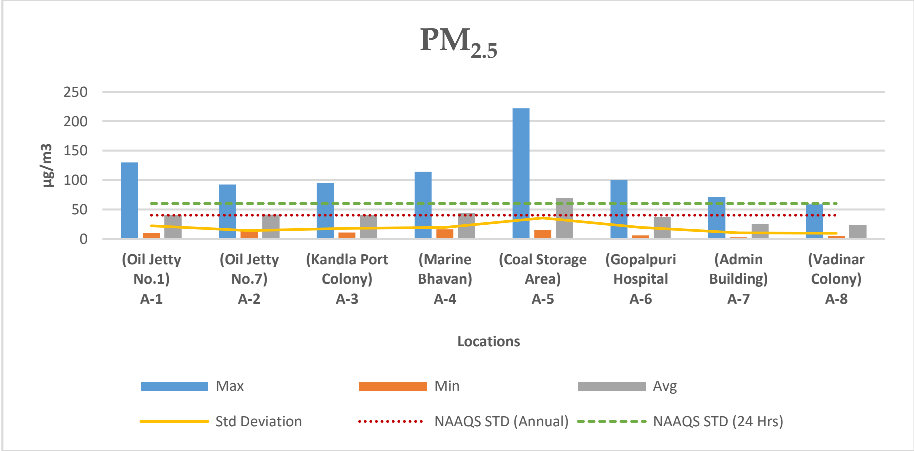
Table 6: Summarized results of PM_{10}, $PM_{2.5}$, SO_2, NO_x, VOC and CO for Ambient Air quality monitoring

Parameters	NAAQS by CPCB	Locations	(Oil Jetty No.1) A-1	(Oil Jetty No.7) A-2	(Kandla Port Colony) A-3	(Marine Bhavan) A-4	(Coal Storage Area) A-5	(Gopalpuri Hospital A-6	(Admin Building) A-7	(Vadinar Colony) A-8
PM_{10} (µg/m3)	24 Hours -100 Annual -60	Max	247.03	279.33	399.25	393.74	448.12	259.88	443.2	140.7
		Min	28.68	34.39	63.28	71.77	89.21	30.3	1.45	13.89
		Avg	136.50	116.67	188.36	229.41	262.04	127.95	63.49	56.54
		Std Deviation	68.203	44.97	60.56	71.74	84.18	55.43	46.36	23.15
$PM_{2.5}$ (µg/m3)	24 Hours -60 Annual -40	Max	129.77	92.24	94.51	114.34	221.9	99.82	71.18	58.73
		Min	10.03	12.85	10.84	15.97	14.85	5.51	2.36	4.7
		Avg	40.27	41.2	40.26	43.70	69.70	36.95	25.11	23.73
		Std Deviation	22.049	13.87	17.52	19.15	35.36	19.04	10.06	9.33
SO_2 (µg/m3)	24 Hours -80 Annual -50	Max	51.87	151.58	79.24	55.04	283	49.89	59.69	69.81
		Min	0.65	1.18	1.1	1.19	1.1	1.12	0.52	1.4
		Avg	11.076	20.01	14.63	11.82	16.82	11.56	12.59	13.69
		Std Deviation	12.142	28.41	17.15	12.25	30.85	12.08	13.35	14.90
NO_X (µg/m3)	24 Hours -80 Annual -40	Max	54.33	52.54	80.67	55.39	80.94	79.88	52.76	33.79
		Min	2.29	1.11	2.36	1.29	1.97	1.01	2.89	0.9
		Avg	14.75	14.58	22.91	20.52	28.12	15.24	12.84	9.70
		Std Deviation	11.68	9.85	14.98	10.53	17.98	13.59	8.62	5.73
VOC (µg/m3)	-	Max	4.85	5.67	17.43	4.41	3.97	4.12	4.52	6.62
		Min	0.01	0.01	0.01	0.02	0.04	0.01	0.01	0.01
		Avg	1.20	1.226	1.52	0.98	0.94	0.96	0.96	0.95
		Std Deviation	1.155	1.298	2.275	0.99	0.94	0.99	0.93	1.12
CO (mg/m3)	8 Hours -2 1 Hour -4	Max	0.98	4.21	2.91	3.16	3.21	2.18	3.14	2.74
		Min	0.08	0.09	0.14	0.39	0.36	0.32	0.03	0.45
		Avg	0.73	0.848	0.89	0.95	1.13	0.74	0.78	0.94
		Std Deviation	0.194	0.557	0.41	0.39	0.53	0.32	0.46	0.36

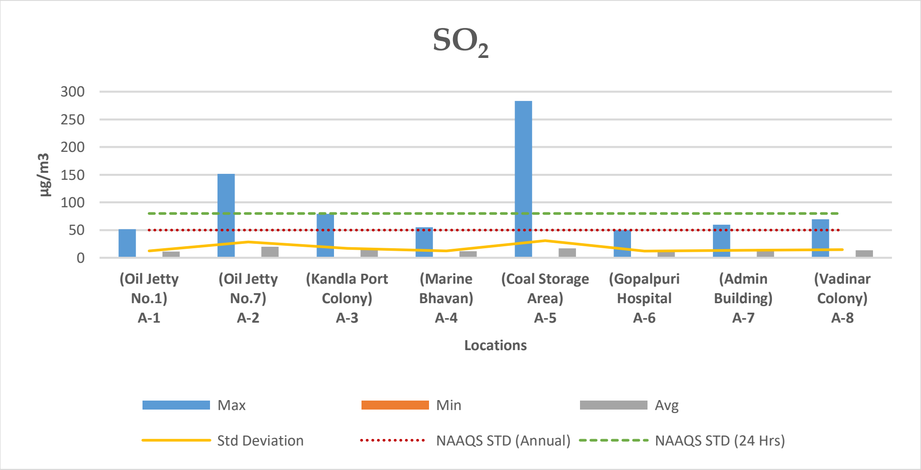
Graphs 1-6 shows spatial trend of ambient air parameter at all the eight-monitoring location (six at Kandla and 2 at Vadinar)



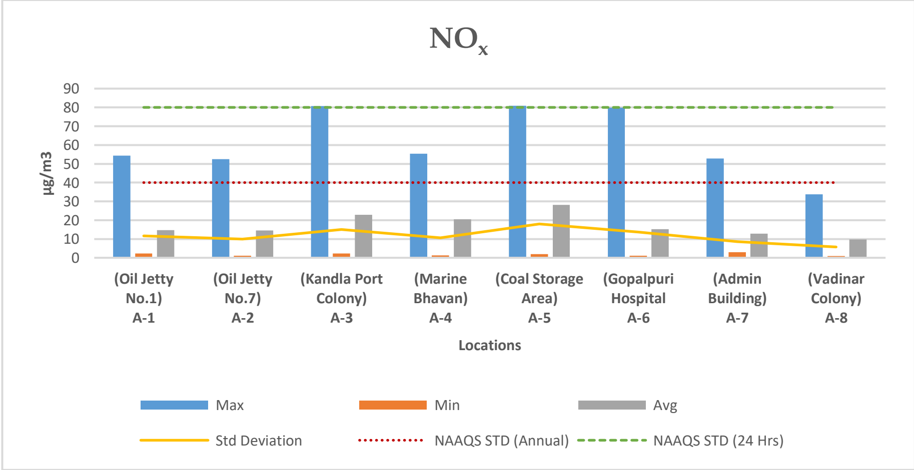
Graph 1 Spatial trend in Ambient PM_{10} Concentration



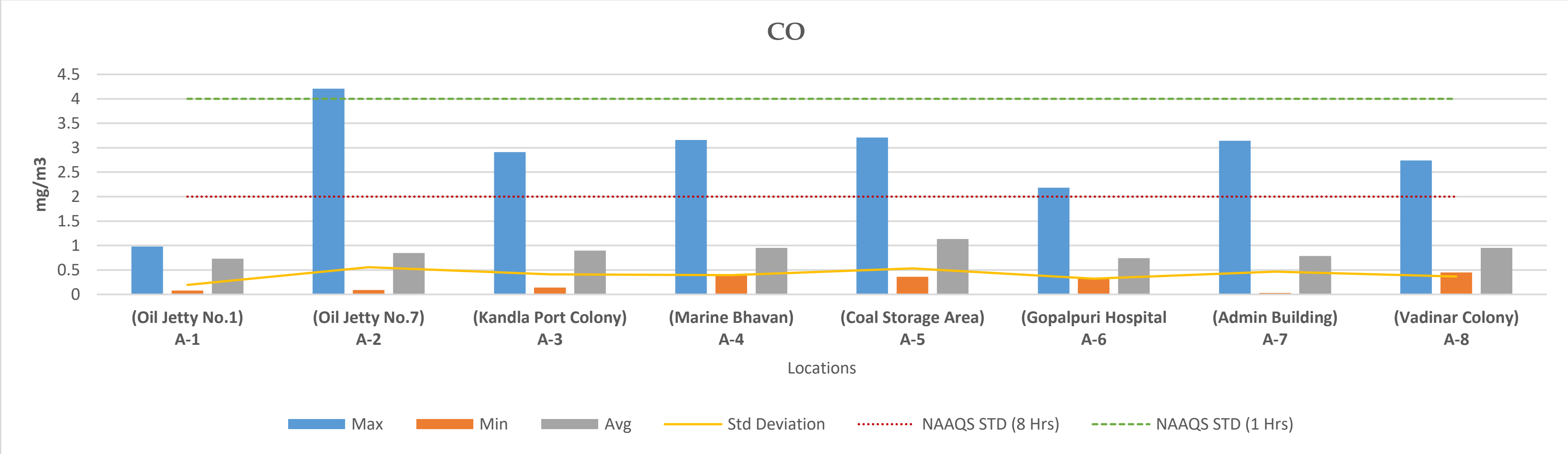
Graph 2 Spatial trend in Ambient $PM_{2.5}$ Concentration



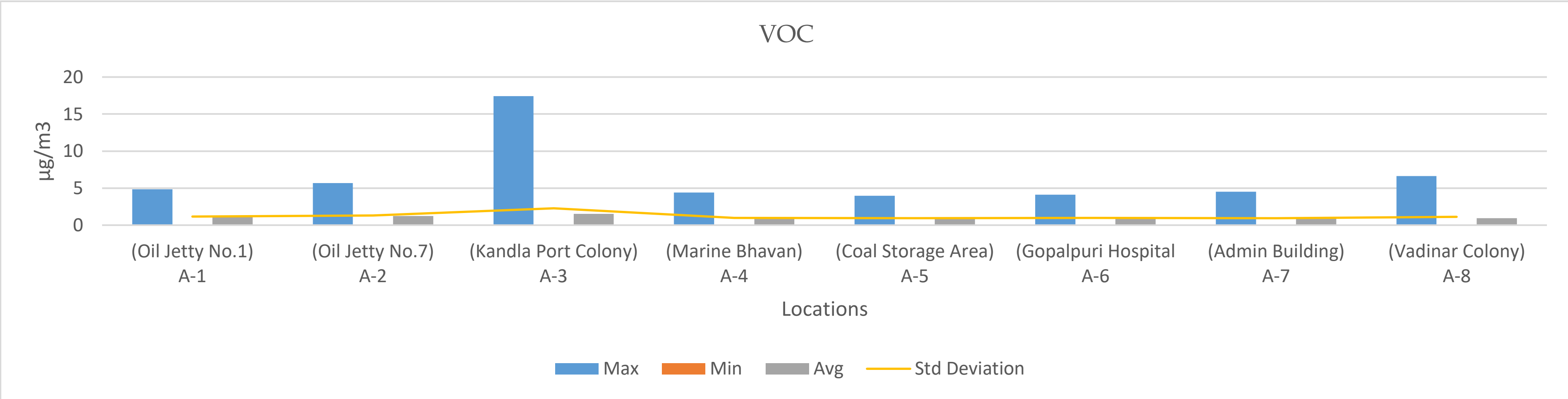
Graph 3 Spatial trend in Ambient SOx Concentration



Graph 4 Spatial trend in Ambient NOx Concentration



Graph 5 Spatial trend in Ambient CO Concentration



Graph 6 Spatial trend in Ambient Total VOCs

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

Parameters \ Locations			(Oil Jetty No.1) A-1	(Oil Jetty No.7) A-2	(Kandla Port Colony) A-3	(Marine Bhavan) A-4	(Coal Storage Area) A-5	(Gopalpuri Hospital A-6	(Admin Building) A-7	(Vadinar Colony) A-8
	NAAQS by CPCB									
Benzene (µg/m3)	Annual - 5	Max	3.8	1.84	1.43	1.95	1.11	1.97	1.03	0.95
		Min	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.01
		Avg	0.83	0.46	0.42	0.32	0.41	0.49	0.33	0.229

Table 8: Summarized results of Polycyclic Aromatic Hydrocarbons

Parameters \ Locations		(Oil Jetty No.1) A-1	(Oil Jetty No.7) A-2	(Kandla Port Colony) A-3	(Marine Bhavan) A-4	(Coal Storage Area) A-5	(Gopalpuri Hospital A-6	(Admin Building) A-7	(Vadinar Colony) A-8
Napthalene (µg/m3)	Max	1.57	17.31	5.24	5.55	7.8	39.82	1.98	1.84
	Min	0.02	0.21	0.04	0.14	0.37	0.02	0.1	0.13
	Avg	0.40	3.29	0.58	1.05	2.01	4.96	0.45	0.42
Acenaphthylene (µg/m3)	Max	0.8	0.67	0.54	0.95	0.53	0.86	0.84	0.65
	Min	0.01	0.01	0.01	0.02	0.007	0.02	0.005	0.005
	Avg	0.15	0.20	0.17	0.31	0.15	0.18	0.19	0.17
Fluorene (µg/m3)	Max	0.39	0.39	22.99	178.72	10.88	27.22	7.57	11.64
	Min	0.01	0.05	0.04	0.11	0.01	0.06	0.01	0.01
	Avg	0.14	0.19	3.435	19.99	1.25	3.52	0.82	1.18
Anthracene (µg/m3)	Max	0.87	0.91	1.25	5.05	2.02	3.78	0.85	0.57
	Min	0.09	0.09	0.07	0.09	0.03	0.01	0.02	0.02
	Avg	0.3	0.42	0.40	0.94	0.94	0.69	0.23	0.19
Phenanthrene (µg/m3)	Max	0.9	0.82	0.84	0.91	1	0.99	0.82	0.74
	Min	0.01	0.009	0.01	0.01	0.01	0.01	0.07	0.06
	Avg	0.23	0.20	0.15	0.22	0.33	0.20	0.25	0.22
Fluoranthene (µg/m3)	Max	2.65	0.84	1.59	19.54	4.16	20.36	0.68	1.71
	Min	0.06	0.15	0.2	0.24	0.2	0.01	0.01	0.01
	Avg	0.43	0.36	0.74	3.61	1	2.12	0.24	0.30
Pyrene (µg/m3)	Max	3.52	1.13	2.4	42.23	40.25	51.22	0.87	0.74
	Min	0.01	0.14	0.23	0.15	0.02	0.01	0.01	0.01
	Avg	0.54	0.48	0.90	7.46	4.37	7.98	0.16	0.14
Chrycene (µg/m3)	Max	4.59	1.03	3.01	6.27	5.51	5.82	0.61	0.79

	Min	0.08	0.15	0.44	0.42	0.08	0.06	0.05	0.05
	Avg	0.78	0.51	1.01	1.50	1.47	1.22	0.19	0.22
Banz(a)anthracene (µg/m3)	Max	5.64	2.84	3.7	15.42	6.57	16.73	1.01	0.97
	Min	0.17	0.17	0.04	0.14	0.05	0.06	0.01	0.01
	Avg	0.89	0.65	0.88	2.66	1.44	2.93	0.25	0.31
Benzo[k]fluoranthene (µg/m3)	Max	7.67	1.99	5.98	4.81	4.06	6.89	0.84	0.69
	Min	0.15	0.38	0.14	0.48	0.05	0.06	0.03	0.03
	Avg	1.32	0.99	1.34	1.21	0.89	1.76	0.35	0.21
Benzo[b]fluoranthene (µg/m3)	Max	7.89	1.93	6.15	5.12	4.73	7.29	0.59	0.71
	Min	0.12	0.04	0.21	0.17	0.07	0.01	0.06	0.01
	Avg	1.09	0.62	1.053	1.43	1.06	1.65	0.17	0.20
Benzopyrene (µg/m3)	Max	10.9	2.79	8.42	7.25	8.91	9.19	0.96	0.69
	Min	0.24	0.08	0.39	0.39	0.01	0.04	0.01	0.01
	Avg	1.64	0.87	1.66	1.75	1.58	1.31	0.30	0.27
Indeno [1,2,3-cd] fluoranthene (µg/m3)	Max	2.39	6.67	0.95	2.46	1.68	4.61	0.52	0.98
	Min	0.13	0.07	0.42	0.26	0.11	0.09	0.07	0.06
	Avg	0.71	1.02	0.57	0.72	0.70	1.25	0.22	0.42
Dibenz(ah)anthracene (µg/m3)	Max	1.82	1.2	0.91	1.25	2.24	0.99	1.34	2.48
	Min	0.11	0.08	0.16	0.1	0.07	0.04	0.08	0.05
	Avg	0.47	0.32	0.35	0.46	0.54	0.24	0.31	0.4
Benzo[ghi]perylene (µg/m3)	Max	16.3	9.7	27.2	13.6	9.4	12.2	8	2.3
	Min	0.1	0.07	0.04	0.06	0.06	0.17	0.07	0.13
	Avg	2.049	2.63	2.95	2.55	1.61	2.13	0.83	0.47
Acenaphthene (µg/m3)	Max	0.69	0.45	15.1	119.08	2.54	11.8	0.67	2
	Min	0.01	0.05	0.04	0.11	0.01	0.06	0.01	0.01
	Avg	0.14	0.22	2.63	11.34	0.369	1.55	0.14	0.33

Table 9: Summarized results of Non-methane VOC

Parameters / Locations		(Oil Jetty No.1) A-1	(Oil Jetty No.7) A-2	(Kandla Port Colony) A-3	(Marine Bhavan) A-4	(Coal Storage Area) A-5	(Gopalpuri Hospital A-6	(Admin Building) A-7	(Vadinar Colony) A-8
Non- Methane VOC (µg/m3)	Max	2.11	2.67	3.54	1.35	1.8	2.01	2.15	1.67
	Min	0.12	0.09	0.1	0.08	0.13	0.11	0.07	0.1
	Avg	0.73	0.79	0.87	0.79	1.09	0.93	0.91	0.74s

4.3 Data Interpretation and Conclusion

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

1) Kandla:

Particulate matter:

- The concentration of PM_{10} varies very widely and is reported in the range of **28.68** to **448.12** µg/m3, with a yearly average value of **176.83** with standard deviation **64.185** µg/m^3. As shown in Graph 1, the highest concentration (value) of PM_{10} is reported at location A-5 (coal storage area) during the winter. It can be seen that PM_{10} exceeds the NAAQS annual limit, i.e., 60 µg/m^3, in all locations. It can be seen that location A-5 (coal storage area) had the maximum percentage exceedance, and location A-1 (oil jetty No. 1) had the minimum percentage exceedance while comparing with the NAAQS 24-hour limit, i.e., 100 µg/m^3.
- The concentration of PM2.5 varies in the range of 5.51 to 221.9 µg/m^3, with a yearly average value of 45.35 with standard deviation 21.16 µg/m^3. As shown in Graph 2, the highest concentration of $PM_{2.5}$ is at location A-5 (the coal storage area) in winter. It can be seen that $PM_{2.5}$ exceeds the NAAQS annual limit, i.e., 40 µg/m3, on five locations, and location A-6, i.e., Gopalpuri hospital, falls within the NAAQS annual limit. It can be seen that location A-5 (coal storage area) had the maximum percentage exceedance, and location A-6 (Gopalpuri hospital) had the minimum percentage exceedance while comparing with the NAAQS 24-hour limit, i.e., 60 µg/m^3.
- The highest concentration of Particulate matter at locations **A–5, (the coal storage area)**, could be attributed to the presence of heavy vehicular traffic in upwind areas, which have a higher impact, causing the dispersion of emitted particulate matter in the ambient air. Ther activities observed in the surrounding such as The unloading of coal directly into the truck using grabs, construction in the vicinity causes the dust to disperse in the air as well as coal dust to fall and settle on the ground. This settled coal dust again mixes with the air while trucks travel through it. Also, the coal-loaded trucks are generally not always covered with tarpaulin sheets, and this might result in increased suspension of coal from trucks or dumpers during their transit from vessel to yard or storage site. This might increase the PM in and around the coal storage area and Marine Bhavan.

Gaseous Pollutants:

- The concentration of SOx varies from **0.52** to **283** µg/m^3, with a yearly average concentration of **14.029** with standard deviation **18.85** µg/m^3. As shown in Graph 3, the highest concentration of SOx is at location **A-5 (the coal storage area)** in winter. It can be seen that at all locations, SOx are within the NAAQS annual limit, i.e., 50 µg/m^3. It can be seen that location A-2 **(Oil Jetty No. 7)** had the maximum percentage exceedance, i.e., **7.36**%, which is about 7 days out of 95 days of monitoring, and the other five locations comply with the standards (compliance more than 98% times) while comparing with the NAAQS 24-hour limit, i.e., 80 µg/m^3. The concentration of NOx varies from **1.01** to **80.94** µg/m3, with a yearly average concentration of **19.35** with standard deviation **13.10** µg/m3. As shown in Graph 4, the highest concentration of NOx is at location A-5 (the coal storage area) in winter. It can be seen that on all locations's NOx within the NAAQS annual limit, i.e., 40 µg/m^3, it can be seen that all locations comply with the standards (complied more than 98% times) while comparing with the NAAQS 24-hour limit, i.e., 80 µg/m^3.

- The concentration of CO varies from **0.08** to **4.21** mg/m^3, with a yearly average concentration of **0.884** with standard deviation **0.40** mg/m^3. As shown in Graph 5, the highest concentration of CO is at location A-2 (Oil Jetty No. 7) in winter. It can be seen that at all locations, they're complying (more than 98% of the time) with the NAAQS 1 hour limit, i.e., 4 mg/m^3. Location A-5 (the coal storage area) had the maximum percentage exceedance, i.e., **7.36**%, which is about 7 days out of 95 days of monitoring, and other locations such as Location A-2 (Oil Jetty No. 7), Location A-3 (Kandla Port Colony), Location A-4 (Marine Bhavan), and Location A-6 (Gopalpuri Hospital) had percentage exceedances of **5.26, 5.26, 2.85**, and **2.85**, respectively. And location A-1 (oil jetty no. 1) comply with the standards (compliance more than 98% times) while comparing with the NAAQS 8-hour limit, i.e., 2 mg/m3.

- The concentration of total VOC levels was recorded in the range of **0.01** to **17.43** µg/m3, with a yearly average value of **1.14** with standard deviation 1.21 µg/m3 at Kandla. As shown in graph 6, the highest concentration of VOCs is at location **A-3, (Kandla port colony)**; this is the only spike observed in the whole monitoring period for VOCs at this location. The main source of VOCs in the ambient air may be attributed to the burning of gasoline and natural gas in vehicle exhaust, burning fossil fuels, and garbage that releases VOCs into the atmosphere. During the monitoring period, the wind flows in the south direction at Kandla, and hence the wind direction and speed also contribute to increased dispersion of pollutants from the upward areas towards the downward areas.

  Polycyclic Aromatic Hydrocarbons (PAHs): are ubiquitous pollutants in urban atmospheres. Anthropogenic sources of total PAHs in ambient air emissions are greater than those that come from natural events. These locations are commercial areas where Vehicular activity and dust emission is common. PAHs are a class of chemicals that occur naturally in coal, crude oil, and gasoline. The higher concentration which results from burning coal, oil, gas, road dust, etc. Other outdoor sources of PAHs may be the industrial plants in-and-around the DPA premises.

- The concentration of Benzene levels was recorded in the range of **0.02** to **3.8** µg/m^3, with a yearly average value of **0.84** with standard deviation **0.64** µg/m^3. The highest concentration of Benzene is at location **A-1, (Oil Jetty No. 1)** in summer. It can be seen that at all locations, Benzene within the NAAQS annual limit, i.e., 5 µg/m3.

- The ambient air monitoring location of Kandla recorded the non-methane VOC (NM-VOC) concentration in the range of **0.08** to **3.54** µg/m3, with a yearly average value of **0.86** µg/m3 at Kandla. The highest concentration is at location **A-3, (Kandla Port Colony** in Winter.

2) Vadinar:

Particulate matter: The concentration of PM10 at Vadinar varies in the range of **1.45 to 443.2** µg/m^3, with a yearly average value of **63.49** with a standard deviation of **34.76** µg/m3. As shown in Graph 1, the highest concentration of PM_{10} is at location A-7 (Admin Building Vadinar) in the winter. It can be seen that at location A-7 (Admin Building Vadinar), PM_{10} exceeds the NAAQS annual limit, i.e., 60 µg/m^3, and at location A-8 (Vadinar Colony), it falls within the annual standards. It can be seen that locations A-7 (Admin Building Vadinar) and A-8 (Vadinar Colony) had a 5.15% percentage exceedance while comparing with the NAAQS 24-hour limit, i.e., 100 µg/m^3.

- The concentration of $PM_{2.5}$ varies in the range of **2.36** to **71.18** µg/m^3, with a yearly average value of **24.42** with a standard deviation **of 9.69** µg/m^3. As shown in Graph 2, the highest concentration of $PM_{2.5}$ is at location **A-7 (Admin Building Vadinar)** in winter. It can be seen that in all two locations, $PM_{2.5}$ is within the NAAQS annual limit, i.e., 40 µg/m^3. it can be seen that on both locations, **A-7 (building Vadinar)** and **A-8 (Vadinar Colony)** comply with the standards (complimented more than 98% times) while comparing with the NAAQS 24-hour limit, i.e., 60 µg/m^3.

Gaseous Pollutants:

- The concentration of SOx varies from **0.52** to **69.91** µg/m3, with a yearly average concentration of 13.146 with a standard deviation of 14.14 µg/m3. As shown in Graph 3, the highest concentration of SOx is at location A-8 (Vadinar Colony) in the winter. It can be seen that in all locations, SOx are within the NAAQS annual limit, i.e., 50 µg/m^3. It can be seen that both locations comply with the standards (compliance more than 98% times) while comparing with the NAAQS 24-hour limit, i.e., 80 µg/m^3.
- The concentration of NOx varies from **0.9** to **52.76** µg/m^3, with a yearly average concentration of **11.28** with a standard deviation of **7.17** µg/m^3. As shown in Graph 4, the highest concentration of NOx is at location A-7 (Admin Building Vadinar) in the winter. It can be seen that in all locations, NOx is within the NAAQS annual limit, i.e., 40 µg/m^3. It can be seen that all locations comply with the standards (compliance more than 98% of the time) while comparing with the NAAQS 24-hour limit, i.e., 80 µg/m^3.
- The concentration of CO varies from **0.03** to **3.14** mg/m3, with a yearly average concentration of **0.87** with a standard deviation **0.41** mg/m^3. As shown in Graph 5, the highest concentration of CO is at location **A-7, (Admin Building Vadinar)** in winter. it can be seen that at all locations they are complying (Complied more than 98% times) with the NAAQS 1 hour limit, i.e., 4 mg/m^3. Both **locations A-7, (Admin building Vadinar)** and **A-8,(Vadinar Colony)** had **5.16%** exceedance, which is about 5 days out of 97 days of monitoring, while comparing with the NAAQS 8-hour limit, i.e., 2 mg/m3.
- The concentration of **Total VOCs** levels was recorded in a range of **0 to 6.62** µg/m^3 with a yearly average value of **0.96** with a standard deviation of **1.051** µg/m^3 at Vadinar. As shown in graph 6, the **highest** concentration of **VOCs** is at

location A-8, (Vadinar Colony), this is the only spike observed in the whole monitoring period for VOCs at this location.

Polycyclic Aromatic Hydrocarbons (PAHs):

- The concentration of **Benzene** levels was recorded in a range of **0.01 to 1.03** $\mu g/m^{3,}$ with a yearly average value of **0.28** with a standard deviation of 0.36 $\mu g/m^3$. the **highest** concentration of Benzene is at **location A-7, (Admin building Vadinar)** in Winter. It can be seen that in all locations **Benzene** within the NAAQS annual limit, i.e., 5 $\mu g/m^3$.
- **Non-methane VOC** (NM-VOC) concentration at Vadinar was observed in the range of **0.07 to 2.15** $\mu g/m^3$ with a yearly average value of **0.82** with a standard deviation **0.085** $\mu g/m^3$. the **highest** concentration is at **A-7, (Admin building Vadinar)** in Winter.

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

1. **Port Machinery:** Port activities involve the use of various machinery and equipment, including cranes, for lifts, tugboats, and cargo handling equipment. These machines often rely on diesel engines, which can emit pollutants such as NO_x, Particulate matter, and CO. Older or poorly maintained equipment tends to generate higher emissions.
2. **Port Vehicles:** Trucks and other vehicles operating within port and port area contributes to air pollution. Similar to port machinery, diesel-powered vehicles can emit NO_x, PM, CO, and other pollutants such as PAH, VOCs etc. Vehicle traffic and congestion in and around port areas can exacerbate the air quality issues.
3. **Coal Handling:** Resuspension of dust occurs due to the transportation of coal and the handling of coal.
4. **Construction Activities:** Another reason for the high particulate matter content in this area is due to high construction activities in the surrounding area.

4.4 Remedial Measures:

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

- Practice should be initiated for using mask as preventative measure, to avoid Inhalation of dust particle-Mask advised in sensitive areas. Covering vehicles with tarpaulin during transportation will help to reduce the suspension of pollutants in air.
- Ensuring maintenance of engines and machinery to comply with emission standards.
- Frequent water sprinkling on roads to reduce dust suspension due to vehicular movement, this can be use during transporting coal to avoid suspension of coal dust.
- Use of proper transport methods, such as a conveyor belt, for excavated material and screens around the construction site.
- End to End pavement of roads in construction site could considerably reduce dust emission. Prohibition of use of heavy diesel oil as fuel could be possibly reduce pollutants. Encouraging use of low-sulfur fuels (viz. Marine Gas Oil (MGO)/Liquefied Natural Gas (LNG), can significantly reduce sulfur and PM emissions from ships.
- Retrofitting ships with exhaust gas cleaning systems can help reduce sulfur emissions. Engine upgrades, such as optimizing fuel combustion and improving engine efficiency, can reduce overall emissions.
- Investing in infrastructure for cold ironing allows ships to connect to the electrical grid while docked, reducing the need for auxiliary engines and associated emissions.
- Implementing efficient cargo-handling processes, optimizing logistics to reduce congestion and idling times, and encouraging use of cleaner port machinery and vehicles can all contribute to reducing air pollution in port areas.
- Shrouding shall be carried out in the work site enclosing the dock/proposed facility area. This will act as dust curtain as well achieving zero dust discharge from the site. These curtain or shroud will be immensely effective in restricting disturbance from wind in affecting the dry dock operations, preventing waste dispersion, improving working conditions through provision of shade for the workers.
- Dust collectors shall be deployed in all areas where blasting (surface cleaning) and painting operations are to be carried out, supplemented by stacks for effective dispersion.
- Periodic vacuum-sweeping mechanisms shall be adopted.

CHAPTER 5: DG STACK MONITORING

5.1 DG Stack Monitoring

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

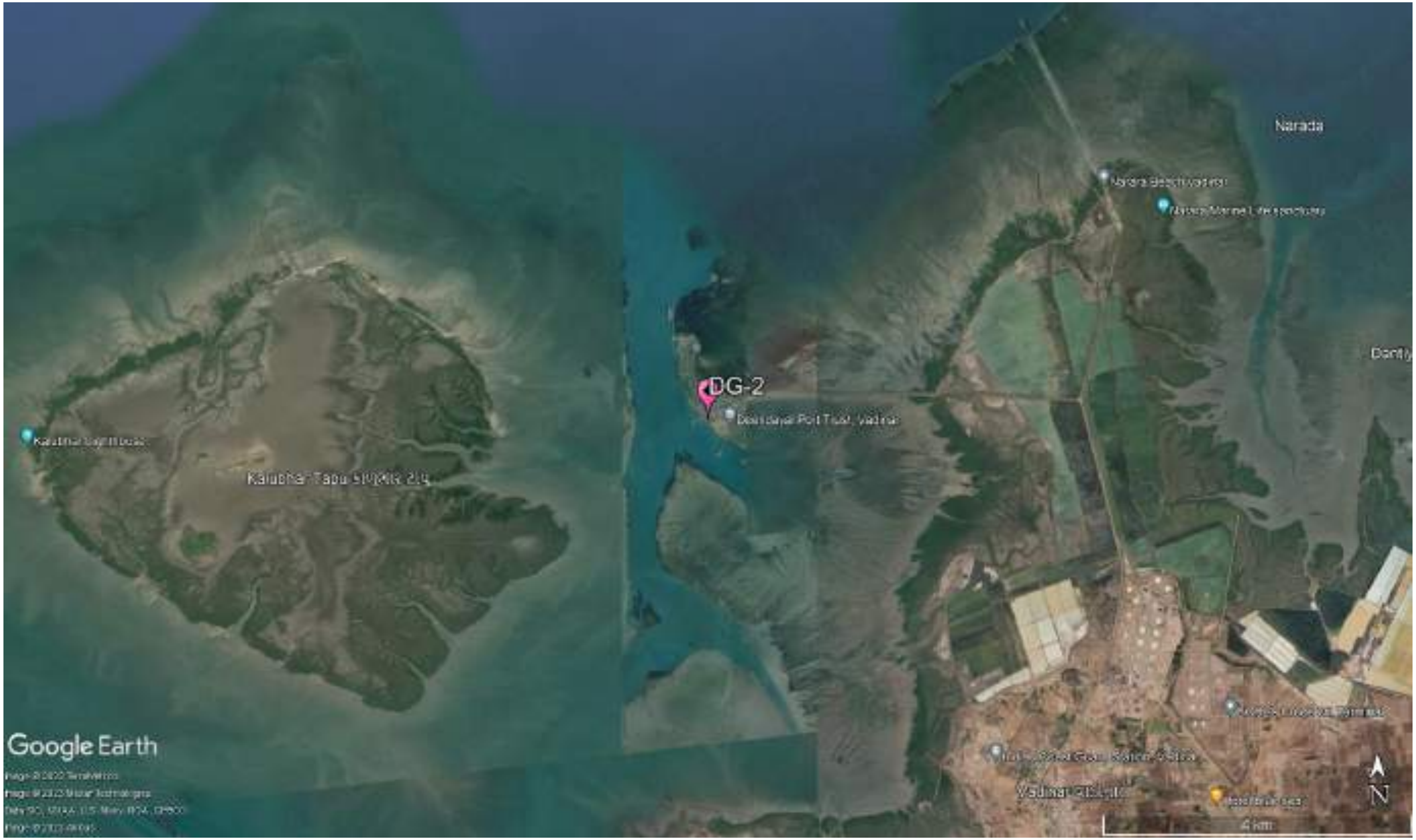
As defined in scope by DPA, the monitoring of DG Stack shall be carried out at two locations, one at Kandla and one at Vadinar. The details of the DG Sets at Kandla and Vadinar have been mentioned in Table 10 as follows:

Table 10: Details of DG Stack monitoring locations

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

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

Map 6: DG Stack monitoring Locations at Kandla



Map 7: DG Stack monitoring Locations at Vadinar

Methodology:

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

Table 11: DG stack parameters

Sr. No.	Parameter	Unit	Instrument
1.	Suspended Particulate Matter	**mg/Nm³**	**Stack Monitoring Kit**
2.	Sulphur Dioxide (SO_2)	PPM	**Sensor based Flue Gas Analyzer (Make: TESTO, Model 350)**
3.	Oxides of Nitrogen (NO_x)	PPM	
4.	Carbon Monoxide	%	
5.	Carbon Dioxide	%	

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

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

Monitoring Frequency

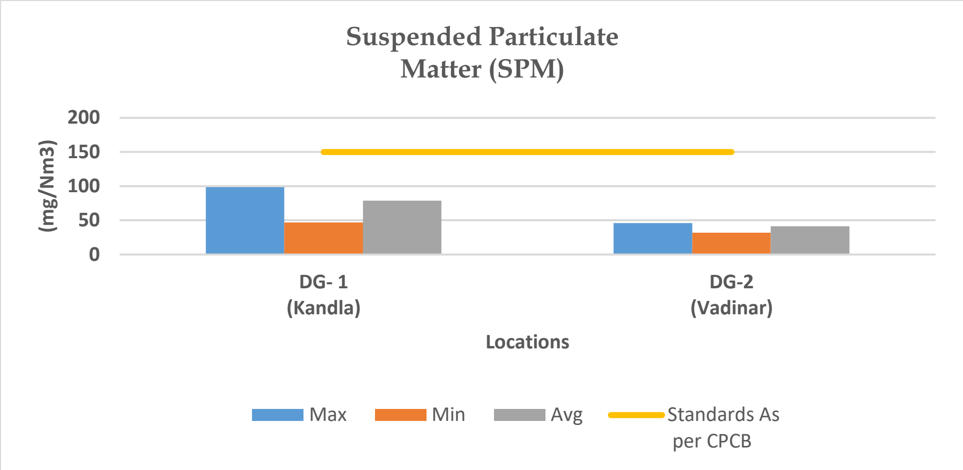
Monitoring is required to be carried out once a month for both the locations of Kandla and Vadinar for a period of April 2023 to March 2024.

5.2 Result and Discussion

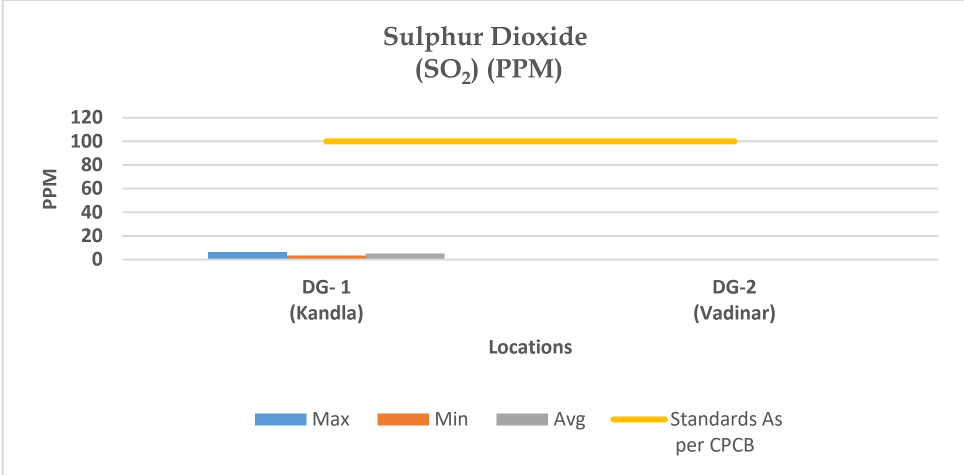
The sampling and monitoring of DG stack emission was carried out for monitoring period at Kandla and Vadinar and its comparison with CPCB or Indian standards for Industrial Stack Monitoring the flue gas emission from DG set has given in **Table 12.**

Table 12: DG monitoring data

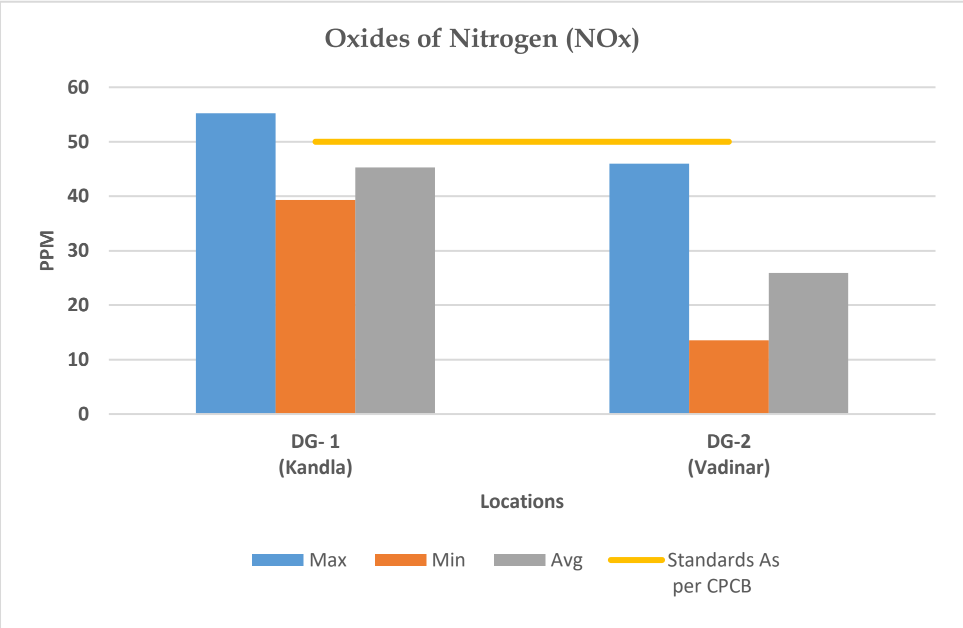
Sr. No.	Stack Monitoring Parameters for DG Sets		DG- 1 (Kandla)	DG-2 (Vadinar)	Stack Monitoring Limits /Standards As per CPCB
1.	**Suspended Particulate Matter (SPM) (mg/Nm³)**	**Max**	98.47	45.32	**150**
		Min	46.82	31.85	
		Avg.	78.96	41.33	
2.	**Sulphur Dioxide (SO2) (PPM)**	**Max**	6.45	N.D.	**100**
		Min	3.25	N.D.	
		Avg.	4.95	N.D.	
3.	**Oxides of Nitrogen (NO_x) (PPM)**	**Max**	55.2	46	**50**
		Min	39.27	13.52	
		Avg.	45.31	25.92	
4.	**Carbon Monoxide (CO) (%)**	**Max**	0.34	0.016	**1**
		Min	0.007	0.002	
		Avg.	0.16	0.01	
5.	**Carbon Dioxide (CO_2) (%)**	**Max**	3.09	1.42	**-**
		Min	1.21	1.03	
		Avg.	1.92	1.19	



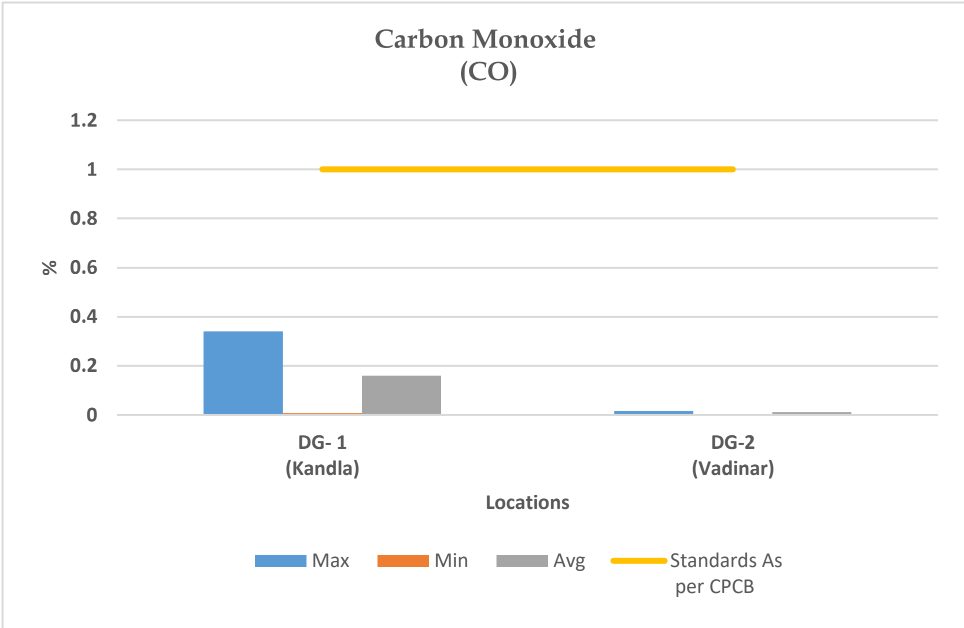
Graph 7 Spatial trend in SPM Concentration



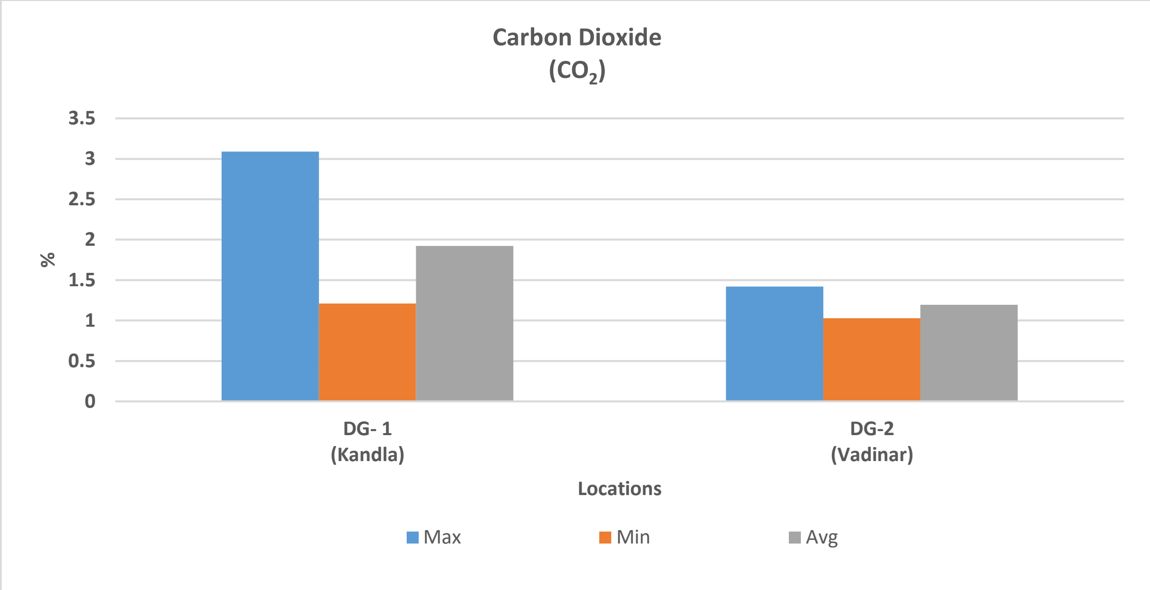
Graph 8 Spatial trend in SO_x Concentration



Graph 9 Spatial trend in NOx Concentration



Graph 10 Spatial trend in CO Concentration



Graph 11 Spatial trend in CO_2 Concentration

5.3 Data Interpretation and Conclusion

1) Kandla:

The Suspended Particulate Matter (SPM) varies in the range of **46.82** to **98.47** mg/m^3. The yearly average SPM of D.G stack-1 is **78.96** mg/m^3. The maximum concentration for SPM was observed in the monitoring period of October to November 2023. The Sulphur dioxide (SO_x) varies in the range of **3.25** to **6.45** PPM. The yearly average SO_x of D.G stack-1 is **4.95** PPM. The maximum concentration of SO_x observed in the monitoring period of October to November 2023.

The NO_x varies in the range of **39.27** to **55.2** PPM. The yearly average of NO_x of D.G stack-1 at Kandla is **45.31** PPM. The maximum concentration of NO_x observed in the monitoring period of July to August 2023.

The CO at Kandla varies in the range of **0.007** to **0.34** %. The yearly average of CO of D.G stack-1 at Kandla is **0.16** % The maximum concentration of CO observed in the monitoring period of March to April 2024.

The CO_2 at Kandla varies in the range of **1.21** to **3.09** %. The yearly average of CO_2 of D.G stack-1 at Kandla is **1.92** % The maximum concentration of CO_2 observed in the monitoring period of March to April 2024.

The results of all the above parameters of DG stack-1 at Kandla emission are compared with the permissible limits mentioned in the consent issued by GPCB, and have been found within the prescribed limit for all the monitored parameters.

2) Vadinar:

The Suspended Particulate Matter (SPM) in the range of **31.85** to **45.32** mg/m^3. The yearly average SPM of D.G stack-2 at Vadinar is **41.33** mg/m^3. The maximum concentration of SPM was observed in the monitoring period of March to April 2024. There is no Sulphur dioxide (SO_x) concentration detected at Vadinar.

The NO_x at Vadinar varies in the range of **13.52** to **46** PPM. The yearly average of NO_x of D.G stack-2 at Vadinar is **25.928** PPM. The maximum concentration of NO_x observed in the monitoring period of June to July 2023.

The CO at Vadinar varies in the range of **0.002** to **0.016** %. The yearly average of CO of D.G stack-2 at Vadinar is **0.0106** % The maximum concentration of CO observed in the monitoring period of October to November 2023.

The CO_2 at Vadinar varies in the range of **1.03 to 1.42** %. The yearly average in CO_2 of D.G stack-2 at Vadinar is **1.92** % The maximum concentration of CO_2 observed in the monitoring period of June to July 2024.

The results of all the above parameters of DG stack-2 at Vadinar emission are compared with the permissible limits mentioned in the consent issued by GPCB, and have been found within the prescribed limit for all the monitored parameters.

CHAPTER 6: NOISE MONITORING

6.1 Noise Monitoring

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

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

Table 13: Details of noise monitoring locations

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

Map 8: Locations for Noise Monitoring at Kandla

Map 9: Locations for Noise Monitoring at Vadinar

Methodology:

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

Monitoring Frequency

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

Table 14: Details of the Noise Monitoring

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

Standard for Noise

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

Table 15: Ambient Air Quality norms in respect of Noise[(2)]

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

6.2 Result and Discussion

The details of the Noise monitoring conducted during the monitoring period April 2023 to March 2024 have been summarized in the **Table 16** as below:

Table 16: The Results of Ambient Noise Quality

Sr. No.	Station Code	Station Name	Category of Area	Standard	Day Time in dB(A)			Standard	Night Time in dB(A)		
					Max.	Min.	Avg.		Max.	Min.	Avg.
1	N-1	Oil Jetty 7	A	75	65.7	36.5	47.75	70	57.5	33	41.801
2	N-2	West Gate No.1	A	75	68.4	36.5	54.35	70	54.2	36.1	47.02
3	N-3	Canteen Area	B	65	66.2	38	52.61	55	52.1	33	43.46
4	N-4	Main Gate	A	75	61.4	35.3	50.69	70	50.8	36.1	43.33
5	N-5	Main Road	A	75	66.1	33.5	51.67	70	55.5	33.6	43.7
6	N-6	Marin Bhavan	B	65	62.3	38.9	52.52	55	52.3	31.9	43.23
7	N-7	Port & Custom Building	B	65	66.3	37.6	50.89	55	54.3	33.9	38.91
8	N-8	Nirman Building	B	65	60.8	40.9	51	55	58.9	35.2	43.02
9	N-9	ATM Building	B	65	65.1	35.1	49.7	55	53.4	34.1	39.25
10	N-10	Wharf Area/ Jetty	A	75	74.5	36.9	52.9	70	52.7	36	42.3
11	N-11	Near Main Gate	A	75	72.3	34	62.51	70	71.2	34.3	55.71
12	N-12	Near Vadinar Jetty	A	75	76.3	39.2	64.98	70	68.5	34.7	56.38
13	N-13	Port Colony Vadinar	C	55	77.5	37.7	50.05	45	65.9	36.2	49.5

6.3 Data Interpretation and Conclusion

1) **Kandla:** The noise level was compared with the standard limits specified in NAAQS by CPCB. During the Day Time, the average noise level at all 10 locations at Kandla ranged from **33.5** dB(A) to **74.5** dB(A) while, during Night Time the average Noise Level ranged from **31.9** dB(A) to **58.9** dB(A), of which six locations out of ten locations, noise level were within the permissible limits for the industrial, commercial area and residential zone for Day time and night time.

   Other Four locations such as i.e., **N-3 (Canteen Area)**, **N-7 (Port & Custom Building), N-8 (Nirman Building)** and **N-9 (ATM building)** which are Commercial areas, slightly exceed the standard limits prescribed by NAAQS by CPCB, in the monitoring period of **April to May 2023 and May to June 2023**.

2) **Vadinar:** The noise level was compared with the standard limits specified in NAAQS by CPCB. During the Day Time, the average noise level at all 3 locations at Vadinar ranged from **34** dB(A) to **77.5** dB(A) while, during Night Time the average Noise Level ranged from **34.3** dB(A) to **71.2** dB(A) at Vadinar, on location **N-11 (Near main gate)** noise level was within the permissible limits for the industrial zone for Day time and night time.

   On locations of Vadinar such as i.e., **N-12 (Near Vadinar jetty)**, which are considered as industrial area slightly exceed the standard limits prescribed by NAAQS by CPCB, in the monitoring period **of June to July 2023**. And on location **N-13 (Port Colony Vadinar)**, most frequently exceed the permissible limit during the day time as well as night time.

6.4 Remedial Measures

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

CHAPTER 7: SOIL MONITORING

7.1 Soil Quality Monitoring:

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

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

Table 17: Details of the Soil quality monitoring

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

Methodology

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

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

Monitoring Frequency

Monitoring is required to be carried out once a month for both the locations of Kandla and Vadinar. The monitoring was done from April 2023, to March, 2024.

Table 18: Soil parameters

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

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

Map 10: Soil Quality Monitoring Locations at Kandla

Map 11: Soil Quality Monitoring Locations at Vadinar

7.2 Result and Discussion

The analysis results of physical analysis of the soil samples collected during environmental monitoring period during April 2023 to March 2024 mentioned in **Table 19** are shown below:

Table 19: Soil Quality for the Monitoring period

Sr. No	Parameters \ Location		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	Max	9.53	8.8	8.88	9.48	8.69	9.36
		Min	7.3	6.48	6.52	7.86	7.19	8.16
		Avg.	8.24	8.20	7.96	8.52	8.14	8.55
2	Conductivity (µS/cm)	Max	71500	36500	75700	17850	501	625
		Min	587	526	586	204	63	127
		Avg	26881.17	11442	20646.33	5470	177.13	281.54
3	Inorganic Phosphate (Kg/ha)	Max	13.32	619.89	20.31	15.87	5.64	8.67
		Min	0.39	0.43	1.24	0.32	0.35	0.26
		Avg	4.21	57.15	5.64	4.71	2.39	2.25
4	Organic Carbon (%)	Max	2.83	2.54	3.83	3.35	0.85	2.48
		Min	0.03	0.08	0.14	0.27	0.06	0.14
		Avg	0.91	0.79	1.06	0.92	0.33	0.59
5	Organic Matter (%)	Max	4.88	4.38	6.6	5.78	1.47	4.28
		Min	0.06	0.14	0.24	0.32	0.09	0.241
		Avg	1.57	1.36	1.82	1.48	0.57	1.01
6	SAR (meq/L)	Max	41.45	22.91	31.51	10.01	0.25	0.45
		Min	0.81	0.36	0.5	0.36	0.05	0.09
		Avg	13.24	6.56	11.71	2.57	0.10	0.17
7	Aluminium (mg/Kg)	Max	8643.04	9065.97	10298.7	9286.91	15921.7	14806.19
		Min	812.75	830.95	840.71	916.4	735.77	754.58
		Avg	2223.8	2322.3	2517.4	2470.4	2848.2	2762.2
8	Chromium (mg/Kg)	Max	92.23	90.7	86.18	87.07	106	91.88
		Min	28.213	28.91	31.57	24.7	71.68	60.93
		Avg	52.28	58.79	59.005	53.30	82.46	70.91
9	Nickel (mg/Kg)	Max	33.32	36.66	38.1	45.41	41.425	42.68
		Min	13.17	11.82	11.91	10.43	27.14	25.52
		Avg	19.17	19.22	22.72	21.72	33.29	32.353
10	Copper (mg/Kg)	Max	92.51	88.31	150.7	192.72	123.18	104.64
		Min	12.42	14.71	14.74	12.8	81.14	60.57
		Avg	49.94	61.10	84.93	56.708	103.06	82.37
11	Zinc (mg/Kg)	Max	210.35	1755.44	188.29	142.71	88.14	97.36
		Min	16.46	42.93	29.9	23.57	37.03	15.33
		Avg	73.75	283.57	99.49	81.77	62.53	49.70
12	Cadmium (mg/Kg)	Max	0.397	23.47	0.59	0	3	0
		Min	0.397	0.5	0.59	0	3	0
		Avg	0.397	6.608	0.59	0	3	0
13	Lead (mg/Kg)	Max	50.28	277.82	47.87	26.48	1.58	21.07
		Min	3.79	2.58	1.29	2.26	0.59	0.89
		Avg	12.09	32.75	15.59	8.88	1.08	6.66

Sr. No	Parameters (Location)		Kandla S-1 (Oil Jetty 7)	Kandla S-2 IFFCO Plant)	Kandla S-3 (Khori Creek)	Kandla S-4 (Nakti Creek)	Vadinar S-5 (Near SPM)	Vadinar S-6 (Near Vadinar Jetty)
14	Arsenic (mg/Kg)	Max	4.87	8.4	5.28	6.62	0.4	5.05
		Min	0.1	0.29	0.88	0.3	0.099	0.59
		Avg	2.38	3.04	2.97	2.26	0.22	2.82
15	Mercury (mg/Kg)	Max	0	0	0	0	0	0
		Min	0	0	0	0	0	0
		Avg	0	0	0	0	0	0
16	Water Holding Capacity (%)	Max	54	77.92	61.99	75.84	60	66
		Min	35.8	34	23.74	15.9	39.85	44
		Avg	42.66	46.48	43.95	48.34	47.70	60.01
17	Sand (%)	Max	77.61	77.7	85.46	82.36	62.4	78.46
		Min	44.4	46.57	48.27	13.39	42.26	42.25
		Avg	59.26	65.74	62.96	65.03	51.61	60.59
18	Silt (%)	Max	53.28	47.28	41.25	57.98	49.27	53.27
		Min	9.77	9.28	9.93	9.28	12.24	12
		Avg	30.41	26.40	28.84	24.13	34.72	29.17
19	Clay (%)	Max	19.53	14.32	22.35	28.63	35.92	21.02
		Min	2.32	0.63	0.64	0.48	1.75	1.74
		Avg	10.29	7.86	8.19	10.83	13.66	10.23
20	Texture		Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Loam	Sandy Loam

7.3 Data Interpretation and Conclusion

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

1) Kandla:

- The value of **pH** ranges from **6.48** to **9.53**, with the highest at location **S-1 (Oil Jetty 7)** and the lowest at **location S-2 (IFFCO plant),** while the average pH for Kandla was observed to be **8.23**. The pH in Kandla varies from **Slightly alkaline to strongly alkaline**

- At all monitoring locations, the value of **Electrical Conductivity** ranges from **204 to 75,700** µs/cm, with the highest at **location S-3 (Khori Creek**) and the lowest at **S-4 (Nakti Creek).** The average Electrical Conductivity is **16,109.87** µs/cm.

- The concentration of inorganic phosphate varied from **0.32** to **619.89** kg/ha, with an average of **17.93** kg/ha. The highest concentration of inorganic phosphate was found at **S-2 (IFFCO plant)** and the lowest concentration was found at **S-4 (Nakti Creek)**. The availability of phosphorus in the soil solution is influenced by several factors, such as organic matter, clay content, pH, temperature, and more.

- The concentration of **Total Organic Carbon** ranges from **0.03% to 3.86%,** with an average TOC of **0.92%** detected. The highest concentration was found at **location S-3 (Khori Creek),** and the minimum concentration was found **at S-1 (Oil Jetty 7).**
- The **Sodium Adsorption Ratio** ranges from **0.36** to **41.45** meq/L, with an average value of **8.25** meq/L at Kandla. The highest concentration of SAR is found at **S-1 (Oil Jetty 7)** and the lowest concentration at **S-4 (Nakti Creek)**.
- The **Water Holding Capacity (WHC)** in the soil samples of Kandla varies from **15.9% to 77.92%**, with an average of **45.36%**. The highest concentration of WHC was observed at **S-2 (IFFCO plant)** and the lowest concentration at **S-4 (Nakti Creek)**.
- The Soil Texture was observed as "**Sandy loam**" to "**loamy sand**" at all the monitoring locations in Kandla.

Heavy Metals

- During the sampling period, the concentration of **Aluminium** varied from **812.75** to **10,298.7** mg/kg. The average **Aluminium** concentration was observed to be **2,383.475** mg/kg at the Kandla monitoring station. The **highest concentration** was observed at **S-3 (Khori Creek)**, and the **lowest concentration** was observed at **S-1 (Oil Jetty 7)**.
- The concentration of **Chromium** varied from **24.7 to 92.23** mg/kg, with an average value of **55.848** mg/kg observed at the Kandla monitoring station. The highest concentration was observed at **S-1 (Oil Jetty 7)**, and the lowest concentration was observed at **S-4 (Nakti Creek)**.
- The concentration of **Nickel** varied from **10.43** to **45.41** mg/kg at Kandla, with an average value of **20.71** mg/kg at the Kandla monitoring station. The highest concentration was observed at **S-4 (Nakti Creek)**, while the lowest concentration was also observed at **S-4 (Nakti Creek)**.
- The concentration of **Zinc** varied from **16.46** to **1755.4** mg/kg at Kandla, with an average value of **134.64** mg/kg at the Kandla monitoring station. The highest concentration was observed at **S-2 (IFFCO plant)**, which was the only spike observed during the entire monitoring period at Kandla. The lowest concentration was observed at **S-1 (Oil Jetty 7)**.
- The concentration of **Copper** varied from **12.42** to **192.72** mg/kg, with an average value of **13.667** mg/kg observed at the Kandla monitoring station. The highest concentration was observed at **S-4 (Nakti Creek)** and the lowest concentration was observed at **S-1 (Oil Jetty 7)**.
- The concentration of Lead varied from **1.29 to 277.82** mg/kg, with an average value of **17.33** mg/kg. The highest concentration was observed at **S-2 (IFFCO plant)**; this was the only spike observed during the entire monitoring period, while the lowest concentration was observed at **S-3 (Khori creek)**.
- The concentration of A**rsenic** varied from **0.1 to 8.4** mg/kg, with an average value of **2.67** mg/kg. The highest concentration was observed at **S-1 (Oil Jetty 7)**, and the lowest concentration was observed at **S-3 (Khori Creek)**.
- The concentration of **Cadmium** varied from **0** to **23.47** mg/kg, with an average value of **1.89** mg/kg. The highest concentration was observed at **S-2 (IFFCO plant)**. During the monitoring period, it was observed that cadmium was mostly found **Below**

Quantification Limit (BQL) at all locations, with only one spike observed at **S-2 (IFFCO plant)** throughout the entire monitoring period.

- During the monitoring period, it was observed that the concentration of **Mercury** was mostly found **below the quantification limit (BQL)** at all locations.

2) Vadinar:

- The value of **pH** ranges from **7.675** to **9.36**, with the highest at location **S-6 (Near Vadinar jetty)** and the lowest at **location S-5 (Near SPM),** while the average pH for Vadinar was observed to be **8.34**. pH of Soil at Vadinar was found to be **moderately alkaline**.
- At all monitoring locations in Vadinar, the value of **Electrical Conductivity** ranges from **63 to 625** µs/cm, with the highest at **S-6 (Near Vadinar jetty)** and the lowest at **location S-5 (Near SPM).** The average Electrical Conductivity is **229.33** µs/cm.
- The concentration of **inorganic phosphate** varied from **0.26** to **8.67** kg/ha, with an average of **2.32** kg/ha. The highest concentration of inorganic phosphate was found at **S-6 (Near Vadinar jetty)** and the lowest concentration was found at **location S-5 (Near SPM)**.
- The concentration of **Total Organic Carbon** ranges from **0.06% to 2.48%,** with an average TOC of **0.46%** detected at Vadinar. The highest concentration was found at **S-6 (Near Vadinar jetty),** and the minimum concentration was found **at S-5 (Near SPM).**
- The **Sodium Adsorption Ratio** ranges from **0.05** to **0.45** meq/L, with an average value of **0.143** meq/L at Vadinar. The highest concentration of SAR is found at **6 (Near Vadinar jetty)** and the lowest concentration at **S-5 (Near SPM)**.
- The **Water Holding Capacity (WHC)** in the soil samples of Vadinar varies from **39.85% to 66%**, with an average of **53.85%**. The highest concentration of WHC was observed at **S-6 (Near Vadinar jetty)** and the lowest concentration at **S-5 (Near SPM)**.
- The soil texture of Vadinar varies from "loam" to "slit loam".

Heavy Metals

- During the sampling period, the concentration of **Aluminium** varied from **735.77** to **15921.72** mg/kg. The average **Aluminium** concentration was observed to be **2,805.2** mg/kg at the Vadinar monitoring station. The **highest concentration** was observed at **S-5 (Near SPM)**, and the **lowest concentration** was observed at **S-5 (Near SPM) but during different months**.
- The concentration of **Chromium** varied from **60.93 to 106** mg/kg, with an average value of **76.69** mg/kg observed at the Vadinar monitoring station. The highest concentration was observed at **S-5 (Near SPM)**, and the lowest concentration was observed at **S-6 (Near Vadinar jetty)**.
- The concentration of **Nickel** varied from **25.62** to **42.68** mg/kg, with an average value of **32.825** mg/kg at the Vadinar monitoring station. The highest concentration was observed at **S-6 (Near Vadinar jetty)**, and the lowest concentration was also observed at **S-6 (Near Vadinar jetty)** but during different months.

- The concentration of **Zinc** varied from **15.33** to **97.36** mg/kg, with an average value of **56.118** mg/kg at the Vadinar monitoring station. The highest concentration was observed at **S-6 (Near Vadinar jetty)**, and the lowest concentration was also observed at **S-6 (Near Vadinar jetty)** but during different months.
- The concentration of **Copper** varied from **60.57** to **123.18** mg/kg, with an average value of **92.71** mg/kg observed at the Vadinar monitoring station. The highest concentration was observed at **S-5 (Near SPM)** and the lowest concentration was observed at **S-6 (Near Vadinar jetty)**.
- The concentration of **Lead** varied from **0.59 to 21.07** mg/kg, with an average value of **3.875** mg/kg. The highest concentration was observed at **S-6 (Near Vadinar jetty)**; this was the only spike observed during the entire monitoring period at Kandla, while the lowest concentration was observed at **S-5 (Near SPM)**.
- The concentration of A**rsenic** varied from **0.099 to 0.59** mg/kg, with an average value of **5.05** mg/kg. The highest concentration was observed at **S-6 (Near Vadinar jetty)**, and the lowest concentration was observed at **S-5 (Near SPM)**.
- The concentration of **Cadmium** varied from **0** to **3** mg/kg, with an average value of **3** mg/kg. The highest concentration was observed at **S-5 (Near SPM)**. During the monitoring period, it was observed that cadmium was mostly found **Below Quantification Limit (BQL)** at all locations.
- During the monitoring period, it was observed that the concentration of **Mercury** was mostly found **below the quantification limit (BQL)** at all locations.

CHAPTER 8: DRINKING WATER MONITORING

8.1 Drinking Water Monitoring

It is necessary to check with the drinking water sources regularly so as to know whether water quality conforms to the prescribed standards for drinking. Monitoring the drinking water quality is essential to protect human health and the environment. With reference to the scope specified by DPA, a total of 20 locations (18 at Kandla and 2 at Vadinar) were monitored to assess the Drinking Water quality.

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

Table 20: Details of Drinking Water Sampling Locations

Sr. No.	Location Code		Location Name	Latitude/ Longitude
1.	Kandla	DW-1	Oil Jetty 7	23.043527N 70.218456E
2.		DW-2	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

Map 12: Drinking Water Monitoring Locations at Kandla

Map 13: Drinking Water Monitoring Locations at Vadinar

Methodology

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

Table 21: List of parameters for Drinking Water Quality monitoring[3]

Sr. No.	Parameters	Units	Reference method	Instrument
1.	pH	-	APHA, 23rd Edition (Section-4500-H^+B):2017	pH Meter
2.	Colour	Hazen	APHA, 23rd Edition, 2120 B:2017	Color Comparator
3.	EC	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
4.	Turbidity	NTU	APHA, 23rd Edition (Section -2130 B):2017	Nephlo Turbidity Meter
5.	TDS	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with filtration assembly and Oven
6.	TSS	mg/L	APHA, 23rd Edition, 2540 D: 2017	
7.	Chloride	mg/L	APHA, 23rd Edition (Section-4500-Cl-B):2017	Titration Apparatus
8.	Total Hardness	mg/L	APHA, 23rd Edition (Section-2340 C):2017	
9.	Ca Hardness	mg/L	APHA, 23rd Edition (Section-3500-Ca B):2017	
10.	Mg Hardness	mg/L	APHA, 23rd Edition (Section-3500-Mg B):2017	
11.	Free Residual Chlorine	mg/L	APHA 23rd Edition, 4500	
12.	Fluoride	mg/L	APHA, 23rd Edition (Section-4500-F-D):2017	UV- Visible Spectrophotometer
13.	Sulphate	mg/L	APHA, 23rd Edition (Section 4500-SO4-2-E):2017	
14.	Sodium	mg/L	APHA, 23rd Edition (Section-3500-Na-B):2017	Flame Photometer
15.	Potassium	mg/L	APHA,23rd Edition, 3500 K-B: 2017	
16.	Salinity	mg/L	APHA, 23rd Edition (section 2520 B, E.C. Method)	Salinity /TDS Meter
17.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3- B: 2017	UV- Visible Spectrophotometer
18.	Nitrite	mg/L	APHA, 23rd Edition, 4500 NO2-B: 2017	
19.	Hexavalent Chromium	mg/L	APHA, 23rd Edition, 3500 Cr B: 2017	
20.	Manganese	mg/L	APHA,23rd Edition, ICP Method 3120 B: 2017	ICP-OES

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

Monitoring Frequency

Monitoring is required to be carried out once a month for both the locations of Kandla and Vadinar. Sample Collected from this location during the monitoring period April/2023 to March/2024.

8.2 Result and Discussion

The drinking water quality of the locations at Kandla and Vadinar and its comparison with the to the stipulated standard (Drinking Water Specifications i.e., IS: 10500:2012) [(4)] have been summarized in **Table 22A, 22B, 22C** as follows:

Table 22A: Drinking Water Quality for the Monitoring period

Parameters	Standard values as per IS-		DW-1 (Oil Jetty 7)			DW-2 (Port & Custom Building)			DW-3 (North Gate)			DW-4 (Workshop)			DW-5 (Canteen Area)			DW-6 (West Gate 1)			DW-7 (Sewa Sadan -3)		
	A	P	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
pH	6.5-8.5		7.9	6.6	7.4	8.4	6.8	7.3	8.0	6.8	7.3	8.1	7.1	7.4	8.2	7.3	7.7	8.4	7.2	7.7	8.2	7.2	7.5
Colour (Hazen)	5	15	5.0	1.0	1.7	5.0	1.0	1.3	5.0	1.0	1.3	5.0	1.0	1.3	5.0	1.0	3.3	5.0	1.0	1.7	5.0	1.0	1.3
EC (µS/ cm)			370	19.4	195.6	600.	36.0	153.8	1653	27.0	259.7	401	12.8	85.6	2200	42.0	1056	1470	28.0	336.3	150	22	57.8
Salinity (PSU)			1.0	0.0	0.2	0.3	0.0	0.1	0.8	0.0	0.1	0.2	0.0	0.0	1.1	0.0	0.5	0.7	0.0	0.2	0.1	0	0.0
Turbidity (NTU)	1	5	1.2	1.1	1.1	2.0	1.5	1.8	1.9	0.7	1.2	3.7	0.9	2.3	3.1	0.9	1.9	1.5	1.0	1.2	5.9	1.1	3.5
Chloride (mg/L)	250	1000	81	5.8	41.6	92	7.5	34.1	354.9	8.0	56.9	110	3	22.9	437.4	10.3	192.0	329.9	9.0	78	42.5	6.5	15.7
Total Hardness (mg/L)	200	600	42	3	13.3	148	3	24.8	320	2.0	33.4	20.0	2	7.5	310	10	181	230	5.0	53.2	10	2	4.1
Ca Hardness (mg/L)			27	2	6.3	92	2	13.9	200	1.0	20.3	8.0	1	3.3	210.0	5	103.9	120.0	2.5	28.9	5.0	1	2.2
Mg Hardness (mg/L)			15	1	6.8	56	1	10.1	120	1.0	13.1	12	1	3.9	120.0	5	76.6	110.0	2.0	24.4	5.0	1	2
Free Residual Chlorine (mg/L)	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TDS (mg/L)	500	2000	184	10	101.7	306	20	81.8	840	14	132.7	204	8.0	44.7	928	22	452.4	752	20.0	171.6	78	14	30.8
TSS (mg/L)			0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0	0
Fluoride (mg/L)	1	1.5	0.4	0.4	0.4	0.5	0.4	0.5	0.7	0.3	0.4	0.0	0.0	0.0	0.9	0.3	0.5	0.9	0.7	0.8	0.4	0.4	0.4
Sulphate (mg/L)	200	400	15.7	15.7	15.7	35.7	35.7	35.7	73.9	73.9	73.9	0.0	0.0	0.0	113.3	2.2	64.0	97.3	2	55.3	0	0	0

Parameters	Standard values as per IS-		DW-1 (Oil Jetty 7)			DW-2 (Port & Custom Building)			DW-3 (North Gate)			DW-4 (Workshop)			DW-5 (Canteen Area)			DW-6 (West Gate 1)			DW-7 (Sewa Sadan -3)		
	A	P	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Nitrate (mg/L)	45		26	3.7	12.5	4.2	0.5	1.8	7.5	1.3	4.6	2.4	2.4	2.4	8.8	3.4	5.8	5.7	1.3	2.8	2.1	2.1	2.1
Nitrite (mg/L)			0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0.1	0.2	0.2	0.2	0	0	0
Sodium (mg/L)			86	5	34.5	38.5	7	21.2	178.6	9.7	38.0	42.6	5.7	18.0	319.6	12.0	118.4	197.5	8.8	44.1	15.1	5.5	9.6
Potassium (mg/L)			0	0	0	0	0	0	0	0	0	0	0	0	5.8	5.8	5.8	0	0	0	0	0	0
Hexavalent Chromium (mg/L)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odour (TON)	Agreeable			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Arsenic (mg/L)	0.01	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadmium (mg/L)	0.003		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copper (mg/L)	0.05	1.5	17.3	0	5.8	8.4	0.0	2.8	6.2	0.0	3.1	11.1	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iron (mg/L)	0.3		0.6	0	0.3	0.2	0.2	0.2	0.2	0.0	0.1	0.2	0.2	0.2	0.2	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.1
Lead (mg/L)	0.01		3.1	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Manganese (mg/L)	0.1	0.3	0.1	0	0.1	0	0	0	0.5	0.5	0.5	0.1	0.1	0.1	0	0	0	0.5	0	0.2	0	0	0
Mercury (mg/L)	0.001		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Chromium (mg/L)	0.05		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinc (mg/L)	5	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Coliform* (MPN/ 100ml)	Shall not be detected		630.0	5.0	118.0	12500.0	5.0	1629.3	250.0	10.0	100.7	50.0	5.0	24.0	144500	5.0	17137	4350	5.0	1407	23500	2.0	3963.3

Table 22B: Drinking Water Quality for the Monitoring period

Parameters	Standard values as per IS		DW-8 (Nirman Building)			DW-9 (Custom Building)			DW-10 (Port Colony Kandla)			DW-11 (Wharf Area/ Jetty)			DW-12 (Hospital Kandla)			DW-13 (A.O. Building)			DW-14 (School Gopalpuri)		
	A	P	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
pH	6.5-8.5		8	7	7.5	8	6.2	7.3	7.9	6.82	7.31	8.3	6.85	7.71	7.75	6.62	7.224	8.5	7.2	7.61	8.2	7.08	7.56
Colour (Hazen)	5	15	5.0	1.0	2.3	5.0	1.0	2.0	5.0	1	2	10	1	3.083	5	1	1.67	5	1	1.33	10	1	3.28
EC (µS/ cm)			2000	40.0	403.8	2900.0	48.0	492.9	3100	105.4	554.9	2460	55	980.1	269	47	141.2	1412	23.2	187.2	1467	43.3	412.15
Salinity (PSU)			1.0	0.0	0.2	1.5	0.0	0.2	1.6	0.05	0.283	1.2	0.02	0.42	0.13	0.03	0.072	0.71	0.02	0.151	0.73	0.03	0.22
Turbidity (NTU)	1	5	3.6	1.1	1.8	4.7	1.0	2.8	2.2	0.95	1.575	3.79	1	2.09	2	1.02	1.57	9.9	0.9	3.67	13.9	0.5	5.48
Chloride (mg/L)	250	1000	499.9	10.0	93.1	689.8	12.5	108.7	504.8	21.99	75.52	404.8	13.54	173.9	67.98	12.5	31.79	307.4	7.5	44.28	332.4	11.5	93.83
Total Hardness (mg/L)	200	600	280.0	4.0	61.8	480	6.0	80.2	340.0	3	62.83	320	15	176.4	30	3	17.84	240	1.5	70.3	270	2	82.64
Ca Hardness (mg/L)			140.0	2.0	31.8	240	3.0	38.7	190.0	2	33.5	170	5	91.30	17	2	9.67	120	1	31.12	140	1.5	42.96
Mg Hardness (mg/L)			140.0	2.0	30.1	190	3.0	37.5	150.0	1	29.32	150	10	84.76	14	1	8.167	120	0.5	33.15	130	2	43.6
Free Residual Chlorine (mg/L)	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TDS (mg/L)	500	2000	1012	22.0	205.2	1522	24.0	255.8	1064	54	165.4	872	29	403.8	138	24	73.17	718	14	101.9	742	22	218
TSS (mg/L)			2.0	2.0	2.0	12.0	2.0	7.0	2.0	2	2	2	2	2	0	0	0	0	0	0	12	8	10
Fluoride (mg/L)	1	1.5	0.0	0.0	0.0	1.5	0.6	1.1	0.5	0.416	0.433	1.06	0.367	0.57	1.108	1.108	1.108	0	0	0	0.35	0.15	0.25
Sulphate (mg/L)	200	400	100.8	45.5	73.2	142.0	41.5	80.0	115.6	3.17	59.39	134.7	1.97	59.51	0	0	0	108.7	108.77	108.7	113.4	11.55	56.304
Nitrate (mg/L)	45		4.5	1.1	2.6	5.6	2.4	3.8	7.5	1.04	3.68	8.49	3.78	5.929	2.023	1.42	1.752	3.392	1.524	2.585	4.48	1.382	2.38

Parameters	Standard values as per IS		DW-8 (Nirman Building)			DW-9 (Custom Building)			DW-10 (Port Colony Kandla)			DW-11 (Wharf Area/ Jetty)			DW-12 (Hospital Kandla)			DW-13 (A.O. Building)			DW-14 (School Gopalpuri)		
	A	P	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Nitrite (mg/L)			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.201	0.11	0.147	0	0	0	0	0	0	0	0	0
Sodium (mg/L)			109.5	9.2	39.4	396.2	8.0	75.4	105.8	11.98	37.65	356.5	12.8	106.5	31.35	11.59	20.22	83.91	8.66	21.44	173.5	6.24	46.666
Potassium (mg/L)			0	0	0	13.6	13.6	13.6	7.0	2.6	4.8	0	0	0	0	0	0	0	0	0	0	0	0
Hexavalent Chromium (mg/L)			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odour (TON)	Agreeable			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Arsenic (mg/L)	0.01	0.05	0	0	0	0	0	0	0	0.007	0.007	0.005	0.0039	0.004	0	0	0	0	0	0	0.015	0.015	0.015
Cadmium (mg/L)	0.003		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.005	0.005	0.005	0.006	0.006	0.006
Copper (mg/L)	0.05	1.5	6.8	0	3.4	0	0	0	10.2	0.005	2.049	0	0	0	9.257	0.005	3.57	0.008	0.0079	0.008	0	0	0
Iron (mg/L)	0.3		0.1	0.1	0.1	0	0	0	0.3	0.0001	0.16	0.17	0.0001	0.092	0	0	0	0.13	0.13	0.13	0.0001	0.0001	0.0001
Lead (mg/L)	0.01		0.2	0	0.1	0	0	0	0	0.0033	0.003	0.004	0.0038	0.004	0.0028	0.003	0.003	0.002	0.002	0.002	4.27	4.27	4.27
Manganese (mg/L)	0.1	0.3	0.2	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05	0.05	0	0	0
Mercury (mg/L)	0.001		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Chromium (mg/L)	0.05		0	0	0	0	0	0	0	0	0	0	0	0	0.0122	0.012	0.012	0.006	0.006	0.006	0	0	0
Zinc (mg/L)	5	15	0	0	0	0.6	0.6	0.6	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Coliform* (MPN/ 100ml)	Shall not be detected		240.0	2.0	114.7	12050	4.0	1826	37080	35	5374	25550	5	3329	140	4	47.2	685	20	166.7	4900	15	636.4

Table 22C: Drinking Water Quality for the Monitoring period

Parameters	Standard values as per IS		DW-15 (Guest House)			DW-16 (E- Type Quarter)			DW-17 (F- Type Quarter)			DW-18 (Hospital Gopalpuri)			DW-19 (Near Vadinar Jetty)			DW-20 (Near Port Colony)		
	A	P	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
pH	6.5-8.5		7.99	6.87	7.35	7.68	6.93	7.28	8.19	6.78	7.46	8.27	7.12	7.6	8.38	7.21	7.685	8.07	7.05	7.435
Colour (Hazen)	5	15	5	1	1.67	5	1	1.67	5	1	1.67	10	1	3.5	5	1	2.333	20	1	6
EC (µS/ cm)			264	34.3	120.22	746	17.79	116.84	1337	15.93	298.6	7930	30.2	1037	537	30	199.7	1736	88.4	427.7
Salinity (PSU)			0.7	0.02	0.113	0.38	0.02	0.06	0.67	0.02	0.16	4.39	0.02	0.55	0.26	0.02	0.100	0.87	0.05	0.235
Turbidity (NTU)	1	5	2.29	0.63	1.27	2.8	0.52	1.50	1.97	1.1	1.66	3.98	0.7	2.03	1.5	1.2	1.35	5.3	0.7	3.25
Chloride (mg/L)	250	1000	60.98	10.5	26.98	124.96	4	24.58	287.41	4	61.99	163.9	9	75.28	66.98	9	27.20	407.37	13	73.15
Total Hardness (mg/L)	200	600	20	2	11.97	180	1.5	22.86	230	2	52.6	195	4	96.25	160	2	44.58	240	20	88.5
Ca Hardness (mg/L)			10	1.5	6.25	80	1	10.77	120	1	28.5	102	2	49.43	80	1.5	21.54	140	10	44.08
Mg Hardness (mg/L)			12.5	1	6.136	100	0.5	13.25	110	1	24.1	100	1	46.79	80	1	25.09	100	8	44.41
Free Residual Chlorine (mg/L)	0.2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TDS (mg/L)	500	2000	138	18	62.75	382	10	60.5	682	8	157.5	448	16	198.8	272	15	100.9	882	46	218.5
TSS (mg/L)			0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	12	4	8
Fluoride (mg/L)	1	1.5	0.34	0.34	0.34	0	0	0	0.5	0.37	0.43	0.51	0.38	0.44	0.35	0.35	0.35	1.06	1.06	1.06
Sulphate (mg/L)	200	400	10.62	10.3	10.46	34.35	34.35	34.35	104.64	8.37	41.20	59.94	1.81	40.82	42.2	13.07	31.87	102.92	25.4	48.22
Nitrate (mg/L)	45		5.63	1.12	2.53	1.97	1.97	1.97	6.06	1.19	3.20	16.51	1.17	5.1	15.79	1.82	5.55	18.54	1.06	6.45
Nitrite (mg/L)			0	0	0	0	0	0	0	0	0	0.20	0.11	0.16	0	0	0	1.89	1.89	1.89

Parameters	Standard values as per IS		DW-15 (Guest House)			DW-16 (E- Type Quarter)			DW-17 (F- Type Quarter)			DW-18 (Hospital Gopalpuri)			DW-19 (Near Vadinar Jetty)			DW-20 (Near Port Colony)		
	A	P	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Sodium (mg/L)			40.46	14.3	19.38	74.46	7.06	24.85	82.61	5.75	35.30	185.2	7.08	55.81	58.37	6.08	20.49	204.04	7.18	46.23
Potassium (mg/L)			0	0	0	0	0	0	0	0	0	3.2	3.2	3.2	0	0	0	5.85	5.85	5.85
Hexavalent Chromium (mg/L)			0	0	0	0	0	0	0	0	0	0	0	0	0.041	0.041	0.041	0.01	0.01	0.01
Odour (TON)	**Agreeable**			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Arsenic (mg/L)	**0.01**	**0.05**	0.007	0.007	0.007	0	0	0	0.008	0.008	0.008	0.015	0.01	0.012	0.08	0.08	0.08	0	0	0
Cadmium (mg/L)	**0.003**		0.007	0.007	0.007	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008	0.008	0	0	0	0	0	0
Copper (mg/L)	**0.05**	**1.5**	7.24	0.006	2.42	0	0	0	0.012	0.012	0.012	7.3	0.006	3.65	16.25	0.006	7.99	15.403	0.01	3.09
Iron (mg/L)	**0.3**		0.25	0.0002	0.13	0	0	0	0.52	0.0001	0.213	0.11	0.0003	0.055	1.47	1.47	1.47	0	0	0
Lead (mg/L)	**0.01**		2.21	0.002	1.10	0	0	0	0	0	0	0	0	0	10.53	0.003	5.26	0.002	0.002	0.002
Manganese (mg/L)	**0.1**	**0.3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.13	0	0.08
Mercury (mg/L)	**0.001**		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Chromium (mg/L)	**0.05**		0	0	0	0	0	0	0	0	0	0.006	0.006	0.006	0	0	0	0	0	0
Zinc (mg/L)	**5**	**15**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Coliform* (MPN/ 100ml)	**Shall not be detected**		200	5	57.75	7650	5	1669	57000	9	6635	310	5	131	2850	120	1485	130000	10	16647

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

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

8.3 Data Interpretation and Conclusion

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

Physico-Chemical Parameters:

- **pH:** The pH values of drinking water samples in Kandla were reported to be in the range of **6.24 to 8.5**, with an average pH of **7.5**. In Vadinar, its values ranged from **7.05 to 8.38**, with an average pH of **7.36**. Notably, the pH levels at both project sites fall within the acceptable range of 6.5 to 8.5, as specified under IS:10500:2012.
- **Colour:** The colour varies from 1 to 10 at the monitoring locations in Kandla. Locations DW-11, DW-14 and DW-10 showed the value of 10 Hazen at Kandla. At Vadinar, the color was observed within the range of 1 to 20 Hazen. the Colour levels at both project sites fall within the acceptable range of 1 to 15, as specified under IS:10500:2012, except of one location DW-20 within the monitoring period of April to May 2023
- **Electrical Conductivity (EC):** It is a measure of the ability of a solution to conduct electric current, and it is often used as an indicator of the concentration of dissolved solids in water. During the monitoring period, the EC values for samples collected in Kandla were observed to range from **12.83 to 7930 µS/cm**, with an average value of **708.65** µS/cm. In Vadinar, the EC values showed variation from **30 to 1736 µS/cm**, with an average value of **503.14** µS/cm. It's important to regularly monitor EC levels in drinking water as it can provide valuable information about water quality and presence of dissolved substances.
- **Salinity:** Salinity at Kandla varies from **0.02 to 4.39 PSU** with an average of **0.396** PSU, while at Vadinar, salinity was observed within the range of **0.02** to **0.87 PSU**.
- **Turbidity**: The Turbidity values of drinking water samples in Kandla were reported to be in the range of **0.5 to 13.9 NTU**, with an average of **2.32**. In Vadinar, its values ranged from **0 to 5.3**, with an average **2.21**. Notably, the Turbidity levels at both project sites fall within the acceptable range of 1 to 5 NTU, as specified under IS:10500:2012, except DW-7, in the monitoring period of July to August 2023, DW-13 in the monitoring period of May to June 2023 and DW-14 in the monitoring period of September to October and October to November 2023. On all this location most of the time Turbidity observed Below Quantification Limit
- **Chlorides:** The chloride concentrations in Kandla varied from **3 to 689.78 mg/L**, with an average value of **116.85** mg/L. At Vadinar the chloride concentration was observed within the range of **9** mg/L to **407.37** mg/L, with an average value of **99.45** mg/L. Thus, the chloride levels at both project sites fall within the Permissible limit of 1000 mg/L, as specified under IS:10500:2012.
- **Total Hardness (TH):** The concentration of Total Hardness varies from **1.5 to 480 mg/L**, with an average concentration of **88.68** mg/L. While at Vadinar, the observed values were within range of **2 to 240** mg/L. at both study areas Total Hardness found

to be within the Permissible limit norm of 600 mg/L as specified by IS:10500:2012 and is not harmful for local inhabitants.

- **Total Dissolved Solids (TDS):** Monitoring TDS is crucial because it provides an indication of overall quality of the water. During the monitoring period, the TDS concentrations in Kandla were observed to vary in a wide range i.e., between **8** to **1522** mg/L, with an average concentration of **264.4** mg/L. which is within the permissible limit. while in Vadinar, it ranged from **6** to **882** mg/L, with an average of **255.75** mg/L. It is important to note that the TDS concentrations in both Kandla and Vadinar fall well within the Permissible limit of 2000 mg/L.
- **Fluoride:** The concentration Fluoride varies from **0** to **1.477** mg/L, with an average concentration of **0.44** mg/L. While at Vadinar Fluoride concentration was varies within range of **0** to **1.06** mg/L**,** with an average concentration of **0.708** mg/L**.** The Fluoride concentration was found to be **BQL** in majority of the monitoring location at Kandla and Vadinar. at both study areas Fluoride found to be within the Permissible limit norm of 1.5 mg/L as specified by IS:10500:2012
- **Sulphate:** The concentration Sulphate varies from **0** to **141.99** mg/L, with an average concentration of **45.67** mg/L. While at Vadinar Sulphate concentration was varies within range of **13.07** to **102.92** mg/L**,** with an average concentration of **43.94** mg/L**.** During monitoring period in Kandla and Vadinar, the sulphate concentrations were found to be within the acceptable limits i.e., 200 mg/L as per the specified norms.
- **Nitrate:** The concentration Nitrate varies from **0** to **25.96** mg/L, with an average concentration of **4.08** mg/L. While at Vadinar Nitrate concentration was varies within range of **0** to **18.54** mg/L**,** with an average concentration of **8.20** mg/L**.** The Nitrate concentration was found to be **BQL** in majority of the monitoring location at Kandla and Vadinar. at both study areas Nitrate found to be within the Acceptable limit norm of 45 mg/L as specified by IS: 10500:2012.
- **Nitrite:** The concentration Nitrite varies from **0** to **0.2** mg/L. While at Vadinar Nitrite concentration was varies within range of **0** to **1.89** mg/L**,** with an average concentration of **0.945** mg/L**.** The Nitrite concentration was found to be **BQL** in majority of the monitoring location at Kandla and Vadinar.
- **Sodium:** During the monitoring period, at Kandla variation in the concentration of Sodium was observed to be in the range of **5.01 to 396.2 mg/L**, with the average concentration of **63.71** mg/L. While at Vadinar, the concentration recorded between **6.08** to **204.4** mg/L, with the average concentration of **57.067** mg/L.
- **Odour:** Odour values recorded 1 TON at all monitoring locations of Kandla and Vadinar.

Metals:

- **Arsenic:** The Arsenic concentrations in Kandla varied from **0 to 0.042 mg/L**. At Vadinar the Arsenic concentration was observed within the range of **0** mg/L to **0.08** mg/L. Thus, the Arsenic levels at both project sites fall within the Permissible limit of 0.05 mg/L, as specified under IS:10500:2012, except on one location at Vadinar DW-19 where Arsenic Concentration found 0.08 mg/L in the monitoring period of November to December 2023. In Kandla and Vadinar, the Arsenic concentrations were recorded

BQL for majority of the locations except the locations DW-2, DW-12, and DW-18 in Kandla and DW-20 In Vadinar.

- **Copper:** The Copper concentrations in Kandla varied from **0 to 17.3 mg/L**. At Vadinar the Copper concentration was observed within the range of **0** mg/L to **16.25** mg/L. Thus, the Copper levels at both project sites fall within the Permissible limit of 1.5 mg/L, as specified under IS:10500:2012, except for locations DW-1, DW-2, DW-4, DW-8, DW-10, DW-12, DW-15, DW-18 in Kandla and on both Locations DW-19 and DW-20 of Vadinar for some samples taken during whole monitoring period. The Copper concentrations were recorded BQL for majority of the locations in Kandla and Vadinar.
- **Iron:** The Iron concentrations in Kandla varied from **0 to 0.64 mg/L**, with an average concentration of **0.10** mg/L. At Vadinar the Iron concentration was observed within the range of **0** mg/L to **1.478** mg/L. Thus, the Iron levels at both project sites fall within the Acceptable limit of 0.3 mg/L, as specified under IS:10500:2012, except for locations DW-1, DW-10, and DW-17 in Kandla and on Location DW-19 of Vadinar for some samples taken during the whole monitoring period. The Iron concentrations were recorded by BQL for the majority of the locations in Kandla and Vadinar.
- **Lead:** The Lead concentrations in Kandla varied from **0 to 4.279 mg/L**, with an average concentration of **0.37** mg/L. While at Vadinar the Lead concentration was observed within the range of **0** mg/L to **10.53** mg/L, with an average concentration of **2.6344**. Thus, the Lead levels at both project sites fall within the Acceptable limit of 0.01 mg/L, as specified under IS:10500:2012, except for locations DW-1, DW-8, DW-14 and DW-15 in Kandla and on Location DW-19 of Vadinar for some samples taken during the whole monitoring period. The Lead concentrations were recorded in BQL for the majority of the locations in Kandla and Vadinar.
- **Manganese:** The Manganese concentrations in Kandla varied from **0 to 0.51 mg/L**, with an average concentration of **0.1** mg/L. While at Vadinar, the Manganese concentration was observed within the range of **0** mg/L to **0.13** mg/L. Thus, the Manganese levels at both project sites fall within the Acceptable limit of 0.3 mg/L, as specified under IS:10500:2012, except for locations DW-3, and DW-6 in Kandla and on Location DW-20 of Vadinar for some samples taken during the whole monitoring period. The Manganese concentrations were recorded BQL for the majority of the locations in Kandla and Vadinar.
- The concentrations of parameters such as **Free Residual Chlorine, Total Suspended Solid, Potassium Hexavalent Chromium** and **the metals (Cadmium, Mercury, Total Chromium and Zinc)** were observed to fall within the Permissible limit at both project sites. Observed "Below the Quantification Limit (BQL)" at majority of the locations during the monitoring period.
- Bacteriological Analysis of the drinking water reveals that **Total Coliforms (TC)** were detected in the range of **0** to **144500** MPN/100ml, with the average of **6964.8** MPN/100ml. While at Vadinar the observed within the range of **0** MPN/100ml to **1,30,000** MPN/100ml, with the average concentration of **25,185** MPN/100ml. And for the rest of the monitoring locations of Kandla and Vadinar were detected "Below the Quantification Limit (BQL)". Reporting such concentration of Coliforms indicates

certain external influx may contaminate the source. Hence, it should be checked at every distribution point. The higher concentration of total coliforms were observed on locations DW-2, DW-5, DW-7, DW-10, DW-11, and DW-17 in Kandla and DW-20 location in Vadinar.

8.4 Remedial Measures

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

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

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

CHAPTER 9: SEWAGE TREATMENT PLANT MONITORING

9.1 Sewage Treatment Plant (STP) Monitoring:

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

Frequency of monitoring: weekly

Table 23A: Details of the monitoring locations of STP

<table>
<tr><th>Sr. No.</th><th colspan="2">Location Code</th><th>Location Name</th><th>Latitude Longitude</th></tr>
<tr><td>1.</td><td rowspan="2">Kandla</td><td>STP-1</td><td>STP Kandla</td><td>23.021017N 70.215594E</td></tr>
<tr><td>2.</td><td>STP-2</td><td>STP Gopalpuri</td><td>23.077783N 70.136759E</td></tr>
<tr><td>3.</td><td>Vadinar</td><td>STP-3</td><td>STP at Vadinar</td><td>22.406289N 69.714689E</td></tr>
</table>

The Consolidated Consent and Authorization (CC&A) issued by the GPCB were referred for the details of the STP for Kandla and Gopalpuri. The CC&A of Kandla and Gopalpuri entails that the treated domestic sewage should conform to the norms specified in **Table 23B**. 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 22B: Discharge norms (as per CC&A of Kandla STP)

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

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

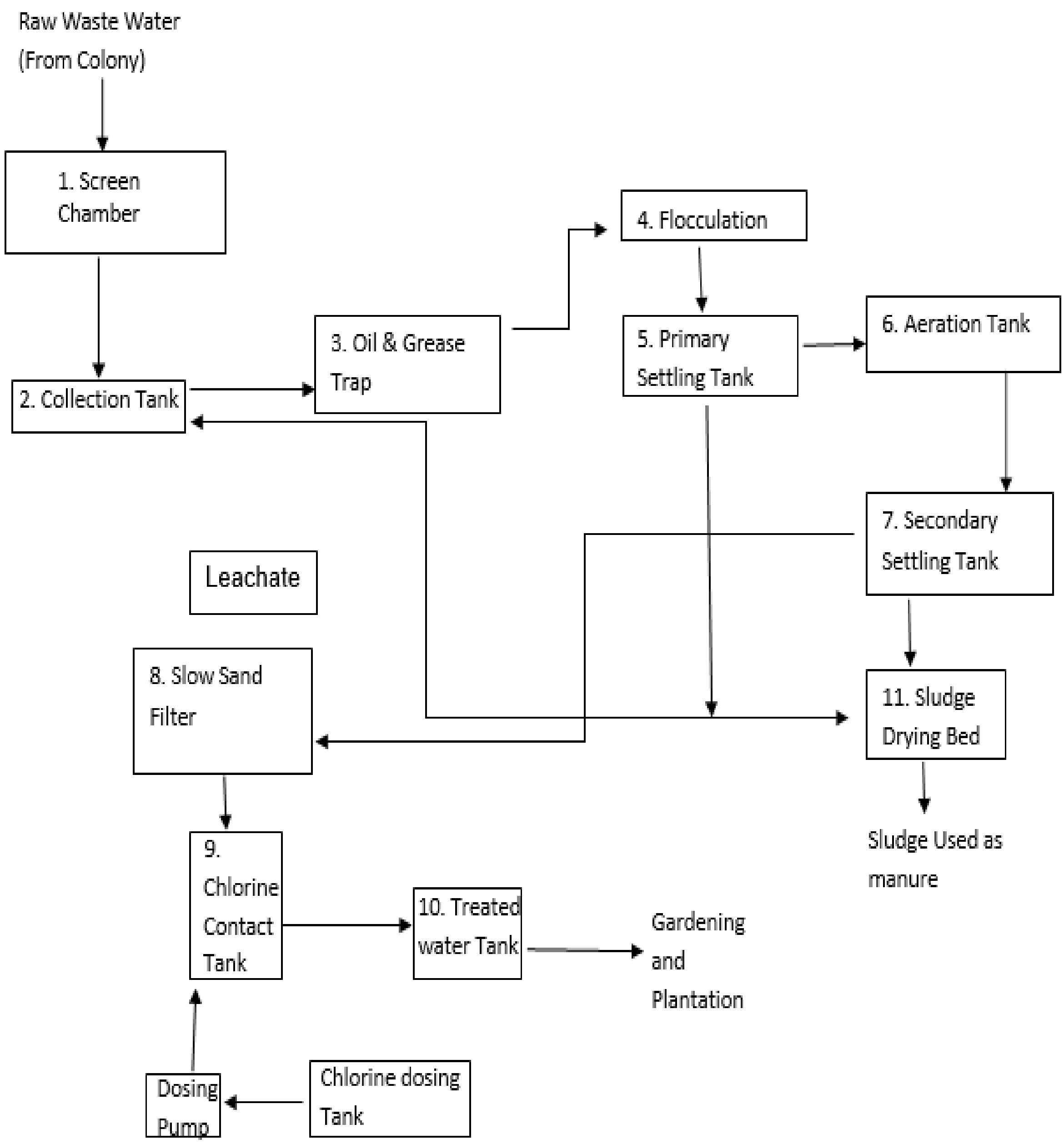


Figure 3: Process flow diagram of STP at Kandla

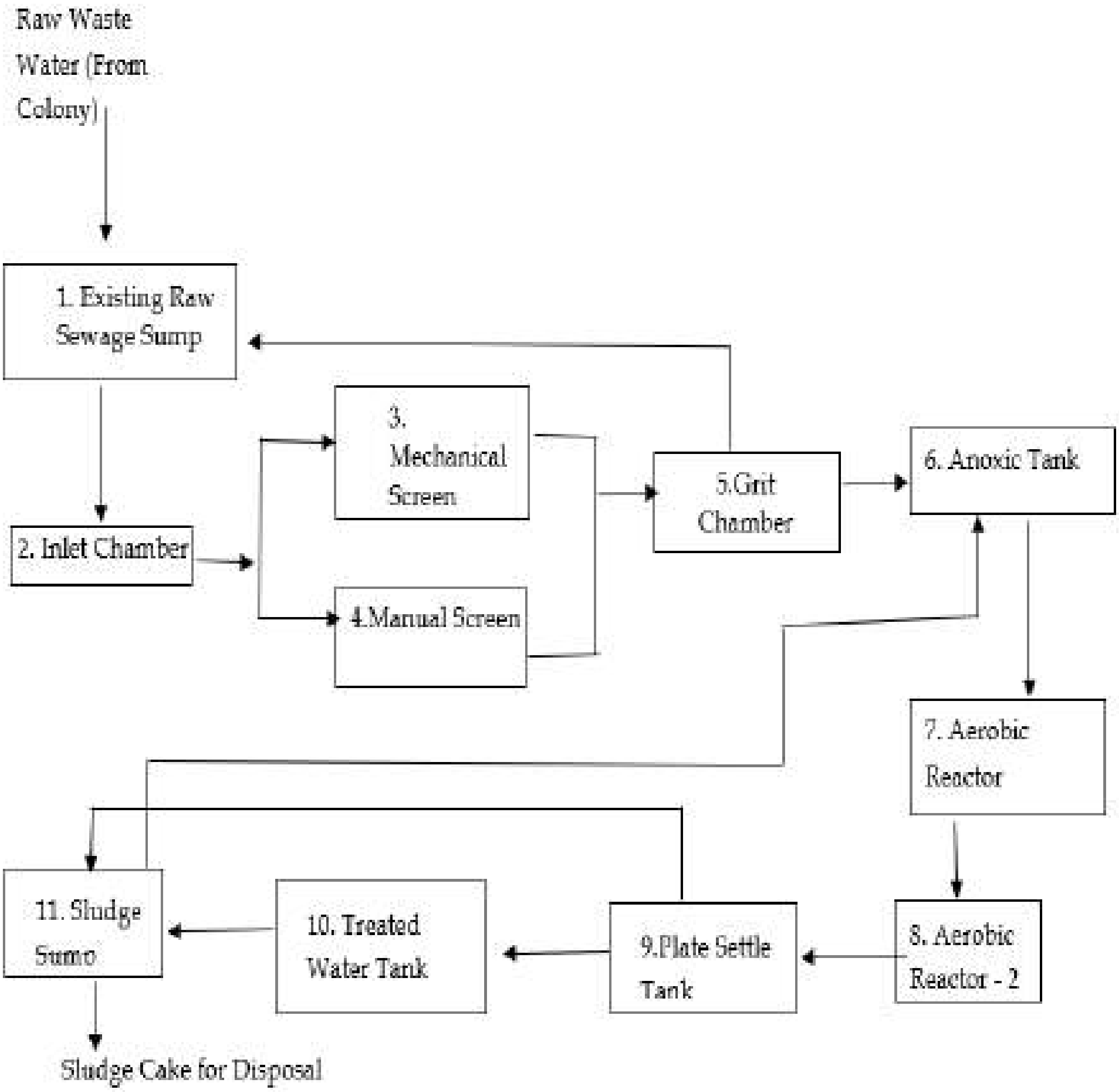


Figure 4: Process flow diagram of STP at Gopalpuri, Kandla

STP at Vadinar

The STP at Vadinar has been built with a treatment capacity of 450 KLD/day. The Consolidated Consent and Authorization (CC&A) issued by the GPCB has been referred for the details of the said STP. The CC&A of the Vadinar STP suggests that the domestic effluent generated shall be treated as per the norms specified in **Table 24**. The treated effluent conforming to the norms shall be discharged on the land within the premises strictly for the gardening and plantation purpose. Whereas, no sewage shall be disposed outside the premises in any manner.

Table 23: Norms of treated effluent as per CC&A of Vadinar STP

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

Sr. No.	Parameters	Prescribed limits
5.	COD	50 mg/L

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

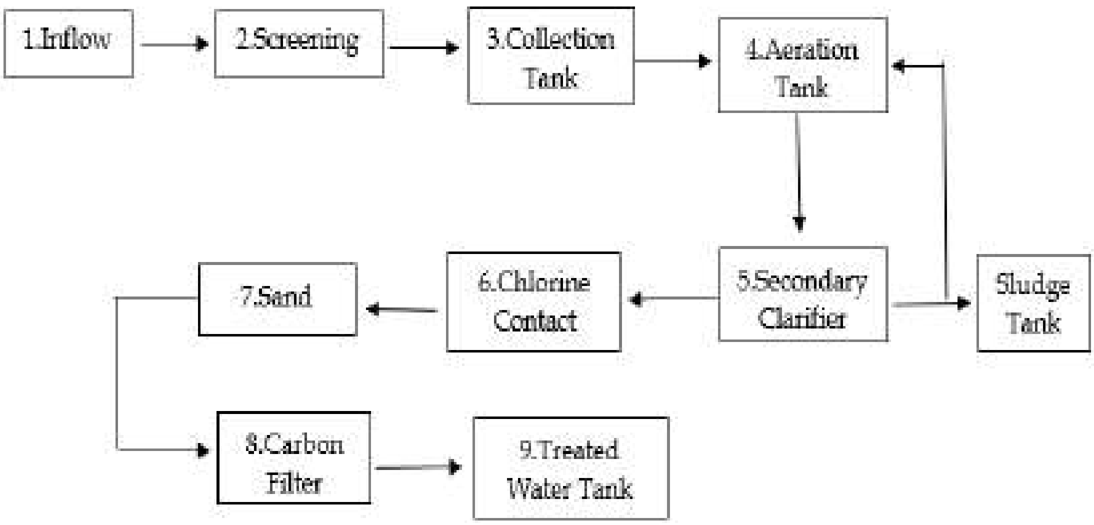


Figure 5: Process flowchart for the STP at Vadinar

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

Map 14: STP Monitoring Locations at Kandla

Map 15: STP Monitoring Locations at Vadinar

Methodology

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

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

Monitoring Frequency

Monitoring is required to be carried out once a week for monitoring location of Kandla and Vadinar i.e., two STP station at Kandla and one STP station at Vadinar. Sample Collected from this location during the monitoring period April 2023 to March 2024.

Table 24: List of parameters monitored for STP's at Kandla and Vadinar

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

9.2 Result and Discussion

Analytical results of the STP samples collected from the inlet and the outlet of the STP's of Kandla and Vadinar have been summarized in **Table 26**. Further it was compared with the standard norms specified in the CC&A of the respective STPs.

Table 25: Water Quality of inlet and outlet of STP of Kandla

Sr No.	Parameter	Units	Kandla							Vadinar			
			GPCB Norms (Kandla)	STP-1			STP-2			GPCB Norms (Vadinar)	STP-3		
				Inlet	Outlet		Inlet	Outlet			Inlet	Outlet	
				Avg	Avg	Max	Avg	Avg	Max		Avg	Avg	Max
1.	pH	-	6.5-8.5	7.17	7.302	7.65	6.99	7.48	8.88	5.5-9	7.19	7.41	8.46
2.	TDS	mg/L	-	3065.7	2069.28	6228	1099.40	1003.3	1814	-	471.61	402.67	482
3.	TSS	mg/L	100	183.4	20.97	88	115.17	16.45	46	20	38.78	8.42	36
4.	COD	mg/L	-	184.7	32.57	133.1	213.54	25.98	88.4	50	138.27	16.18	40.2
5.	DO	mg/L	-	145.91	37.780	277.09	162.29	21.98	76.92	-	115.12	18.69	54.5
6.	BOD	mg/L	30	56.82	11.937	52.4	61.75	8.40	18.45	10	44.62	6.053	11
7.	SAR	meq/L	-	12.06	9.318	21.04	5.75	5.43	13.1	-	2.71	2.12	3.2
8.	Total Coliforms	MPN/ 100ml	<1000	1565.95	1530.66	1600	1537.02	1500.51	1600	100-230	1551	1492.3	1600

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

9.3 Data Interpretation and Conclusion

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

- The average pH at the inlet of STP-1, STP-2, and STP-3 is, respectively, **7.17, 6.99, and 7.19**. After treatment, the treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) had a maximum pH of **7.65, 8.88, and 8.46** and an average pH of **7.302, 7.48, and 7.41**, respectively. Which conform to their respective stipulated norms of 6.5–8.5 at Kandla and 5.5–9 at Vadinar, respectively.
- The average TDS concentrations at the inlet of STP-1, STP-2, and STP-3 are, respectively, **3065.8, 1099.4, and 471.33** mg/L. After treatment, the treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) had a maximum TDS concentration of **6228, 1814, and 482** mg/L, and an average TDS concentration of **2069.3, 1003.3, and 402.67** mg/L, respectively.
- The average TSS at the inlet of STP-1, STP-2, and STP-3 is respectively **183.43, 115.17, and 38.78** mg/L. After treatment, the treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) had a maximum TSS of **88, 46**, and **36** mg/L, and an average TSS of **20.974, 16.452, and 8.41** mg/L, respectively. Which conform to their respective stipulated norms of 100 mg/L at Kandla and 20 mg/L at Vadinar, respectively, as mentioned in their respective CCA, except in STP-3 at Vadinar, which exceeds norms in the 3rd and 4th weeks of April 2023.
- The average COD at the inlet of STP-1, STP-2, and STP-3 is respectively **184.7, 213.54, and 138.27** mg/L. After treatment, the treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) had maximum COD concentrations of **133.1, 88.4, and 40.2** mg/L, and average COD concentrations of **32.576, 25.97, and 16.18** mg/L, respectively. There are no discharge norms for the COD parameter in STP-1 and STP-2 at Kandla, and they conform to their respective stipulated norms of 50 mg/L at Vadinar as mentioned in their respective CCA.
- The average DO concentrations at the inlet of STP-1, STP-2, and STP-3 are, respectively, **145.91, 162.29, and 115.12** mg/L. After treatment, the treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) had a maximum DO concentration of **277.09, 76.92, and 54.5** mg/L, and an average DO concentration of **37.78, 21.98, and 18.68,** mg/L respectively.
- The average BOD at the inlet of STP-1, STP-2, and STP-3 is respectively **56.82, 61.76, and 44.62** mg/L. After treatment, the treated effluent from STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) had a maximum BOD of **52.4, 18.45, and 11** mg/L, and an average BOD of **11.93, 8.40, and 6.05** mg/L, respectively. Which conform to their respective stipulated norms of 30 mg/L at Kandla and 10 mg/L at Vadinar, respectively, as mentioned in their respective CCA, except in STP-3 at Vadinar, which exceeds norms in the 3rd and 4th weeks of April 2023.
- The average SAR concentrations at the inlet of STP-1, STP-2 and STP-3 are respectively **12.068**, **5.75** and **2.71** meq/L**.** After treatment, the treated effluent from

STPs at Kandla (STP-1 and STP-2) and Vadinar (STP-3) having maximum SAR concentration **21.04**, **13.1** and **3.2** meq/L, and having Average SAR concentration **9.31**, **5.46** and **2.12** meq/L respectively.

- The **Total Coliforms** was observed to exceed the norms at the locations of the STP-1 & STP-2 for the treated effluent at Kandla and STP-3 at Vadinar.

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

9.4 Remedial Measures:

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

CHAPTER 10: MARINE WATER QUALITY MONITORING

10.1 Marine Water

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

Major water quality concerns at ports include wastewater and leakage of toxic substances from ships, stormwater runoff, etc. This discharge of wastewater, combined with other ship wastes which includes sewage and wastewater from other on-board uses, is a serious threat to the water quality as well as to the marine life. As defined in the scope by DPA, the Marine Water sampling and analysis has to be carried out at a total of eight locations, six at Kandla and two at Vadinar. The marine water sampling has been carried out with the help of Niskin Sampler with a capacity of 5L. The Niskin Sampler is a device used to take water samples at a desired depth without the danger of mixing with water from other depths. Details of the locations to be monitored have been mentioned in **Table 27:**

Table 26: Details of the sampling locations for Marine water

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

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

Map 16: Marine Water Monitoring Locations at Kandla

Map 17: Marine Water Monitoring Locations at Vadinar

Methodology

The methodology adopted for the sampling and monitoring of Marine Water was carried out as per the '**Sampling Protocol for Water & Wastewater'** developed by GEMI. The water samples collected through the Niskin Sampler are collected in a clean bucket to reduce the heterogeneity. The list of parameters to be monitored under the project for the Marine Water quality have been mentioned in **Table 28** along with the analysis method and instrument.

Monitoring Frequency

As defined in the scope by DPA, the sampling and analysis of Marine Water has to be carried out once in a month at the eight locations (i.e., six at Kandla and two at Vadinar). For the period April 2023 to March 2024.

Table 27: List of parameters monitored for Marine Water

Sr. No	Parameters	Units	Reference method	Instrument
1.	Electrical Conductivity	µS/cm	APHA, 23rd Edition (Section-2510 B):2017	Conductivity Meter
2.	Dissolved Oxygen (DO)	mg/L	APHA, 23rd Edition, 4500 O C, 2017	Titration Apparatus
3.	pH	-	APHA, 23rd Edition (Section-4500-H+B):2017	pH meter
4.	Color	Hazen	APHA, 23rd Edition, 2120 B: 2017	Color comparator
5.	Odour	-	IS 3025 Part 5: 2018	Heating mantle & odour bottle
6.	Turbidity	NTU	IS 3025 Part 10: 1984	Nephlo Turbidity Meter
7.	Total Dissolved Solids (TDS)	mg/L	APHA, 23rd Edition (Section-2540 C):2017	Vaccum Pump with Filtration Assembly and Oven
8.	Total Suspended Solids (TSS)	mg/L	APHA, 23rd Edition, 2540 D: 2017	
9.	Particulate Organic Carbon	mg/L	APHA, 23rd Edition, 2540 D and E	TOC analyser
10.	Chemical Oxygen Demand (COD)	mg/L	IS-3025, Part- 58: 2006	Titration Apparatus plus Digester
11.	Biochemical Oxygen Demand (BOD)	mg/L	IS-3025, Part 44,1993,	BOD Incubator plus Titration apparatus
12.	Silica	mg/L	APHA, 23rd Edition, 4500 C, 2017	UV- Visible Spectrophotometer
13.	Phosphate	mg/L	APHA, 23rd Edition, 4500 P-D: 2017	
14.	Sulphate	mg/L	APHA, 23rd Edition, 4500 SO4-2 E: 2017	
15.	Nitrate	mg/L	APHA, 23rd Edition, 4500 NO3-B: 2017	
16.	Nitrite	mg/L	APHA, 23rd Edition, 4500 NO2- B: 2017	
17.	Sodium	mg/L	APHA, 23rd Edition, 3500 Na-B: 2017	Flame photometer

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

10.2 Result and Discussion

The quality of the Marine water samples collected from the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 29**. The said water quality has been represented in comparison with the standard values as stipulated by CPCB for Class SW-IV Waters.

Table 28: Results of Analysis of Marine Water Sample for the sampling period

Parameters	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		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Density (kg/m³)	-	1.02	1.03	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.021	1.02	1.02	1.02	1.02	1.02	1.02
pH	6.5-9.0	6.12	8.32	7.89	7.04	8.36	7.99	7.83	8.33	8.11	7.69	8.31	8.05	7.19	8.48	8.03	6.01	8.31	7.94	7.98	8.2	8.11	7.07	8.22	8.06
Colour (Hazen)	No Noticeable	1	10	5.41	1	20	7.83	1	15	7.16	5	20	9	5	15	7.41	5	20	8.27	1	10	5.66	1	10	5.08
EC (µS/ cm)	-	49700	63600	54282.5	49800	61700	54490.91	50200	60600	53767.75	50400	75300	55689.91	50100	65100	55115.58	15950	61528	50873.17	52200	56900	54239.2	52.119	57500	50312.6
Turbidity (NTU)	-	56.4	310	188.26	33.9	314	206.76	61.8	317	203.81	69	300	216.66	94.5	379	202.5	70.1	346	209.23	3.15	12.5	5.36	3.42	13.8	6.39
TDS (mg/L)	-	24800	44466	36356.3	24900	41922	36679.5	25100	41624	35690.92	25200	64721	38189.5	25000	47159	36938.58	9970	41436	32927.91	25784	38620	35400.16	26882	41790	35965.75
TSS (mg/L)	-	44	436	342.42	26	563	374.58	52	478	340.75	58	924	402.33	80	682	427.66	58	852	387.72	78	341	255.08	151	346	282.33
COD (mg/L)	-	29.2	79.37	49.62	11.98	79.37	47.81	25.41	81	47.68	22.65	81	52.12	31.56	79.37	53.76	22.97	88.8	49.34	21.28	75	50.98	17.92	75	47.63
DO (mg/L)	3.0 mg/L	4.7	6.4	5.76	5.3	6.4	6.07	4.5	6.7	5.87	3.4	6.5	5.85	5	6.6	6.07	5.6	8.4	6.49	4.3	7.6	6.25	4.4	7.9	6.48
BOD (mg/L)	5.0 mg/L	5.24	8.54	7.56	8.4	8.9	8.57	3.74	8.45	6.81	5	8.78	7.755	9.32	9.87	9.57	3.6	11.1	8.64	3.91	7.5	6.51	4.2	7.16	6.16
Oil & Grease (mg/L)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sulphate (mg/L)	-	2056	2937.5	2529.7	2156.32	2897.7	2544.18	2083.7	2925.2	2530.85	2239	3704.9	2879.88	2334.9	2916.8	2652.42	632.62	3612.8	2561.07	1846.3	3225.8	2472.195	2039.9	3236.8	2664.27
Nitrate (mg/L)	-	1.89	5.40	4.28	1.12	5.16	3.75	3.21	5.68	4.17	3.41	5.85	4.64	3.17	6.92	4.21	3.06	6.84	4.06	2.225	5.17	3.56	1.759	5.1	3.39
Nitrite (mg/L)	-	0.12	0.12	0.12	0	0	0	0	0	0	0	0	0	0.11	0.11	0.11	0.13	0.16	0.14	0	0	0	0	0	0!
Phosphate (mg/L)		0.25	1.59	0.82	0.09	1.34	0.69	0.57	1.46	0.96	0.61	2.01	0.92	0.29	1.34	0.76	0.54	1.61	0.81	0.64	0.94	0.79	1.43	1.43	1.43
Silica (mg/L)	-	0.29	3.24	2.12	0.22	4.04	2.24	0.2	3.73	2.19	1.12	3.69	2.54	1.26	4	2.64	0.33	3.74	1.92	0.11	0.96	0.56	0.09	1.86	0.76
Sodium (mg/L)	-	7686	10625	9475.57	7811	10341	9242.42	7763	10308	9347.33	9101	10323	9724.14	8789	10278	9403.67	2086	10722	8042.71	2149.6	9485	6743.97	2349.4	9542	7244.66
Potassium (mg/L)	-	68.35	451.9	318.57	69.27	446.5	303.94	68.57	421	290.60	71.73	543.96	342.71	69.63	423.34	324.92	68.34	442.63	272.9	10.86	421.7	259.6	76.31	518	327.43
Hexavalent Chromium (mg/L)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	321	321	321	333	333	333
Odour	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Arsenic (mg/L)	-	5.13	5.13	5.13	5.25	5.25	5.25	5.4	5.4	5.4	0	0	0	0	0	0	9.44	12.94	11.19	0.11	1	0.41	0.08	1	0.38
Cadmium (mg/L)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copper (mg/L)	-	5.1	6.99	5.8175	0.006	10.9	5.79	0.005	7.7	3.85	5.34	12.01	8.224	0.0067	7.6	5.13	8.07	10.2	9.49	3.4	3.4	3.4	0	0	0
Iron (mg/L)	-	0.69	4.11	1.38	0.21	4.07	1.76	0.37	3.92	1.79	1.02	7.93	2.49	0.98	5.45	2.09	0.43	5.3	2.005	0.01	0.25	0.145	0.08	0.66	0.21
Lead (mg/L)	-	0.002	3.44	2.067	0.0029	3.44	2.29	0.0026	3.06	1.98	0.002	9.68	4.32	0.002	4.65	2.39	0.0029	3.65	2.47	0.0023	2.26	1.035	0.002	2.75	0.96
Manganese (mg/L)	-	0.082	129.91	71.47	0.12	159.78	83.88	0.1085	125.66	74.0	0.096	294.91	93.56	0.074	213.14	74.7	0.11	156.41	80.27	2.39	113.93	39.62	1.97	98.8	34.64
Total Chromium (mg/L)	-	0	0	0	5.62	7.8	6.71	5.67	5.67	5.67	5.14	15.99	12.28	5.11	9.65	7.207	0	0	0	0	0	0	45.75	45.75	45.75
Zinc (mg/L)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercury (mg/L)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Particulate Organic	-	0.51	900	76.22	0.51	35	3.98	0.42	10	1.94	0.58	55	6.03	0.92	30	3.89	0.85	44	5.01	0.47	4.67	1.62	0.32	4.76	1.51

Parameters	Primary	Kandla																		Vadinar					
Carbon (mg/L)																									
Total Coliform* (MPN/ 100ml)	500/100 ml	0.32	1600	159.61	0.16	120	29.76	0.56	108	31.55	0.25	47	14.02	0.35	170	37.19	0.29	50	21.86	0.36	240	39.76	0.39	240	35.28
Floating Material (Oil grease scum, petroleum products) (mg/L)	10 mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	23	23

10.3 Data Interpretation and Conclusion

The Marine water quality of Deendayal Port Harbor waters at Kandla and Vadinar has been monitored for various physico-chemical and biological parameters during the monitoring 2023 at high tide. The detailed interpretation of the parameters in comparison to the Class SW-IV for Harbour Waters is as follows:

- **Density** at Kandla was observed in the range of **1.02 to 1.03 kg/m³**, with the average of **1.022 kg/m³.** Whereas for the location of Vadinar, it was observed in the range of **1.021 to 1.026 kg/m³**, with the average of **1.022 kg/m³**.
- **pH** at Kandla was observed in the range of **6.01 to 8.48**, with the average pH as **7.78**. Whereas for the locations of Vadinar, it was observed in the range of be **7.07** to **8.22**, with the average pH as **7.94**. For the monitoring location of both the study areas, pH was found to comply with the norms of 6.5-8.5.
- **Color** range varied from **1 to 20 Hazen** at all the monitoring locations in Kandla, and for Vadinar, it varied from **1 to 10 Hazen**.
- **Electrical conductivity (EC)** was observed in the range of **15,950 to 75,300 µS/cm**, with the average EC as **54,344.32** µS/cm for the locations of Kandla, whereas for the locations of Vadinar, it was observed in the range of **52,199 to 57,500 µS/cm**, with the average EC as **45,200.67** µS/cm.
- For all monitoring locations of Kandla the value of **Turbidity** was observed in the range of **33.9 to 379 NTU**, with average value of **198.83** NTU. For Vadinar it ranges from **3.15 to 13.8 NTU**, with average of **7.43** NTU. Materials that cause water to be turbid include clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and microscopic organisms. Turbidity affects the amount of light penetrating to the plants for photosynthesis.
- For the monitoring locations at Kandla the value of **Total Dissolved Solids (TDS)** ranged from **9,970 to 64,721 mg/L**, with an average value of **35,171** mg/L. Similarly, at Vadinar, the TDS values ranged from **25,784 to 41,790 mg/L**, with an average value of **34,073** mg/L.

- **TSS** values in the studied area varied between **26 to 924 mg/L** at Kandla and **78 to 346 mg/L** at Vadinar, with the average value of **362.69** mg/L and **242.23** mg/L respectively for Kandla and Vadinar.
- **COD** varied between **11.98 to 88.8 mg/L** at Kandla and **17.92 to 75 mg/L** at Vadinar, with the average value as **51.83** mg/L and **47.86** mg/L respectively for Kandla and Vadinar.
- **DO** level in the studied area varied between **3.4 to 8.4 mg/L** at Kandla and **4.3 to 7.9 mg/L** at Vadinar, with the average value of **5.86** mg/L and **6.15** mg/L respectively for Kandla and Vadinar. Which represents that the marine water is suitable for marine life.
- **BOD** observed was observed in the range of **3.6 to 11.1 mg/L**, with average of **7.76** mg/L for the location of Kandla and for the locations of Vadinar, it was observed in the range of **3.91 to 7.5 mg/L**, with an average value of **5.9** mg/L.
- **Sulphate** concentration in the studied area varied between **632.92 to 3704.9 mg/L** at Kandla and **1846.3 to 3236.8 mg/L** at Vadinar. The average value observed at Kandla was **2566.45** mg/L, whereas **2580.87** mg/L was the average value of Vadinar. Sulphate is naturally formed in inland waters by mineral weathering or the decomposition and combustion of organic matter.
- **Nitrate** in the study area was observed in the range of **1.12 to 6.92 mg/L**, with the average of **4.26** mg/L. Whereas for the Vadinar the concentration of Nitrate was observed in the range of **1.759 to 5.17** mg/L, with the average **3.53** mg/L.
- **Nitrite** in the study area was observed in the range of **0 to 0.16 mg/L**, with the average of **0.625** mg/L. Whereas for the Vadinar the concentration of Nitrite was observed Below Quantification Limit During whole monitoring period.
- **Phosphate** in the study area was observed in the range of **0.09 to 2.01 mg/L**, with the average of **0.92** mg/L. Whereas for the Vadinar the concentration of Phosphate was observed in the range of **0.64 to 1.43** mg/L, with the average **1.11** mg/L.
- **Silica** in the study area was observed in the range of **0.2 to 4.04 mg/L**, with the average of **2.19** mg/L. Whereas for the Vadinar the concentration of silica was observed in the range of **0.09 to 1.86** mg/L, with the average **0.724** mg/L.
- In the study area of Kandla the concentration of **Potassium** varied between **68.34 to 543.68 mg/L** and **10.86 to 518 mg/L** at Vadinar, with the average value as **277.71** mg/L and **268.99** mg/L respectively for Kandla and Vadinar.
- **Sodium** in the study area varied between **2,086 to 10,722 mg/L**, with average of **8948.26** mg/L, at Kandla whereas at Vadinar its value recorded within range of **2149.6 to 9542 mg/L,** with the average of **6252.43** mg/L.
- **Odour** was observed 1 for all locations of Kandla and Vadinar.
- **Arsenic** concentration observed to be BQL for majority of location for Kandla and Vadinar except locations MW-1, MW-2, MW-3, MW-6, MA-7 and MW-8 for some instant of time during whole monitoring period.
- **Copper** in the study area varied between **0.005 to 12.01 mg/L**, with average of **6.23** mg/L, at Kandla whereas at Vadinar its value recorded within range of **0 to 3.4 mg/L,**

with the average of **2.04** mg/L, on both project sites during monitoring majority of time Copper found Below Quantification Limit.

- **Iron** in the studied area varied between **0.21 to 7.93 mg/L**, with the average of **2.55** mg/L, at Kandla, and for Vadinar value were recorded within range of **0.01** to **0.66** mg/L, with average value of **0.22** mg/L.
- **Lead** concentration varied **0.002 to 9.68 mg/L**, with an average of **2.41** mg/L at Kandla. At Vadinar location within range of **0.002** to **2.753** mg/L with an average **1.17** mg/L
- **Manganese** in the studied area varied between **0.0748 to 294.91 mg/L**, with the average of **86.57** mg/L, at Kandla and for Vadinar, recorded value were observed within the range of **1.97** to **113.93 mg/L**, with the average of **48.56** mg/L.
- **Total Chromium** in the study area varied between **0 to 15.99 mg/L**, with average of **5.13** mg/L, at Kandla whereas at Vadinar its value recorded **45.76** mg/L at MW-8 in the monitoring period of January to February 2024**,** While on both project sites during monitoring majority of time Total Chromium found Below Quantification Limit
- **Particulate Organic Carbon** in the study area was observed in the range of **0.42 to 900**, with the average value of **65.27**. the maximum spike of 900 is only observed once in the period of April to May 2023 during whole monitoring period. Whereas for the Vadinar, the value observed was Within the range of **0.32** to **4.76**, with the average of **2.22**.
- **Oil & Grease, Nitrite, Phosphate, Hexavalent Chromium, Arsenic, Cadmium, Total Chromium, Zinc, Mercury and Floating Material (Oil grease scum, petroleum products)** were observed to have concentrations **"Below the Quantification Limits (BQL)"** for most of the locations of Kandla and Vadinar, majority of time during whole monitoring period.
- **Total Coliforms** were detected complying with the specified norm of 500 MPN/100ml for all the locations of Kandla and Vadinar, except on location MW-1 in the month of May to June 2023.

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

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

CHAPTER 11: MARINE SEDIMENT QUALITY MONITORING

11.1 Marine Sediment Monitoring

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

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

Methodology

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

Table 29: Details of the sampling locations for Marine Sediment

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

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

Map 18: Marine Sediment Monitoring Location at Kandla

Map 19: Marine Sediment Monitoring Locations at Vadinar

The list of parameters to be monitored under the projects for the Marine Sediment sampling been mentioned in **Table 31** as follows:

Table 30: List of parameters to be monitored for Sediments at Kandla and Vadinar

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

11.2 Result and Discussion

The quality of Marine Sediment samples collected from the locations of Kandla and Vadinar during the monitoring period of April 2023 to March 2024 has been summarized in the **Table 32.**

Table 31: Summarized result of Marine Sediment Quality

Parameters	Kandla																		Vadinar					
	MS-1			MS-2			MS-3			MS-4			MS-5			MS-6			MS-7			MS-8		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Inorganic Phosphate (kg/ha)	16.85	0.86	6.6042	14.37	0.67	8.81	41.2	0.8	16.98	19.44	0.81	9.532	45.1	0.72	14.48	34.6	0.66	15.24	14.5	1.24	5.65	18.51	0.82	5.7325
Phosphate (mg/Kg)	3247.8	290.8	1280.63	2514.7	258.3	1304	3736	226.6	1515	3871	353.7	1287	3741	306.8	1442	14076	578.3	2793.9	3002	152.5	770.24	3477.29	167.93	940.70
Organic Matter (%)	1.42	0.21	0.7875	2.17	0.29	1.13	1.01	0.17	0.593	2.1	0.33	0.975	1.24	0.67	0.911	2.06	0.21	0.915	2.29	0.15	1.04	1.65	0.17	0.89
Sulphate as SO^{4-} (mg/Kg)	905.25	110.2	366.8	1022.25	98.2	370.03	571.64	95.33	275.09	650.25	97.45	268.51	768	87.28	294.27	732	96.38	249.1	296	74.07	126.31	213.4	80.06	132.03
Calcium as Ca (mg/Kg)	13800	1612	3464.3	5800	1259	2836	4200	962	2163	4200	1102	2669	10500	1089	3102	3800	1047	2274.6	3700	2200	2930.9	3974.2	2100	2805.45
Magnesium as Mg (mg/Kg)	1952	1225	1538.53	3050	826.46	1810.84	2136	764	1592.59	3172	866.94	1810.6	2440	1032	1622.80	2745	906.98	1581.95	1952	854	1385.18	14640	1167	2920.83
Silica (g/Kg)	671.25	261.3	479.11	612.51	289.4	481.7	571.5	329.1	444.8	555.2	245.7	392.1	597.1	179.2	418.6	580.4	245.3	436.12	529.8	220.9	377.71	546.08	264.92	426.66
Nitrite (mg/Kg)	0.75	0.12	0.41	0.92	0.13	0.50	0.81	0.08	0.41	0.91	0.01	0.43	0.71	0.11	0.375	0.89	0.07	0.489	0.22	0.07	0.159	0.37	0.04	0.23
Nitrate (mg/Kg)	22.34	5.86	16.58	37.12	7.59	18.29	36.47	4.51	15.50	25.94	4.31	13.99	10.34	5.24	13.17	20.38	6.34	14.52	25.33	9.54	15.36	25.21	4.75	10.52
Sodium (mg/Kg)	7860	3194	4512.43	14688	2453	5318	8612	2072	4550	18308	2612	6435	10520	2063	4665	14076	2072	5639.6	11944	3971	7904.6	13660	2719.42	9536.63
Potassium (mg/Kg)	2610.7	241	1525.98	11580	276	2320	3479	260.7	2126	4208	294	2424	3152	205	1790	3479	236.9	2233.4	3372	699	1876.1	4377	1028	2025.66
Aluminium (mg/Kg)	8371.7	2116	3827.74	10641	1237.1	4465.9	10363.1	1278.5	4370.2	12008.4	1971.2	5025.2	10361.1	1264.58	3891.23	12314.1	1273.22	4384.20	14179.7	358.3	4028.56	19356.55	479.16	4883.52
Mercury (mg/Kg)	4.71	4.71	4.71	10.74	10.74	10.74	41.29	41.29	41.29	6.44	6.44	6.44	15.21	15.21	15.21	34.69	34.69	34.69	0	0	0	0	0	0
Texture	Sandy loam	Sandy loam	Silt loam	Sandy loam	Silt loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Loam	Loam	Loam

11.3 Data Interpretation and Conclusion

The Marine sediment quality at Kandla and Vadinar has been monitored for various physico-chemical parameters during the monitoring April 2023 to March 2024. The detailed interpretation of the parameters is given below:

- **Inorganic Phosphate** for the sampling period was observed in range of **0.66 to 45.12** Kg/ha for Kandla. Whereas for Vadinar the value observed Within range of **0.82** to **18.51** Kg/ha. For Kandla and Vadinar the average value of Inorganic Phosphate was observed **13.77** and **7.74** Kg/ha respectively.
- The concentration of **Phosphate** was observed in range of **226.6 to 3871.15 mg/Kg** for Kandla and for Vadinar the value observed within the range of **152.53** to **3477.29** mg/Kg. For Kandla and Vadinar the average concentration of Phosphate was observed **1616.78** and **1418.5** mg/Kg respectively.
- The **Organic Matter** for the sampling period was observed in the range of **0.17 to 2.17 %** for Kandla with the average value of **0.95**% and for Vadinar the value recorded Within range of **0.15 to 2.29**%, with average concentration as **1.03 %.**
- The concentration of **Sulphate** was observed in the range of **87.28 to 1022 mg/Kg** for Kandla and for Vadinar the value observed Within range of **74.07** to **296** mg/Kg. For Kandla and Vadinar the average value of Sulphate was observed **392.10** and **153.64** mg/Kg respectively.
- The value of **Calcium** was observed in the range of **962 to 13800 mg/Kg** for Kandla and for Vadinar the value observed within the range of **2100** to **3974.5** mg/Kg. The average value of Calcium for the monitoring period was observed **3660.21** mg/Kg and **2951.76** mg/Kg at Kandla and Vadinar, respectively.
- The value of **Magnesium** for the sampling period was observed in the range of **764 to 3172 mg/Kg** for Kandla and for Vadinar the value observed Within the range of **854** to **1952** mg/Kg. For Kandla and Vadinar the average value of Magnesium was observed **1726**.35 mg/Kg and **1440.69** mg/Kg respectively.
- For the sampling period **Silica** was observed in the range of **179.25 to 671.25 mg/Kg** for Kandla with average value **432.83** mg/Kg and for Vadinar the value observed within the range of **220.98** and **546.5** mg/Kg with average **394.35** mg/Kg.
- The value of **Nitrate** was observed in the range of **4.31 to 37.12 mg/Kg** for Kandla with average value **15.47** mg/Kg and for Vadinar the value observed within the range of **4.75** to **25.33** mg/Kg. with average **15.12** mg/Kg.
- The value of **Nitrite** was observed in the range of **0.01 to 0.92 mg/Kg** for Kandla with average value **0.45** mg/Kg and for Vadinar the value observed to be within the range of **0.04** to **0.37** mg/Kg, with average **0.1828** mg/Kg.
- The value of **Sodium** was observed in the range of **2063.3 to 18308 mg/Kg** for Kandla with average value **6647.43** mg/Kg and for Vadinar the value observed within the range of **2719.42** and **13660** mg/Kg, with average **8289** mg/Kg.
- The value of **Potassium** was observed in the range of **205.08 to 11580 mg/Kg** for Kandla with average value **2357.95** mg/Kg and for Vadinar the value observed within range of **699.09** to **4377** mg/Kg, with average **2229.65** mg/Kg.

- The value of **Aluminium**, was observed in the range of **1237.13 to 12314.13 mg/Kg** for Kandla with average value **5509.23** mg/Kg and for Vadinar the value observed within the range of **358.3** to **19356** mg/Kg, with average **7214.30** mg/Kg.
- The value of **Mercury**, was observed in the range of **4.71 to 41.29 mg/Kg** for Kandla with average value **18.84** mg/Kg and for Vadinar the value of **Mercury** was observed "Below the Quantification Limit" at both two locations. During monitoring period majority of time Mercury was observed Below Quantification limit.
- Texture was observed to be "**Sandy Loam**" at location MS-1, MS-2, MS-4 and MS-6 "**Silt loam"** at location MS-3 & MS-5 in Kandla. "**Sandy Loam**" at location MS-7 & "**Silt loam"** at location MS-8 in Vadinar during sampling period.

Heavy Metals

The sediment quality of Kandla and Vadinar has been compared with respect to the Average Standard guideline applicable for heavy metals in marine sediment specified by EPA have been mentioned in **Table 33.**

Table 32: Standard Guidelines applicable for heavy metals in sediments

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

(Source: G Perin et al. 1997)

Table 33: Comparison of Heavy metals with Standard value in Marine Sediment

Parameters	Kandla																		Vadinar					
	MS-1			MS-2			MS-3			MS-4			MS-5			MS-6			MS-7			MS-8		
	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg
Arsenic (mg/Kg)	5.13	1.09	3.527	4.43	2.11	3.264	6.17	2.06	3.92	5.86	1.28	3.75	5.2	1.75	3.458	5.78	1.98	3.67	5.36	2.04	2.84	5.17	2.5	3.69
Copper (mg/Kg)	5.6	2.13	3.282	11.4	2.14	5.013	8.1	2.08	4.49	9.8	3.48	5.71	12	2.14	5.97	8.9	2.98	4.97	6.13	2.19	4.567	412	2.1	39.05
Chromium (mg/Kg)	64.1	42.12	53.94	67.45	32.74	47.04	73.02	32.41	48.31	83.23	41.08	55.17	59.95	41.87	51.50	104.2	36.71	59.71	59.27	23.18	44.01	104.1	29.7	61.12
Nickel (mg/Kg)	51.4	16.8	31.76	38.9	10.21	23.87	36.41	4.54	22.77	40.87	7.61	27.45	31.86	21.72	25.881	50.78	4.54	25.058	36.21	12.23	22.84	43.66	12.47	29.282
Lead (mg/Kg)	7.05	1.25	5.3	7.45	4.21	5.76	28.73	2.36	6.683	8.25	3.46	5.9	14.22	1.21	6.055	5.01	2.81	7.88	7.94	2.85	4.90	10.58	2.97	5.65
Zinc (mg/Kg)	63.2	35.88	54.63	65.69	32.11	50.455	301.32	23.63	69.545	82.9	18.15	50.86	159.42	19.54	60.65	157.82	23.63	57.7	52.13	11.47	34.6	104.87	13.65	53.8595
Cadmium (mg/Kg)	1.08	0.88	0.98	0.6	0.6	0.6	1.25	0.87	1.1	1.12	0.78	1.022	1.08	0.91	0.995	7.53	0.15	2.302	0	0	0	0	0	0

- **Arsenic** was observed in the range of **1.09 to 6.17 mg/Kg** for Kandla with average value **3.58** mg/Kg and for Vadinar the value observed within range of **2.04** to **5.36** mg/Kg, with average of **3.6** mg/Kg. during monitoring period majority of time arsenic concentration found within moderately polluted class on both study area.
- **Copper** was observed in the range of **2.08 to 12 mg/Kg** for Kandla with average value **5.6** mg/Kg and for Vadinar the value observed within the range of be **2.1** to **8.33** mg/Kg, with average **4.72** mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to copper falls in non-polluted class.
- **Chromium** was observed in the range of **32.41 to 104.24 mg/Kg** for Kandla with average value **55.25** mg/Kg and for Vadinar the value observed within the range of **23.18** to **104.16** mg/Kg, with average **53.57** mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to chromium falls majority of time in moderately polluted and for some instance it location MS-4, MS-6, and MS-8 fall in Heavily polluted class.
- **Nickel** was observed in the range of **4.54 to 51.47 mg/Kg** for Kandla with average value **26.25** mg/Kg and for Vadinar the value observed within range of **12.23** to **43.66** mg/Kg, with average **26.115** mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to nickel falls in moderately polluted class and for some instance it location MS-1, and MS-6 fall in heavily polluted class.

- **Lead** was observed in the range of **1.21 to 28.73 mg/Kg** for Kandla with average value **5.63** mg/Kg and for Vadinar the value observed within the range of **2.85** and **10.58** mg/Kg, with average **5.81** mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to lead falls in not polluted class.
- **Zinc** was observed in the range of **18.15 to 301.32 mg/Kg** for Kandla with average value **73.73** mg/Kg and for Vadinar the value observed within the range of **11.47** to **104.87** mg/Kg, with average **46.997** mg/Kg. With reference to the guidelines mentioned in table 35, the sediment quality with respect to zinc falls in non-polluted class and for some instance its location MS-1, MS-3, MS-6 and MS-8 fall in Moderately polluted class.
- **Cadmium** was observed in the range of **0.15 to 7.53 mg/Kg** for Kandla with average value **1.325** mg/Kg**.** During the monitoring period majority of time **Cadmium** found BQL, which falls in non-polluted. While exception on one location MS-6 fall within moderately polluted for the duration of July to August 2023. **Cadmium** was observed BQL for all locations at Vadinar during sampling period. With reference to the guidelines mentioned in table 35, the sediment quality with respect to cadmium falls in non-polluted class.

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

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

CHAPTER 12: MARINE ECOLOGY MONITORING

12.1 Marine Ecological Monitoring

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

As defined in the scope by DPA, the Marine Ecological Monitoring is required to be carried out once a month specifically at eight locations, six at Kandla and two at Vadinar. The sampling of the Benthic Invertebrates has been carried out with the help of D-frame nets, whereas the sampling of zooplankton and phytoplankton has been carried out with the help of Plankton Nets (60 micron and 20 micron). The details of the locations of Marine Ecological Monitoring have been mentioned in **Table 35** as follows:

Table 34: Details of the sampling locations for Marine Ecological

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

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

Map 20 Marine Ecological Monitoring: Locations at Kandla

Map 21: Marine Ecological Monitoring Locations at Vadinar

The various parameters to be monitored under the study for Marine Ecological Monitoring are mentioned in **Table 36** as follows:

Table 35: List of parameters to be monitored for Marine Ecological Monitoring

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

Methodology

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

- **Phytoplankton Estimation**
  Phytoplankton are free floating unicellular, filamentous and colonial eutrophic organisms that grow in aquatic environments whose movement is more or less dependent upon water currents. These micro flora acts as primary producers as well as the basis of food chain, source of protein, bio-purifier and bio-indicators of the aquatic ecosystems of which diverse array of the life depends. They are considered as an important component of aquatic flora, play a key role in maintaining equilibrium between abiotic and biotic components of aquatic ecosystem. The phytoplankton includes a wide range of photosynthetic and phototrophic organisms. Marine phytoplankton is mostly microscopic and unicellular floating flora, which are the primary producers that support the pelagic food-chain. The two most prominent groups of phytoplankton are Diatoms (*Bacillariophyceae*) and Dinoflagellates (*Dinophyceae*). Phytoplankton also include numerous and diverse collection of extremely small, motile algae which are termed micro

flagellates (naked flagellates) as well as Cyanophytes (Bluegreen algae). Algae are an ecologically important group in most aquatic ecosystems and have been an important component of biological monitoring programs. Algae are ideally suited for water quality assessment because they have rapid reproduction rates and very short life cycles, making them valuable indicators of short-term impacts. Aquatic populations are impacted by anthropogenic stress, resulting in a variety of alterations in the biological integrity of aquatic systems. Algae can serve as an indicator of the degree of deterioration of water quality, and many algal indicators have been used to assess environmental status.

- **Zooplankton Estimation**

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

- **Diversity Index**

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

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

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

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

Where, ∑ = Summation symbol,

pi = Relative abundance of the species,

ln = Natural logarithm

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

2. **Simpson's index:**

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

The formula for calculating D is presented as:

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

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

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

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

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

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

Where, N = total number of individuals collected

S = No. of taxa or species or genera

4. **Berger-Parker index:**

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

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

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

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

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

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

5. Evenness index–

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

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

Where, H= Shannon value

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

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

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

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

Monitoring Frequency:

Monitoring is required to be carried out once a month for both the locations of Kandla and Vadinar. Sample Collected from this location during the monitoring period April 2023 to March 2024.

12.2 Result and Discussion

The details of Marine Ecological Monitoring conducted for the locations of Kandla and Vadinar during the monitoring period has been summarized in the **Table 37.**

Table 36: Values of Biomass, Net Primary Productivity (NPP), Gross Primary Productivity (GPP), Pheophytin and Chlorophyll for Kandla and Vadinar

Sr. No.	Parameters	Kandla						Vadinar	
		ME-1 (Near Passenger Jetty One)	ME-2 (Kandla Creek)	ME-3 (Near Coal Berth)	ME-4 (Khori Creek)	ME-5 (Nakti Creek-near Tuna Port)	ME-6 (Nakti Creek near NH - 8A)	ME-7 (Near SPM)	ME-8 (Near Vadinar Jetty)
		Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.	Avg.
1.	Biomass	115	115	96	142	102	121	78	111
2.	Net Primary Productivity	2.91	3.77	3.08	2.99	5.47	2.49	4.16	2.64
3.	Gross Primary Productivity	2.95	3.04	3.73	3.26	2.44	2.85	3.67	3.09
4.	Pheophytin	1.10	1.28	0.80	1.35	0.82	5.81	2.66	2.43
5.	Chlorophyll-a	2.40	1.61	1.72	1.72	2.04	12.43	2.37	3.24
6.	Particulate Oxidisable Organic Carbon	1.34	1.12	1.18	1.51	1.45	1.40	1.26	1.20
7.	Secchi Depth	0.61	0.63	0.56	0.60	0.56	0.62	3.93	2.61

- **Biomass:**
  With reference to **Table 37**, the average concentration of biomass during the monitoring period, for locations ME-1 to ME-6 was reported within the range of **96–142** mg/L, with the lowest biomass present in **ME-3 (near coal berth)** and the highest biomass present in **ME-4 (Khori Creek)** during the sampling period. In Vadinar, the value of biomass was observed at **78** mg/L at ME-7 (near SPM) and **111** mg/L at ME-8 (near Vadinar Jetty) monitoring station.

- **Productivity (Net and Gross)**
  Gross primary productivity (GPP) is the rate at which organic matter is synthesised by producers per unit area and time (GPP). The amount of carbon fixed during photosynthesis by all producers in an ecosystem is referred to as gross primary productivity. During the Monitoring Period, the monitoring location of Kandla reported GPP value in range between **2.44 to 3.73 mg/L/48 Hr** where the highest value recorded

for ME-3 (Near Coal Bearth) and lowest recorded at ME-5 (Nakti creek-near tuna port). In Vadinar, the value of **GPP** was observed **3.67** at ME-7 (Near SPM) and **3.09** mg/L/48 Hr at ME-8 (Near Vadinar Jetty) monitoring station.

Net primary productivity, is the amount of fixed carbon that is not consumed by plants, and it is this remaining fixed carbon that is made available to various consumers in the ecosystem. During the monitoring period of 2023 to 2024 the Net primary productivity of the monitoring location at Kandla from (ME-1 to ME-6) has been estimated to be between **2.49 to 5.47 mg/L/48 Hr**. While in Vadinar, the value of **NPP** was observed **4.16** at ME-7 (Near SPM) and **2.64** mg/L/48 Hr at ME-8 (Near Vadinar Jetty) monitoring station.

- **Pheophytin**

  The level of Pheophytin was detected in the range from **0.8 to 5.81 mg/m^3** where the highest value observed at ME-6 (Nakti Creek (Near NH-8A)) and the lowest value observed at ME-3(Near Coral Breth), While in Vadinar, the value of Pheophytin was observed **2.66** mg/m^3 at ME-7 and **2.43** mg/m^3 at ME-8 monitoring station.

- **Chlorophyll-a**

  In the sub surface water, the value of Chlorophyll-a reported in range from **1.61 to 12.43 mg/m^3**. The highest value observed at ME-6 (Nakti Creek (Near NH-8A)), while the lowest value observed at ME-2 (Kandla Creek). In Vadinar, the value of chlorophyll-a was observed **2.37** mg/m^3 at ME-7 (Near SPM) and **3.24** mg/m^3 in ME-8 (Near Vadinar Jetty) monitoring station.

- **Particulate Oxidisable Organic Carbon**

  During the sampling period, the particulate oxidisable organic carbon falls within the range of **1.12 to 1.51 mg/L** from monitoring location ME-1 to ME-6 at Kandla, whereas for Vadinar, the value of POC observed **1.26** mg/L at ME-7 (Near SPM) and **1.20** mg/L in ME-8 (Near Vadinar Jetty) monitoring station.

- **Secchi Depth**

  In monitoring station of Kandla (ME-1 to ME-6) the level of Secchi Depth was observed between **0.56 to 0.63 ft** whereas at Vadinar, the value recorded at ME-7 i.e. Near SPM is **3.93** ft and in Near Vadinar Jetty is **2.61** ft.

Ecological Diversity

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

The details of variation in abundance and diversity in phytoplankton communities is mentioned in **Table 38**.

Table 37: Phytoplankton variations in abundance and diversity in sub surface sampling stations

Genera	ME-1 (Near Passenger Jetty One)	ME-2 (Kandla Creek)	ME-3 (Near Coal Berth)	ME-4 (Khori Creek)	ME-5 (Nakti Creek-near Tuna Port)	ME-6 (Nakti Creek near NH - 8A)	ME-7 (Near SPM)	ME-8 (Near Vadinar Jetty)
	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg
Bacillaria sp.	360	391	271	404	374	521	390	347
Biddulphia sp.	492	340	73	542	315	434	402	274
Chaetoceros sp.	279	379	316	258	627	322	462	394
Chlamydomonas sp.	286	312	147	329	478	456	325	503
Cyclotella sp.	367	443	284	418	454	609	303	378
Coscinodiscus sp.	455	412	290	206	330	376	370	244
Ditylum sp	342	322	124	241	225	205	227	294
Fragilaria sp.	395	381	336	300	355	0	350	360
Bacteriastrum sp.	178	96	52	166	111	252	162	252
Pleurosigma sp.	236	236	129	565	276	675	352	219
Navicula sp.	366	488	472	393	420	332	375	856
Nitzschia sp.	309	272	249	295	366	284	418	435
Synedra sp.	479	328	82	322	144	541	192	327
Skeletonema sp.	270	566	130	0	488	536	521	495
Oscillatoria sp.	341	351	176	251	493	423.5	144	306
Thallassiosira	147	134	64	132	170	224	235	161
Gomphonema sp.	550	495	128	360	600	310	564	500
Planktothrix sp.	140	302	123	411	393	495	272	353
Gyrosigma sp.	410	560	130	750	0	685	400	667
Actinestrum sp.	0	0	0	0	0	500	0	0
Cymbella	500	500	0	550	0	685	700	500
Limnothrix sp.	0	700	0	650	0	800	750	0
Scendesmus sp.	0	0	0	485	0	630	0	0
Mougeotia sp.	0	0	0	8	0	20	0	4
Chlorella sp.	0	0	0	0	0	850	0	0
Density-Units/L	3107.1	3525	3177.3	2918	3073	3704	3357	3576
No. of genera	**20**	**21**	**19**	**22**	**18**	**24**	**21**	**21**

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

The density of phytoplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from **2918** to **3704** units/L, while for Vadinar its density of phytoplankton observed **3357** units/L at ME-7 and **3576** units/L at ME-8. During the sampling, all communities were contributing in phytoplankton on both location of Kandla & Vadinar except *Gyrosigma sp*, *Actinestrum sp*, *cymbella*, *Limnothrix sp*, *Scendesmus sp*, *Mougeotia sp* and *cholera sp*.

The details of Species richness Index and Diversity Index in Phytoplankton is mentioned in **Table 39**.

Table 38: Species richness Index and Diversity Index in Phytoplankton

Indices	ME-1 (Near Passenger Jetty One)	ME-2 (Kandla Creek)	ME-3 (Near Coal Berth)	ME-4 (Khori Creek)	ME-5 (Nakti Creek-near Tuna Port)	ME-6 (Nakti Creek near NH - 8A)	ME-7 (Near SPM)	ME-8 (Near Vadinar Jetty)
	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg
Taxa S	13	14	13	14	13	15	14	13
Individuals	3099	3408	3202	2926	3094	3768	3357	3597
Shannon diversity	2.09	2.12	2.05	1.97	1.94	2.02	2.10	1.95
Simpson 1-D	0.86	0.86	0.85	0.83	0.83	0.84	0.86	0.80
Species Evenness	0.92	0.91	0.90	0.89	0.90	0.87	0.90	0.85
Margalef richness	1.03	1.09	1.02	1.00	0.93	1.01	1.07	1.01
Berger-Parker	0.20	0.21	0.22	0.24	0.25	0.24	0.22	0.28
Relative abundance	0.41	0.44	0.38	0.44	0.38	0.41	0.40	0.41

- **Shannon- Wiener's Index (H):** During monitoring period 2023 to 2024, Average Shanon- Wierner's index of phytoplankton communities was in the range of **1.94 to 2.12** between selected sampling stations from ME-1 to ME-6. While for Vadinar, Average Shannon Wiener's index of phytoplankton communities recorded to be **2.10** at ME-7 and **1.95** at ME-8. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Vadinar.
- **Simpson diversity index (1-D):** During the monitoring period **2023 to 2024,** average Simpson diversity index (1-D) of phytoplankton communities was ranged between **0.83 to 0.86** at all sampling stations in the Kandla creek and nearby creeks. Similarly, for Vadinar average Simpson diversity index (1-D) of phytoplankton communities was **0.86** at ME-7 and **0.80** at ME-8.
- **Margalef's diversity index** (Species Richness): During the monitoring period **2023 to 2024,** average margalef's diversity index of phytoplankton communities in Kandla and nearby creeks sampling stations was varying from **0.93 to 1.09.** While for Vadinar, average Margalef's diversity index (Species Richness) of phytoplankton communities observed **1.07** at ME-7 and **1.01** at ME-8.

- **Berger-Parker Index (d):** During the monitoring period **2023 to 2024,** average Berger-Parker Index (d) of phytoplankton communities was in the range of **0.20 to 0.25** between selected sampling stations from ME-1 to ME-6. at Kandla creek and nearby creeks.

Average Berger-Parker Index (d) of phytoplankton communities in the sampling stations of Vadinar, was in the range of **0.22** to **0.28.** All the monitoring station signifies a low diversity with an even distribution among the different species.

- The Average **Species Evenness** is observed in the range of **0.87 to 0.92** for all the six-monitoring station of Kandla and for the Vadinar the average species evenness is observed in the range of **0.85** to **0.90**.

- During the sampling period, average **Relative Abundance** of phytoplankton communities was in range of **0.38 to 0.44** between selected sampling stations from ME-1 to ME-6 at Kandla creek and nearby creeks. Whereas for Vadinar the Average relative Abundance value **0.40** at ME-7 and **0.41** at ME-8. thus, it is concluded that the studied species can be stated as neither highly dominant nor rare.

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

Table 39: Zooplankton variations in abundance and diversity in sub surface sampling stations

Genera	ME-1 (Near Passenger Jetty One)	ME-2 (Kandla Creek)	ME-3 (Near Coal Berth)	ME-4 (Khori Creek)	ME-5 (Nakti Creek-near Tuna Port)	ME-6 (Nakti Creek near NH - 8A)	ME-7 (Near SPM)	ME-8 (Near Vadinar Jetty)
	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg
Acartia sp.	2	2	2	2	2	2	3	2
Acrocalanus	2	2	2	2	2	2	2	4
Amoeba	3	2	3	3	4	2	3	2
Brachionus sp.	3	2	2	2	2	3	4	2
Calanus sp.	2	3	3	2	2	3	2	3
Cladocera sp.	2	3	5	2	3	2	3	3
Cyclopoid sp.	5	4	4	4	2	2	4	2
Copepod larvae	2	3	2	3	2	4	2	2
Diaptomus sp.	5	2	4	2	3	2	3	3
Eucalanus sp.	3	2	2	4	3	6	3	4
Mysis sp.	3	9	7	5	1	6	6	8
Oithona sp.	1	2	4	2	1	4	4	9
Paracalanus sp.	8	7	4	8	11	8	9	10
Density Unit/L	24.45	24.91	25.82	26.00	22.91	26.45	27.64	27.36
No. of genera	13	13	13	13	13	13	13	13

A total of 13 groups/taxa of zooplankton were recorded in Kandla and Vadinar during the study period which mainly constituted by *diaptomus*, *copepods*, *brachionus*, *cladocera*, fish and shrimp larval forms. *Amoeba* and *Cyclopoida* had the largest representation at all stations from (ME-1 to ME-8). The average density of Zooplankton of the sampling stations from ME-1 to ME-6 (Kandla) varying from **22.91** to **26.45** units/L, while for Vadinar its average density of zooplankton observed **27.64** units/L at ME-7 and **27.36** units/L at ME-8. During the sampling, all communities were contributing in zooplankton except *Oithana sp.* in Kandla and Vadinar.

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

Table 40: Species richness Index and Diversity Index in Zooplankton

Indices	ME-1 (Near Passenger Jetty One)	ME-2 (Kandla Creek)	ME-3 (Near Coal Berth)	ME-4 (Khori Creek)	ME-5 (Nakti Creek- near Tuna Port)	ME-6 (Nakti Creek near NH - 8A)	ME-7 (Near SPM)	ME-8 (Near Vadinar Jetty)
	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg
Taxa S	11	13	10	13	10	12	13	10
Individuals	24	57	26	26	23	26	28	27
Shannon diversity	1.77	1.74	1.76	1.79	1.67	1.76	1.79	1.72
Simpson (1-D)	0.79	0.75	0.79	0.79	0.76	0.77	0.79	0.77
Species Evenness	0.78	0.61	0.78	0.79	0.79	0.73	0.82	0.76
Margalef	2.15	2.21	2.07	2.21	2.06	2.34	2.22	2.16
Berger-Parker	0.34	0.42	0.32	0.34	0.35	0.37	0.31	0.35
Relative abundance	34.93	40.08	31.95	37.76	39.98	38.18	39.18	37.27

- **Shannon- Wiener's Index (H):** During monitoring period 2023 to 2024, Average Shanon- Wierner's index of zooplankton communities was in the range of **1.67 to 1.79** between selected sampling stations from ME-1 to ME-6, at Kandla creek and its nearby creeks. While for Vadinar, average Shannon Wiener's index of zooplankton communities recorded to be **1.79** at ME-7 and **1.72** at ME-8. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Near SPM (Vadinar).
- **Simpson diversity index (1-D):** During the monitoring period **2023 to 2024,** average Simpson diversity index (1-D) of zooplankton communities was ranged between **0.75 to 0.79** at all sampling stations in the Kandla creek and nearby creeks, for Vadinar average Simpson diversity index (1-D) of zooplankton communities was **0.79** at ME-7 and **0.77** at ME-8.
- **Margalef's diversity index** (Species Richness): During the monitoring period **2023 to 2024,** average margalef's diversity index of zooplankton communities in Kandla and nearby creeks sampling stations was varying from **2.06 to 2.34,** during the sampling period. While for Vadinar, average Margalef's diversity index (Species Richness) of zooplankton communities observed **2.2** at ME-7 and **2.16** at ME-8.

- **Berger-Parker Index (d):** During the monitoring period **2023 to 2024,** average Berger-Parker Index (d) of zooplankton communities was in the range of **0.32 to 0.42** between selected sampling stations from ME-1 to ME-6, at Kandla creek and nearby creeks. Average Berger-Parker Index (d) of zooplankton communities in the sampling stations of Vadinar, was in the range of **0.31** to **0.35.** All the monitoring station signifies a low diversity with an even distribution among the different species.

- The average **Species Evenness** is observed in the range of **0.61 to 0.79** for all the six-monitoring station of Kandla whereas, for the Vadinar the average species evenness was observed in the range of **0.76** to **0.82**, during the monitoring period.

- During the sampling period, **average Relative Abundance** of zooplankton communities was in range of **31.95** to **40.08** between selected sampling stations from ME-1 to ME-6. at Kandla creek and nearby creeks. Whereas for Vadinar the average relative abundance value **39.18** at ME-7 and **37.27** at ME-8, thus it can be concluded that the studied species is stated as neither highly dominant nor rare.

The details of variation in abundance and diversity in **Benthic organism** is mentioned in **Table 42.**

Table 41: Benthic Fauna variations in abundance and diversity in sub surface sampling

Genera	ME-1 (Near Passenger Jetty One)	ME-2 (Kandla Creek)	ME-3 (Near Coal Berth)	ME-4 (Khori Creek)	ME-5 (Nakti Creek- near Tuna Port)	ME-6 (Nakti Creek near NH - 8A)	ME-7 (Near SPM)	ME-8 (Near Vadinar Jetty)
	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg
Thiaridae	2	1	2	2	2	2	1	3
Mollusca sp.	2	1	2	2	3	2	2	3
Odonata sp.	2	1	2	3	2	2	2	3
Lymnidae	2	1	5	2	2	2	3	2
Planorbidae	1	1	2	1	2	2	2	1
Atydae	2	1	2	2	1	2	2	2
Gammaridae	2	1	1	2	1	2	2	3
Portunidae	1	1	1	1	0	1	1	1
Turbinidae	2	1	3	1	1	2	2	2
Palaemonidae	1	1	2	3	3	1	2	2
Diapatra sp.	2	1	3	4	2	4	2	3
Coleoptera sp.	2	1	3	3	0	1	3	2
Crustacea sp.	3	1	3	3	3	3	2	1
Hemiptera sp.	2	1	0	2	2	2	3	2
Tricoptera sp.	2	1	3	4	3	5	2	1
Hydrobidae	1	1	1	2	1	3	0	3
Viviparidae	3	1	0	1	2	2	3	3
Neridae	2	1	2	0	4	2	1	2
Density-m³	10.18	8.82	9.64	10.09	8.5	9.73	9.73	9.55
No of genera	**18**	**18**	**16**	5.00	**16**	**18**	**17**	**18**

Few Benthic organisms were observed in the collected sample by using the Van-Veen grabs during the sampling conducted for DPA Kandla and Vadinar. Majority of the species were found under the Macro-benthic organisms during the sampling period were represented by *Atyde, Palaemonidae, Mollusca sp.*, etc. The average density of benthic fauna was varying from **8.55** to **10.18** m^3.

The details of Species richness Index and Diversity Index in Benthic Organisms is mentioned in **Table 43.**

Table 42: Species richness Index and Diversity Index in Benthic Organisms

Indices	ME-1 (Near Passenger Jetty One)	ME-2 (Kandla Creek)	ME-3 (Near Coal Berth)	ME-4 (Khori Creek)	ME-5 (Nakti Creek- near Tuna Port)	ME-6 (Nakti Creek near NH - 8A)	ME-7 (Near SPM)	ME-8 (Near Vadinar Jetty)
	Avg.	Avg	Avg	Avg	Avg	Avg	Avg	Avg
Taxa S	6	7	6	6	7	6	6	6
Individuals	10	9	10	10	9	10	9	10
Shannon diversity	1.55	1.42	1.47	1.50	1.43	1.48	1.43	1.43
Simpson 1-D	0.76	0.73	0.75	0.75	0.73	0.75	0.73	0.74
Species Evenness	0.89	0.89	0.92	0.92	0.90	0.91	0.90	0.89
Margalef	1.92	1.77	1.73	1.81	1.83	1.79	1.76	1.68
Berger-Parker	0.33	0.37	0.33	0.34	0.37	0.34	0.38	0.36
Relative abundance	55.92	57.66	53.67	56.55	60.63	56.18	57.46	51.58

- **Shannon- Wiener's Index (H):** During monitoring period 2023 to 2024, Average Shanon- Wierner's index of benthic organism was in the range of **1.42 to 1.55** between selected sampling stations from ME-1 to ME-6, at Kandla creek and its nearby creeks. While for Vadinar, average Shannon Wiener's index of benthic organism recorded to be **1.43** at ME-7 and ME-8. The apportionment of the numbers of individuals among the species observed higher stability at all monitoring location of Kandla and Vadinar.

- **Simpson diversity index (1-D):** During the monitoring period **2023 to 2024,** average Simpson diversity index (1-D) of benthic organism was ranged between **0.73 to 0.76** at all sampling stations in the Kandla creek and nearby creeks, Similarly, for Vadinar average Simpson diversity index (1-D) of benthic organism was **0.73** at ME-7 and **0.74** at ME-8.

- **Margalef's diversity index** (Species Richness): During the monitoring period **2023 to 2024,** average margalef's diversity index of benthic organism in Kandla and nearby creeks sampling stations was varying from **1.73 to 1.92**. While for Vadinar, average Margalef's diversity index (Species Richness) of benthic organism observed to be **1.76** at ME-7 and **1.68** at ME-8.

- **Berger-Parker Index (d):** During the monitoring period **2023 to 2024,** average Berger-Parker Index (d) of benthic organism was in the range of **0.33 to 0.37** between selected sampling stations from ME-1 to ME-6, at Kandla creek and nearby creeks. average Berger-Parker Index (d) of benthic organism in the sampling stations of Vadinar, was in the range of **0.36** to **0.38**. All the monitoring station signifies a low diversity with an even distribution among the different species.

- The average **Species Evenness** is observed in the range of **0.89 to 0.92** for all the six-monitoring station of Kandla and for the Vadinar the species evenness is observed in the range of **0.89** to **0.90.**

- During the sampling period, **average Relative Abundance** of Benthic organisms was in range of **53.67 to 60.63** between selected sampling stations from ME-1 to ME-6 at Kandla creek and nearby creeks. Whereas for Vadinar the Average relative abundance value **57.46** at ME-7 and **51.58** at ME-8, thus it is concluded that the studied species can be stated as neither highly dominant nor rare.

CHAPTER 13: SUMMARY AND CONCLUSION

13.1 Summary and Conclusion

The report, prepared by the Gujarat Environment Management Institute (GEMI), details the environmental monitoring and management plan for the Deendayal Port Authority (DPA) at Kandla and Vadinar. The monitoring covers the period from April 2023 to March 2024.

The primary objective is to systematically assess and monitor environmental parameters including ambient air, water (drinking and surface), soil, sediment, noise, and ecology to ensure compliance with environmental standards and statutory norms.

Methodology

Environmental monitoring was conducted using standard operating procedures, protocols, and guidelines to ensure accurate data collection. Various parameters were measured, including air quality, water quality, soil characteristics, noise levels, and meteorological data.

Based on the results obtained for both study areas, Kandla and Vadinar, during the monitoring period from April 2023 to March 2024, the following observations are concluded.

- **Ambient Air Quality Monitoring**
  Particulate matter (PM_{10} and $PM_{2.5}$) levels exceeded the national ambient air quality standards (NAAQS) at most monitoring locations, especially at the coal storage area. The high particulate matter levels were attributed to heavy vehicular traffic, loading/unloading of cargo, and dust from unpaved roads. For Gaseous monitoring, sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs), and carbon monoxide (CO) were generally within the NAAQS limits.
  The noise level was within the permissible limits for the industrial, commercial, and residential zones for daytime and nighttime.

- **DG Stack Monitoring**
  Monitoring of the diesel generator (DG) stacks was conducted at one location each in Kandla and Vadinar. Parameters like suspended particulate matter, SO_2, NO_x, CO, and CO_2 were measured and found to be within the prescribed emission limits.

- **Soil Monitoring**
  The pH in Kandla varies from slightly alkaline to strongly alkaline, while the soil at Vadinar was found to be moderately alkaline. The soil texture was observed as "sandy loam" to "loamy sand" at all the monitoring locations in Kandla, and the soil texture of Vadinar varies from "loam" to "slit loam. Kandla displays higher salinity and nutrient levels, while Vadinar exhibits lower nutrient levels. Vadinar generally shows moderate conditions with higher water holding capacity and more consistent soil composition. The presence of heavy metals such as aluminium, chromium, nickel, copper, zinc, lead, arsenic, and cadmium vary considerably at both study area.

- **STP Monitoring**
  After the effluent treatment in both the study areas, the treated water followed the GPCB discharge norms except for total coliform.

- **Drinking Water Quality Monitoring**
  Drinking water samples were collected from 20 locations across Kandla and Vadinar. Most water quality parameters like pH, color, turbidity, chloride, and total hardness were within the drinking water standards (IS 10500:2012). A few locations showed slightly elevated levels of electrical conductivity, salinity, and total dissolved solids, likely due to the coastal location.

- **Marine Water and Sediment Quality Monitoring**
  Marine water and sediment samples were collected from 6 locations in Kandla and 2 locations in Vadinar. The water quality parameters like pH, salinity, dissolved oxygen, and nutrients were within the acceptable limits for coastal waters. The sediment quality in terms of heavy metals and organic contaminants was also found to be within the prescribed standards.

- **Marine Ecology Monitoring**
  Monitoring of marine ecology was conducted at 6 locations in Kandla and 2 locations in Vadinar. The analysis indicates that both regions exhibit low diversity with an even distribution among species, as evidenced by the Berger-Parker Index and Simpson Diversity Index values. These indices suggest a stable ecosystem where no single species overwhelmingly dominates, nor are any species exceedingly rare. The even distribution of species, coupled with moderate levels of biomass and primary productivity, highlights the resilience of these ecosystems.

Overall, the report concludes that the environmental monitoring conducted by the DPA during the period of April 2023 to March 2024 indicates compliance with the applicable environmental regulations, with some exceptions related to particulate matter levels in the ambient air.

Annexure 1: Photographs of the Environmental Monitoring conducted at Kandla


STP Monitoring


Noise Monitoring


Soil Monitoring


Marine Monitoring


Air Monitoring


Drinking Water Monitoring

Annexure 2: Photographs of the Environmental Monitoring conducted at Vadinar

Air Monitoring

Noise Monitoring

STP Monitoring

Drinking water Monitoring

Marine Monitoring

Soil Monitoring

Source: GEMI

CHAPTER 14: REFERENCES

References:

(1) National ambient air quality standards central pollution control board, 2009

(2) Ambient Air Quality Standards in respect of Noise,2000.

(3) American Public Health Association 23rd Addition, Standard Methods for Water and Waste water analysis, 2017.s

(4) Indian Standard DRINKING WATER — SPECIFICATION (Second Revision), 2012.

Gujarat Environment Management Institute (GEMI)

(An Autonomous Institute of Government of Gujarat)

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

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“We Provide Environmental Solutions”

MARINE DEPARTMENT
(ACCOUT SECTION)

Annexure C

Sub :- Annual return statement showing the collection and disposal of Hazardous and Non Hazardous Wastes carried out by various parties for the year 04/2023 to 03/2024.

With reference to the above subject, the annual return showing the collection and Disposal of Hazardous and Non Hazardous Wastes carried out by various parties for the period 01.04.2023 to 31.03.2024 of Marine department is enclosed herewith.

Encl : AS above

Dy. Conservator
Deendayal Port Authority

EMC (I/C)

NO: MR/WK/1316/282

Dt. 21.06.2024

Deendayal Port Authority
Marine Department

Statement of Hazardous and Non hazardous Waste disposal from the Vessels at Kandla Port for the Period April 2023 to March 2024 – For the Whole Port Area

(PCB ID 28494)

Sr.No.	Month	Year	Hazardous Waste Generation in MT			Solid Waste Generated in MT
			Total Quantity	Used Oil	Waste Residue Containing Oil	
1.	April	2023	484.45	121.11	363.34	169.57
2.	May	2023	1065.92	266.48	799.44	307.83
3.	June	2023	671.82	167.96	503.87	155.03
4.	July	2023	743.45	185.86	557.59	207.71
5.	August	2023	814.63	203.66	610.97	221.78
6.	September	2023	758.07	189.52	568.55	318.76
7.	October	2023	1002.51	250.63	751.89	144.20
8.	November	2023	982.88	245.72	737.16	198.54
9.	December	2023	802.58	200.65	601.94	254.75
10.	January	2024	825.89	206.47	619.41	207.61
11.	February	2024	549.50	137.38	412.13	200.38
12.	March	2024	1023.87	255.97	767.90	186.79
Total			**9725.56**	**2431.39**	**7294.17**	**2572.94**

Deputy Conservator
Deendayal Port Authorit

Marine Department

Statement showing the Collection and disposal of Hazardous and Non-Hazardous Wastes carried out by

	Name of Party	Type of Licence	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Total
	Alkali Organic Industries Limited	Hazardous	-	-	-	-	-	-	-	-	36.76	-		-	36.76
2	Amar Hydrocarbon Pvt. Ltd	Hazardous	-	-	-	-	-	-	-	18.42				41.48	59.90
3	Atlas Organics Pvt. Ltd	Hazardous	-	-	-	19.24	7.00	-	-	-				-	26.24
4	Aviation Corporation	Hazardous	9.60	18.45	23.97	-	-	-	-	-			-	-	52.02
5	Mahalaxmi Asphalt Pvt Ltd	Hazardous	102.96	-	-	138.88	-	25.23	67.34	-	73.93	50.49	14.85	43.97	517.65
6	Priyanshi Corporation	Hazardous	16.25	91.36	87.35	-	-	29.89	-	35.57	67.03	-	-	-	327.45
7	Revolution Petrochem LLP	Hazardous	379.86	591.26	594.09	622.50	534.20	453.78	589.26	687.93	423.75	383.95	442.62	648.60	6,345.21
8	Shana Oil Process	Hazardous	-	-	-	-	-	-	-	-	-	-	-	-	-
9	United Shipping Company	Hazardous	-	418.14	-	-	314.16	287.07	396.04	296.10	241.83	432.74	119.51	341.01	2,846.60
10	Chitrakut Trading & Industries	Non-Hazardous	7.24	28.39	14.70	14.98	10.70	6.35	4.78	-	-	0.83	-	-	87.97
11	Golden Shipping Services	Non-Hazardous	1.03	61.82	-	56.87	43.26	77.20	36.10	23.64	75.26	42.55	37.33	49.00	504.06
12	Green Earth Marine Solutions	Non-Hazardous	18.50	37.68	4.42	18.50	27.60	5.00	-	20.34	-	3.71	6.71	-	142.46
13	Harish A. Pandya	Non-Hazardous	12.00	7.18	1.95	-	5.02	-	6.42	-	12.59	7.29	-	-	52.45
14	K M Enterprise	Non-Hazardous	62.00	99.18	74.30	64.40	64.00	48.37	36.34	56.74	70.28	64.32	67.04	113.62	820.79
15	Naaz Shipping Services Ent	Non-Hazardous	-	-	-	7.56	-	12.40	6.35	5.47	6.35	6.36	-	-	44.49
16	New India Marine Works	Non-Hazardous	4.00	-	-	10.50	23.70	45.15	7.00	11.00	17.80	9.00		-	128.15
17	Omega Marine Services	Non-Hazardous	23.81	31.42	30.68	-	-	68.44	19.51	47.35	46.10	30.31	58.85	-	356.45
18	V K Enterprise	Non-Hazardous	24.00	30.00	-	15.00	18.00	18.00	18.00	15.00	15.00	15.00	9.00	-	177.00
19	Vishwa Trade-link Inc	Non-Hazardous	16.99	12.16	29.00	19.90	29.50	37.85	9.70	19.00	11.37	29.34	21.45	24.17	259.13
		Hazardous - Total	508.67	1,119.21	705.41	780.62	855.36	795.97	1,052.64	1,032.02	842.71	867.18	576.98	1,075.06	10,211.83
		Non-Hazardous - Total	169.57	307.83	155.03	207.71	221.78	318.76	144.20	198.54	254.75	207.61	200.38	186.79	2,572.94

Copy to : GPCB, Gandhidham / Harbour Master

Annexure D

Statement Showing the quantity of Domestic Waste Water Generation (STP – Kandla) for the period from April 2023 to March 2024

Sr. No.	Month	Average Quantity of Domestic Waste Water Generation (KLD)
1.	April 2023	225
2.	May 2023	200
3.	June 2023	210
4.	July 2023	220
5.	August 2023	230
6.	September 2023	225
7.	October 2023	230
8.	November 2023	210
9.	December 2023	235
10.	January 2024	255
11.	February 2024	230
12.	March 2024	220
Average	**224.16**	

XEN (Road)
19/06/24

DEENDAYAL PORT AUTHORITY

ANNEXURE 2
Monitoring Data Sheet

Monitoring the Implementation of Environmental Safeguards
Ministry of Environment, Forest & Climate Change
Regional Office, Gandhinagar
(For the period up to September, 2024)

DATA SHEET

1.	Project type: –River-valley/ Mining / Industry / Thermal / Nuclear / Other (specify)		:	Infrastructure & miscellaneous projects + CRZ
2.	Name of the project		:	Development of 7 Integrated facilities (Stage I) within existing KPT by Deendayal Port Authority (Erstwhile: Deendayal Port Trust).
3.	Clearance letter (s) / OM No. and Date		:	Environment and CRZ clearance by MoEF&CC vide file no. 11-82/2011-IA III dated 19/12/2016.
4.	Location		:	
	a.	District (s)	:	Kutch
	b.	State (s)	:	Gujarat
	c.	Latitude/ Longitude	:	$23^{0}01'$ N, $70^{0}13'$ E
5.	Address for correspondence			
	a.	Address of Concerned Project Chief Engineer (with pin code & Telephone/telex/fax numbers	:	Chief Engineer, Deendayal Port Authority, P.O. Box no. 50. A.O. Building, Gandhidham- 370 201.Phone: 02836 233192, Fax. : 02836 220050
	b.	Address of Project: Engineer/Manager (with pin code/ Fax numbers)	:	Same as above
6.	Salient features			
	a.	of the project		1) Development of Oil Jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode (jetty: 300mx15m, back up area 5.5HA, capacity – 3.39MMTPA, as per the concession agreement Tank farm capacity - 1,64,500 KL & Allied facilities, Capital dredging 1,73,660m^3 maintenance dredging 1,56,294m^3; Estimated cost: Rs 233.5 Cr., Revised Cost: Rs 343.0 Cr. 2) Multipurpose cargo Terminal at Tekra off Tuna on BOT basis (T shape jetty 600mX80m Capacity 18MMTPA, back up area 101Ha capital dredging 1,26,57,175m^3 maintenance dredging 18,98,576. 25 m^3 Estimated cost: Rs 1686.66 Crore 3) Up gradation of Barge handling capacity at Bundar basis at Kandla capacity 3.33 MMTPA backup area 5 Ha Estimated cost Rs 109.59 Cr 4) Construction of Rail over Bridge at NH8-A near Nakti Bridge (crossing of NH8-A Estimated cost: 32.17Cr.) 5) Mechanization of Dry Cargo handling capacity at Kandla Port (Berth 7 and 8 capacity 7.35MMTPA). 6) Strengthening of Oil jetty 1. 7) Modification and strengthening of Cargo berth No. 6 at Kandla Port.
	b.	of the environmental management plans	:	The salient features of the EMP had already been communicated in earlier compliance reports submitted.

7.	Production details during the compliance period and (or) during the previous financial year		:	It is under Infrastructure & miscellaneous projects so production is not involved
8.	The breakup of the project area		:	~111.5 Ha
	a.	submergence area forest &non-forest		NIL
	b.	Others		NIL
9.	The breakup of the project affected the Population with an enumeration of Those losing houses/dwelling units Only agricultural land only, both Dwelling units & agricultural Land &landless labours/artisan		:	NIL
	a.	SC, ST/Adivasis	:	Nil
10.	Financial details		:	
	a.	Project cost as originally planned and subsequently revised estimates and the year of price reference:		
	1.	Estimated Cost of the Project	:	Total Estimated Project Cost: Rs. 2271.03 Crore 1) Development of oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode - Estimated cost: Rs 233.5 Crore, Revised Estimated Cost: Rs 343.0 Cr. 2) Multipurpose cargo Terminal at Tekra off Tuna on BOT basis - Estimated cost: 1686.66 Cr. (Revised Cost Rs 2250.64 Cr) 3) Upgradation of Barge handling capacity at Bundar basis at Kandla: Estimated cost: Rs 109.59 Cr. 4) Construction of Rail over Bridge at NH 8 A near Nakti Bridge (crossing of NH 8 A - Estimated cost: Rs 32.17 Cr.). 5) Mechanization of Dry Cargo handling capacity at Kandla Port (Berth 7 and 8)- Estimated cost Rs 80.61 Cr.. 6) Strengthening Oil jetty 1 (Estimated cost: Rs 7.5 Cr.). 7) Modification and strengthening of Cargo berth No. 6 at Kandla Port Estimated cost: Rs 11.5 Cr.
	b.	The allocation made for environmental management plans with item-wise and year-wise Break-up.	:	a) The allocation made by DPA under the scheme of "Environmental Services & Clearance thereof other related Expenditure" during BE 2024-25 is Rs. 657 Lakhs. b) The allocation made by the Concessionaire M/s KOTPL of the project "Development of oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode" - EMP: Rs. 06 Lacs
	c.	Benefit-cost ratio / Internal rate of Return and the year of assessment	:	1) Development of an oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode (Project IRR 14.01% and EIRR 14.53%). 2) Multipurpose cargo Terminal at Tekra off Tuna on BOT basis (Project IRR 16.03% and equity IRR 17.4%). 5) Mechanization of Dry Cargo handling capacity at Kandla Port (Project IRR 18.3% and equity IRR23.6%). Rest of the projects are of up-gradation/strengthening/modification.
	d.	Whether (c) includes the Cost of environmental management as	:	Yes

		shown in above.		
	e.	Actual expenditure incurred on the project so far	:	1) Development of oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode - Actual expenditure incurred on the project: Rs 70.87 Cr 2) Multipurpose cargo Terminal at Tekra off Tuna on BOT basis - Actual cost: NIL (Project under bidding stage). 3) Upgradation of Barge handling capacity at Bundar basis at Kandla: Actual cost: Rs 109.59 Cr.. 4) Construction of Rail over Bridge at NH 8 A near Nakti Bridge (crossing of NH 8 A) - Actual cost: NIL – Construction activity has not started yet. 5) Mechanization of Dry Cargo handling capacity at Kandla Port (Berth 7 and 8)- Actual cost: Rs 80.61 Cr. 6) Strengthening of Oil jetty 1 - Actual cost: Rs 7.5 Cr. 7) Modification and strengthening of Cargo berth No. 6 at Kandla Port Actual cost: Rs 11.5 Cr.
	f.	Actual expenditure incurred on the environmental management plans so far		a) The expenditure made by DPA under the scheme of "Environmental Services & Clearance thereof other related Expenditure" is Rs.172 Lakhs from June, 2024 to September 2024. b) The expenditure made by the Concessionaire M/s KOTPL of the project "Development of oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode" - EMP: Rs. 4 Lakhs
11.	Forest land requirement		:	
	a.	The status of approval for the diversion of forest land for non-forestry use	:	NIL
	b.	The status of clearing felling	:	NIL
	c.	The status of compensatory afforestation it any	:	NIL
	d.	Comments on the viability & sustainability of the compensatory afforestation program in light of actual field experience so far	:	NIL
12.	The status of clear felling in non-forest areas (such as the submergence area of the reservoir and approach roads) is any with quantitative information.		:	NIL
13.	Status of construction		:	
	a.	Date of commencement (Actual and/or planned)	:	1) Development of oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode – Award of the concession granted on 11/12/2020; **Project is under Construction Stage** 2) Multipurpose cargo Terminal at Tekra off Tuna on BOT basis - Construction activity not started yet – **Project is under bidding stage** 3) Upgradation of Barge handling capacity at Bundar basin at Kandla – **Work Completed** 4) Construction of Rail over Bridge at NH 8 A near Nakti Bridge - **Construction activity has not started yet** 5) Mechanization of Dry Cargo handling capacity at Kandla Port –**Mechanization work already completed** 6) Strengthening of Oil jetty 1 – **Work Completed**

				7) Modification and strengthening of Cargo berth No. 6 at Kandla Port –**Work completed**
	b.	Date of completion (Actual and/or planned)	:	1) Development of oil jetty to handle liquid cargo and ship bunkering terminal at old Kandla under PP mode – Construction Schedule – December, 2020 Planned date of completion: **M/s KOTPL vide letter dated 05/09/2024 requested DPA to grant time extension of COD till 04/09/2026.** 2) Multipurpose cargo Terminal at Tekra off Tuna on BOT basis - Construction activity not started yet – **Project is under bidding stage.** 3) Upgradation of Barge handling capacity at Bundar basis at Kandla– **Work Completed (May 2017).** 4) Construction of Rail over Bridge at NH 8 A near Nakti Bridge - Construction activity not started yet 5) Mechanization of Dry Cargo handling capacity at Kandla Port– work completed **(April, 2017).** 6) Strengthening of Oil jetty 1 – Work Completed **(May, 2017)** **7)** Modification and strengthening of Cargo berth No. 6 at Kandla Port – Work completed **(May, 2017).**
14	Reasons for the delay if the Project is yet to start		:	a) Out of a total of 7 project activities, construction activities of 3 projects (project at Sr. No. 3, 5, 6 & 7 mentioned in the EC & CRZ Clearance) have already been completed. Projects at Sr. No. 2 & 4 are still under the planning stage. b) For the Project at Sr. No. 1, reason for delay matter is pending adjudication before Arbitration Tribunal .
15.	Date of the site visit			
	a)	The dates on which the regional office Monitored the project on pervious occasion. if any		---
	b)	The date site visit for this monitoring report.		---
16.	Details of correspondence with project authorities for obtaining action plans/ information on status of compliance to safeguards other than the routine letters for logistic support for site visit. (The first monitoring report may contain the details of all the letters issued so far but the later reports may cover only the letters issued subsequently).			---