ID No.: CSMCRI/SSP-1454/2025-26/01

Study the Marine Ecology and Biodiversity around 10 kms radius of Marine discharge locations of TATA Chemicals, Mithapur (Gujarat)

Final Report

CSIR-Central Salt & Marine Chemicals Research Institute,
GB Marg, Bhavnagar-364002 (Gujarat)

August 2026

DISCLAIMER

The information contained in this report is based on the scientific analysis of data/information/drawings provided by the sponsor during the time of the assessment. While efforts have been made to ensure accuracy of information in the report, CSIR-CSMCRI shall not own, in any manner, any legal, financial or consequential responsibility for any event of occurrence of any accident/hazard or direct or indirect damage/loss to any third party or to sponsor due to the use or inability to use the information contained in the report.

The sponsor shall exercise due diligence and make their own decision to implement the contents of the report. The report shall not be construed as any guarantee or warranty from CSIR-CSMCRI, Bhavnagar.

Project Personnel

Technical Staff	
Mr. Narshibhai R Baraiya	Technician-II
Project Staff	
Ms. Shubhanshi Rathore	Ms. Dhara Vadher
Mr. Kamlesh Mesara	Mr. Abhay Vaidya
Mr. Haresh Solanki	Mr. Biswajit Swain
Mr. Harshdeepsinh Gohil	Mr. Jitendra
Ms. Mehta Nirjari	Mrs. Bedantika Biswas
Co-Principal Investigator	
Dr. Sanak Ray	Senior Scientist
Dr. Hitesh Saravaia	Principal Scientist
Principal Investigator	
Dr. Soumya Haldar	Chief Scientist

Declaration by EIA Coordinator

I hereby confirm that the above-mentioned experts prepared the Report on *"Study the Marine Ecology and Biodiversity around 10 kms radius of Marine discharge locations of TATA Chemicals, Mithapur (Gujarat)"* for Tata Chemicals Limited, Mithapur. I also confirm that in CSIR-CSMCRI, Bhavnagar shall be fully accountable for any misleading information mentioned in this statement.

Signature : 03.08.2026

Name : Dr. Soumya Haldar

Designation : Chief Scientist, HBBME Division

Name of the EIA consultant organization : CSIR-CSMCRI

NABET certificate/Letter No. & Issue Date: NABET/EIA/26-29/RA 0499, Issued on 24.06.2026, Valid upto 15.07.2029.

QUALITY CONTROL							
Name of the Report	Study the Marine Ecology and Biodiversity around 10 kms radius of Marine discharge locations of TATA Chemicals, Mithapur (Gujarat)						
Project's number	SSP-1454	**Issue No.**	01	**Revision No.**	-	**Released on**	August 2026

DECLARTION BY EXPERTS CONTRIBUTING TO THIS REPORT

"I, hereby, certify that I was a part of the EIA team in the following capacity that developed this report."

EIA sector Number as per NABET	36	Name of Sector as per NABET	Common Effluent Treatment Plants (CETPs)

EIA COORDINATOR

Name	Dr. Soumya Haldar	
Signature & Date	S. 3.8.26	
Contact Information	HBBME Division, CSIR-CSMCRI, Bhavnagar-364002 (Gujarat)	Mobile: +91 9879585953 E-mail: shaldar.csmcri@csir.res.in

FUNCTIONAL AREA EXPERTS

No.	Functional areas	Name of the Expert	Task	Signature & Date
1	Water Pollution Prevention & Prediction of Impacts (WP)	Dr. Soumya Haldar	Site visit, collection of water samples. Identification of impacts and suggesting mitigation measures.	S. 3.8.26
2	Ecology and Biodiversity (EB)	Dr. Soumya Haldar	Site visit for identification of flora and fauna. Collection of marine ecological samples.	S. 3.8.26
3	Water Pollution Prevention & Prediction of Impacts (WP)	Dr. Sanak Ray	Participated in report preparation.	Sanak Ray 3/8/26
4	Ecology and Biodiversity (EB)	Dr. Sanak Ray	Participated in report preparation.	Sanak Ray 3/8/26
5	Solid & Hazardous Waste (SHW)	Dr. Hitesh Saravaia	Participated in sampling & report preparation.	03/08/16

Study the Marine Ecology and Biodiversity around 10 kms radius of Marine discharge locations of TATA Chemicals, Mithapur (Gujarat)

INDEX

TABLE OF CONTENTS

Table of Tables

Table of Figures

Table of Graphs

PREAMBLE

A part of the over US$ 185 billion Tata Group, Tata Chemicals Limited (TCL) was established in 1939 at Mithapur, Gujarat, and is a leading supplier to the glass, detergent, industrial, and chemical sectors. The company also has a strong presence in the agri-solutions and crop protection space through its subsidiary, Rallis India Limited. Tata Chemicals is supported by world-class research and development facilities located at Pune and Bengaluru.

TCL has been operating a soda ash manufacturing facility at its Mithapur site since 1943. The site is strategically located on the western coast of Gujarat, in proximity to the Arabian Sea and the Gulf of Kutch. The industrial township of Mithapur lies approximately 20 km north of Dwarka and 9 km south of the port of Okha, and is well connected via State Highway 25A and the Western Railway broad-gauge line connecting Mumbai to Okha.

TCL has undertaken multiple scientific studies and established robust monitoring and compliance mechanisms to assess and manage the environmental impacts associated with its industrial operations, particularly with respect to treated effluent discharge into the marine environment. Impact assessment studies conducted through the National Institute of Oceanography (NIO) for the existing effluent discharge system indicate that the current mode of discharge does not result in adverse impacts on the marine ecology of the receiving waters of the Gulf of Kutch.

In addition, TCL has been carrying out regular marine water quality monitoring studies through CSIR–Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Bhavnagar. These monitoring programmes cover the surrounding marine environment in the vicinity of the effluent discharge area and include assessment of relevant physico-chemical parameters to evaluate baseline conditions and temporal variations in marine water quality.

TCL entrusted a study to CSIR-NIO to identify a suitable location of Marine outfall for releasing the treated effluents in Gulf of Kutchh. CSIR-NIO conducted Environmental Impact Assessment Study and identified a suitable location (Marine Outfall point) in the Gulf of Kutch for discharge of treated waste water through pipeline and diffuser system. The selected marine outfall point (lat. 22° 24’ 36” N, long. 69° 04’ 50” E) is in conformance to the revised Effluent standards prescribed for the soda ash industry (S. No. 75 - Solvay Process). The system has been implemented in compliance with the Environment (Protection) (Fourth Amendment) Rules, 2011, as notified by the Ministry of Environment, Forest & Climate Change, Government of India vide Gazette Notification G.S.R. 424(E) dated 1st June 2011.

Ministry of Environment, Forest & Climate Change accorded Coastal Regulation Zone Clearance vide letter No. File. No. 11-34/2016-IA-III dated 10 July, 2017 for upgradation of effluent disposal system. Company has completed construction activities for laying of treated wastewater pipeline as per Consent to Establish CTE-70701 dated 01.10.2015 and amended further as CTE-107843 dated 02.06.2020 and CTE-142435 dated 30.04.2025 for conversion of open channel discharge into closed pipeline and diffuser system by laying of pipeline on a trestle up to marine outfall point suggested by National Institute of Oceanography (NIO).

TCL has fully commissioned and operationalised the closed pipeline and diffuser system for discharge of treated effluent into the marine outfall point, in line with the recommendations of the National Institute of Oceanography (NIO) and the revised effluent discharge standards prescribed for the soda ash industry (S. No. 75 - Solvay Process). The project has been executed after obtaining all requisite statutory clearances and approvals from the concerned regulatory and governmental authorities. These include Coastal Regulation Zone (CRZ) clearance from the Ministry of Environment, Forest and Climate Change (MoEFCC); wildlife clearance from the Standing Committee of the National Board for Wildlife; forest clearance approved by the Regional Empowered Committee, Western Zone, Government of India; and recommendations from the State Level Eco-Sensitive Zone Monitoring Committee (Director Environment), Department of Environment and Forest, Government of Gujarat. In addition, the project has received a No Objection Certificate from the Gujarat Maritime Board and Consent to Establish from the Gujarat Pollution Control Board (GPCB). The new pipeline and diffuser system is operational as per GPCB CCA No. AWH-138320 dated 30.05.2026. TCL has permanently closed the operation of existing open Channel for discharge of treated wastewater and initiated activities for restoration to its original condition, as directed by the board vide GPCB directions GPCB Directions (Outward No. 902320) dated 29 May 2026.

SCOPE OF THE STUDY

A. Ecological assessment

1 Comprehensive survey of the wildlife and vegetation in buffer areas (Study area map) including terrestrial and Marine Environment

- A detailed survey will be carried out about distribution of flora and fauna in the coastal/intertidal area. The study includes presence of mangrove, coastal plants and animals.

- A detailed survey will be carried out about distribution of seagrass, corals, seaweeds and availability of other coastal water species

2 Monitoring of Marine and coastal biodiversity of Poshitra Bay as per Baseline study conducted in September 2023 (CSMCRI/TSP-1446) with specific focus on sea grass beds, and endemic species Sakuraeolis gujaratica and Anteaeolidiella poshitra.

- A detailed coastal survey will be carried out in the Positra bay and distribution of flora and fauna will be identified.

- Distribution and abundance study of endemic species like Sakuraeolis gujaratica and Anteaeolidiella poshitra will be carried out.

3 Study of marine water and sediment quality parameters in sampling location as per previous study (CSMCRI/TSP-1446).

Identified sampling location as per previous study (CSMCRI/TSP-1446) and following parameters will be analysed:

Parameters	Coastal Water	Coastal Sediments
Physico chemical parameters:	Temperature, Salinity, Dissolved oxygen, Biochemical oxygen demand, Conductivity, Turbidity, pH, Total suspended solids, Nutrient parameters (Nitrite and nitrate, Ammonia, Inorganic phosphate), Heavy metals (As, Al, Cd, Co, Cu, Ni, Mn, Fe, Cr, Pb, Zn, Hg).	Heavy metals (As, Al, Cd, Co, Cu, Ni, Mn, Fe, Cr, Pb, Zn, Hg), PHC, organic carbon Sediment samples will be collected from coastal as well as inter-tidal area.
Biological parameters:	Phytoplankton: Only surface water samples Phytoplankton count, major genera and generic diversity and SWDI Zooplankton: Only surface water samples Zooplankton count; volume of zooplankton, major genera of zooplankton and group diversity and SWDI. Microbiology counts: Total viable count, Total Coliform, E. coli, Vibrio, Aeromonas, Pseudomonas spp.	Microbiology counts: Total viable count, Total Coliform, E. coli, Vibrio spp., Aeromonas, Pseudomonas spp. Benthic fauna: Identification of species and species diversity study

B. Environment Management Plan (EMP):

1. Suggest EMP for Marine and coastal biodiversity of Poshitra Bay with specific focus on sea grass beds, and endemic species Sakuraeolis gujaratica and Anteaeolidiella poshitra.

Based on availability and abundance of marine and coastal species like seagrass beds, and endemic species like Sakuraeolis gujaratica and Anteaeolidiella poshitra, environmental management plan will be developed.

2. Mudflat restoration plan with specific focus on waders and other water birds of the affected region be developed and implemented through concerned authority.

Mudflats will be identified.

Survey will be made on distribution of waders and other water birds in the mud flat and other area. Mudflat restoration plan will be prepared.

3. Status of Rehabilitation plan for Mangrove Plantation approved by Chief Wildlife Warden vide letter dated 13.03.2020.

Health status assessment of mangrove plantation will be carried out by CSIR-CSMCRI and required measured will be suggested.

4. Status of Wildlife Conservation Plan approved by Chief Wildlife Warden vide letter dated 19.06.2018.

Status of approved Wildlife Conservation Plan will be assessed by CSIR CSMCRI and necessary recommendation will be suggested.

5. Compliance status of Environmental approvals for Marine Outfall system (Treated wastewater and diffuser system)

Compliance monitoring of marine outfall are regularly monitored by some third party sponsored by TCL. CSIR-CSMCRI may study the compliance reports and make their recommendation.

Executive Summary of Study Report

A comprehensive environmental assessment was conducted to evaluate the marine water quality, sediment quality, marine biological characteristics, ecological status, floral diversity, and avifaunal diversity of the coastal ecosystem surrounding the long-term disposal area at Mithapur. The study findings collectively demonstrate that the area is characterized by good environmental quality, ecological stability, and healthy marine and coastal habitats, with environmental conditions largely governed by natural marine and tidal processes.

Marine Water Quality

The seawater quality assessment confirmed that the study area exhibits the characteristics of a healthy and well-mixed coastal marine environment. Key physicochemical parameters, including pH, salinity, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), and nutrients, remained within ranges typically associated with good coastal water quality.

Seawater pH (8.11–8.24) reflected the naturally alkaline characteristics of marine waters and indicated a chemically stable environment with no evidence of acidification or significant anthropogenic influence. Salinity (34.9–35.2 ppt) and conductivity (50.54–53.18 mS/cm) exhibited minimal spatial variation, demonstrating strong marine influence, effective tidal exchange, and a well-mixed water column.

Dissolved oxygen concentrations remained consistently high (6.9–8.7 mg/L), while BOD values remained low (0.0–4.0 mg/L), indicating excellent oxygen availability, limited organic loading, and the absence of oxygen stress. Nutrient concentrations, including ammoniacal nitrogen, nitrite nitrogen, and nitrate nitrogen, reflected efficient nutrient cycling and natural biogeochemical processes without indications of eutrophication, nutrient enrichment, or oxygen depletion.

Although localized increases in Total Suspended Solids (TSS) were observed at certain locations, particularly during low tide, these variations were attributable to natural sediment resuspension and tidal hydrodynamics rather than pollution-related influences. Overall, the marine waters exhibited good assimilative capacity, stable hydrographic conditions, and favorable ecological characteristics capable of supporting marine biodiversity and biological productivity.

Heavy Metal Assessment

Heavy metal concentrations in seawater remained within levels typically associated with natural coastal marine environments and exhibited only limited spatial variation across the study area. No evidence of heavy metal accumulation, contamination hotspots, or metal-induced ecological stress was observed.

The observed distribution patterns indicate that natural geochemical processes, seawater circulation, dilution, dispersion, and sediment-water interactions remain the dominant controls on metal concentrations. The results confirm that heavy metals are not adversely affecting water quality or ecological functioning and further support the conclusion that the coastal environment remains chemically stable and environmentally sound.

Marine Biological Characteristics

The biological assessment confirmed the presence of a healthy, ecologically balanced, and biologically productive marine ecosystem. Chlorophyll-a concentrations remained below analytical detection limits, while phaeophytin concentrations were low (0.002–0.015 mg/L), indicating the absence of phytoplankton blooms, excessive organic enrichment, or biological stress.

The phytoplankton community comprised 22 species dominated by diatoms such as *Bacillaria*, *Coscinodiscus*, *Navicula*, and *Nitzschia*, which are characteristic of productive coastal waters. The zooplankton community comprised 23 species dominated by copepods including *Euterpina*, *Calanidae*, *Corycaeus*, *Acartiidae*, and Cyclopoid forms. Moderate to high diversity indices and the influence of tidal exchange on species distribution indicate healthy plankton communities and an active marine food web.

The combined phytoplankton and zooplankton observations demonstrate effective energy transfer through trophic levels and confirm favorable environmental conditions supporting marine productivity and ecosystem stability.

Sediment Quality Assessment

Marine sediment quality was found to be environmentally sound and supportive of healthy benthic ecosystem functioning. Petroleum Hydrocarbon (PHC) concentrations ranged from 0.18 to 0.44 ppm, indicating minimal hydrocarbon contamination and the absence of significant petroleum-related impacts.

Total Organic Carbon (TOC) concentrations ranged from 0.84% to 1.20%, while Total Organic Matter (TOM) ranged from 1.45% to 2.07%, representing moderately organic-rich sediments typical of productive coastal environments. These conditions provide favorable substrates for nutrient recycling, microbial activity, and benthic biological processes.

The observed relationship between TOC and PHC reflects natural adsorption and retention mechanisms associated with sediment organic matter rather than contamination. Overall, sediment characteristics indicate stable geochemical conditions, balanced organic matter dynamics, and the absence of environmental degradation or ecological stress.

Ecological Assessment and Floral Diversity

The ecological survey documented a diverse coastal habitat mosaic comprising mangroves, mudflats, salt marshes, saline grasslands, scrublands, saline wastelands, and intertidal zones. These habitats collectively support a broad range of ecological functions and contribute substantially to ecosystem resilience and biodiversity conservation.

The floral survey recorded 27 plant species comprising 10 tree species, 5 shrub/climber species, and 12 herbaceous species, indicating moderate to high floral diversity and balanced community structure. Diversity indices suggest healthy vegetation communities with no evidence of ecological degradation.

The presence of healthy mangrove stands dominated by *Avicennia marina* is particularly significant, as these habitats provide shoreline stabilization, sediment retention, nursery grounds for aquatic organisms, biodiversity support, and ecological resilience. Other dominant species, including *Acacia nilotica*, *Prosopis juliflora*, *Ziziphus nummularia*, and salt-tolerant grasses, demonstrate strong adaptation to coastal conditions and contribute to long-term ecosystem stability.

Avifaunal Diversity and Conservation Significance

The avifaunal assessment recorded 637 individual birds representing 40 species, highlighting the ecological importance of the Mithapur coastal ecosystem as a habitat for both resident and migratory birds.

The diverse assemblage of birds utilized a range of habitats, including mudflats, wetlands, mangroves, scrublands, grasslands, and shallow coastal waters. The study recorded several ecologically important migratory species, including Greater Flamingo (*Phoenicopterus roseus*), Eurasian Curlew (*Numenius arquata*), Common Sandpiper (*Actitis hypoleucos*), Tibetan Plover (*Anarhynchus atrifrons*), Red-necked Phalarope (*Phalaropus lobatus*), and Little Tern (*Sternula albifrons*).

The occurrence of these species confirms the ecological significance of the Mithapur coastline within the Central Asian Flyway (CAF) and demonstrates that the area continues to provide suitable feeding, resting, and roosting habitats for migratory waterbirds.

Notably, Station S5, located adjacent to the long-term disposal area, recorded the highest bird abundance, including approximately 250 Greater Flamingos. The continued use of habitats near the disposal area by both resident and migratory species indicates that ecological functions remain intact and habitat suitability has been maintained.

Overall Environmental Conclusion

The integrated assessment demonstrates that the Mithapur coastal ecosystem is healthy, productive, environmentally stable, and ecologically resilient. Water quality, sediment quality, marine biological productivity, vegetation communities, and avifaunal diversity all indicate a well-functioning coastal ecosystem governed predominantly by natural marine and tidal processes.

No evidence of significant organic pollution, heavy metal contamination, hydrocarbon accumulation, eutrophication, habitat degradation, biodiversity loss, or adverse ecological impacts associated with long-term disposal activities was observed during the study period. The continued presence of healthy mangroves, diverse plankton communities, productive sediments, rich floral assemblages, and abundant resident and migratory birds further demonstrates the strong ecological integrity of the study area.

Overall, the study confirms that the Mithapur coastal environment continues to support marine biodiversity, ecological productivity, migratory bird habitats, shoreline stability, nutrient cycling, and long-term environmental sustainability, reflecting its high ecological value and conservation significance.

A. INTRODUCTION OF PROJECT

TCL Mithapur complex consists of various units manufacturing Soda ash, Monohydrate and Sodium Bicarbonate, Caustic Soda, Liquid Chlorine, Hydrochloric acid, Bromine, Vacuum Evaporated Salt, Pure salt, Clinker/ Cement and captive power plant. The complex is supported by following facilities like Sea Water intake, return cooling sea water and Treated water discharge systems, Effluent Solids Filtration and Sedimentation basins.

TCL Mithapur Complex is certified to ISO 14001:2015 Environment Management System by Intertek (a UKAS accredited body under schedule of Accreditation) and signatory to Responsible Care Initiative by Indian Chemical Council. TCL has upgraded Air Pollution Control Devices (APCDs) in all stacks attached to units in Cement Plant and Power Plant as per revised emission norms notified by Ministry of Environment, Forest and Climate Change.

TCL has progressively strengthened its wastewater management and disposal systems over the years with the objective of ensuring compliance with the regulatory requirements applicable to marine discharge in the Gulf of Kutch and minimizing potential impacts on the coastal and marine environment. The wastewater management system incorporates multiple treatment and control stages prior to final disposal.

A key component of the existing system is a network of extensive settling ponds covering an area of more than 450 acres, designed to achieve effective removal of suspended solids from process wastewater. These settling facilities enable significant reduction in particulate load, ensuring that clarified effluent is conveyed further in the disposal system. The treated effluent is subsequently subjected to regulated dilution prior to discharge, allowing for control of key discharge parameters so as to meet the prescribed standards at the final outfall location.

In addition to the above, TCL has implemented a large-scale effluent solids filtration and recovery system, developed through an investment exceeding ₹300 crore. This system facilitates mechanical separation of solids from wastewater streams. The recovered solids are beneficially utilized in the captive cement manufacturing facility, thereby reducing waste disposal requirements and supporting resource recovery and circular economy objectives.

Through the integration of settling, controlled dilution, and solids recovery systems, TCL has substantially upgraded its wastewater management infrastructure. These measures collectively contribute to improved regulatory compliance, reduction of inorganic solids load entering the marine environment, and protection of the ecologically sensitive coastal waters of the Gulf of Kutch, while supporting sustainable industrial operations.

Ministry of Environment, Forest & Climate Change accorded environmental clearance to the project for Expansion of Soda Ash Plant from 1091000 TPA to 1316000 TPA and Captive Power Plant from 85 MW to 125 MW by M/s Tata Chemicals Ltd at villages Mithapur and Surajkaradi, Taluka Dwarka, District Devbhumi Dwarka (Gujarat), under the provisions of the EIA Notification, 2006. Company has obtained Consent to Establish from Gujarat Pollution Control Board for expansion capacity vide consent no. 85533 dated 19.06.2017. Consent to Operate for existing operations has also been obtained from Gujarat Pollution Control Board vide consent no. AWH -123320 dated 19.12.2022 (valid up to 11.08.2027). The same has been amended for expansion quantities vide consent no. AWH - 129468 dated 04.10.2023.

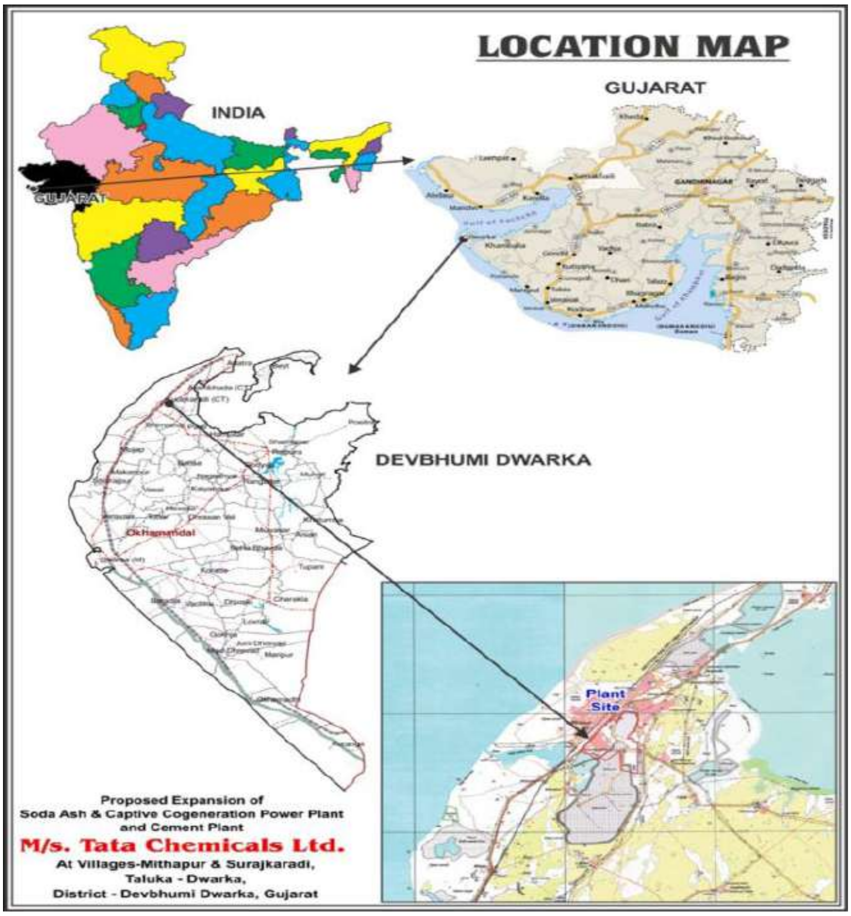


Figure 1 - Location of Tata Chemicals Limited, Mithapur

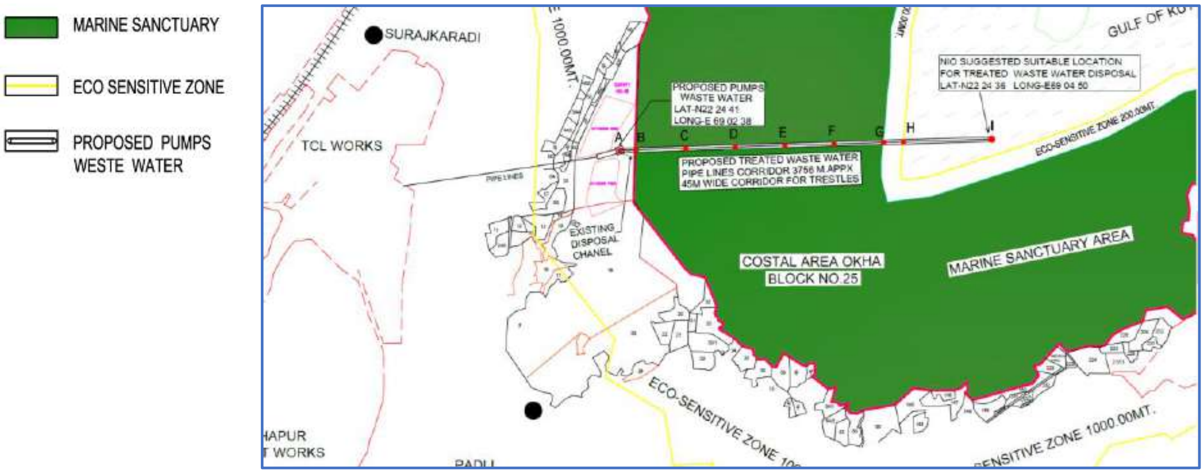


Figure 2 - Map showing effluent pipeline in Gulf of Kutchh

Table 1 - Details of the effluent pipeline system in Gulf of Kutchh

Activity Area	Length in Meter	Width in Meter	Area in Hectare
Pipeline Corridor inside Eco-sensitive zone (Landward side) A to B	158	45	0.711
Pipeline Corridor inside Marine Sanctuary/ Mangrove Forest area B to G	2504	45	11.268
Pipeline Corridor in Eco sensitive zone (Marine side) G to H	204	45	0.9180
Pipeline Corridor in Sea (Non ESZ) H to I	892	45	4.01
Total Length of Pipeline	**3758**		
Pipeline Corridor inside Eco sensitive zone (A to B and G to H)	362	45	1.62
Pipeline Corridor inside Marine Sanctuary/ Mangrove Forest area (B and G)	2504	45	11.268

B. PROJECT DESCRIPTION WITH PROCESS DETAILS

I. Soda Ash Plant

Soda ash, at TCL is manufactured by the conventional Ammonia Soda (Solvay) process. Salt, sea water, lime stone, coke and ammonia are the main raw materials. The overall chemical reaction is as follows:

$CaCO_3 + 2NaCl = Na_2CO_3 + CaCl_2$

The major steps involved in the manufacturing process of soda ash are as follows:

A. Brine preparation and purification
B. Limestone calcination
C. Lime hydration- milk of lime production
D. Absorption of ammonia
E. Gas compression
F. Carbonation of ammoniated brine
G. Filtration
H. Calcination
I. Recovery of ammonia
J. Storage and packing

Process flow diagram for Soda ash plant is given in Figure 3

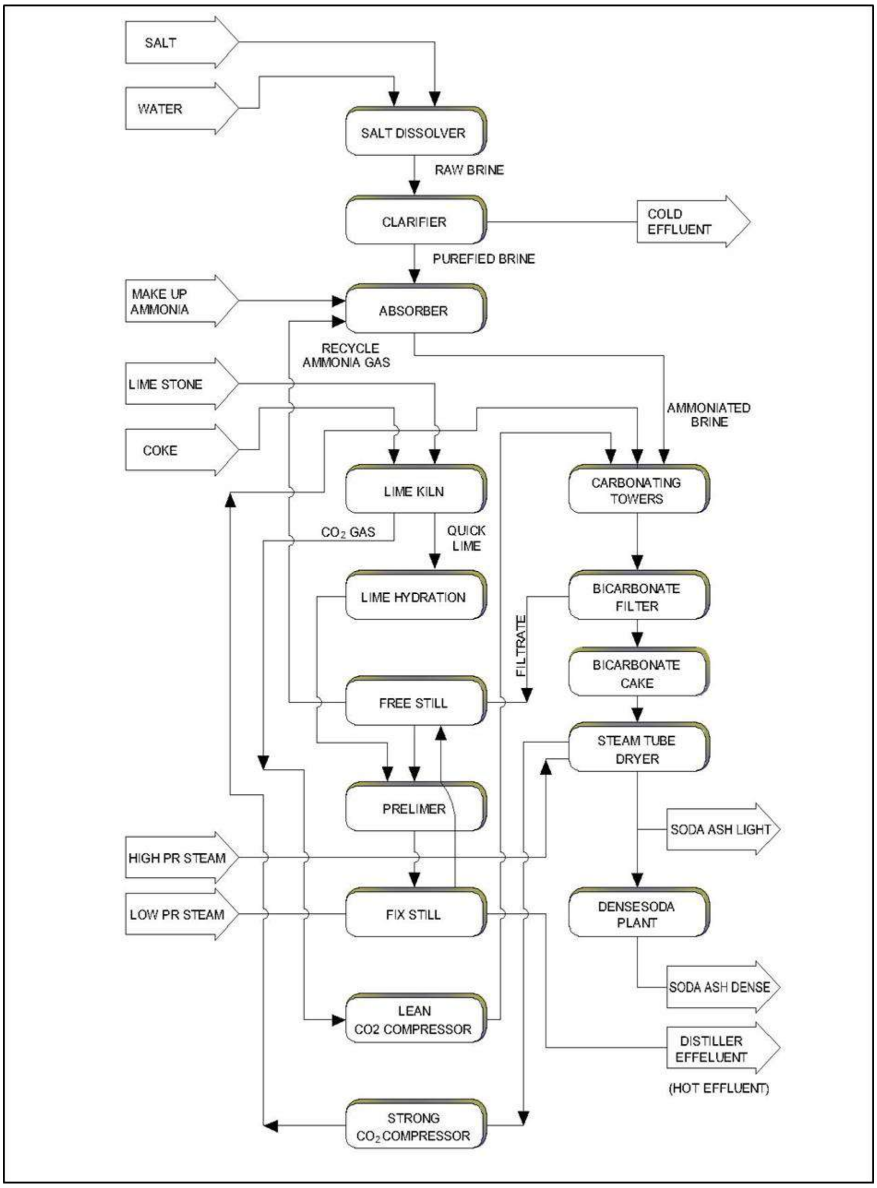


Figure 3 - Process flow diagram for Soda ash plant

II. Cement Plant

The raw materials for manufacture of cement are limestone, blue dust, clay, sandstone, laterite, dry soda ash effluent solids, gypsum, fly ash and undersize limestone from soda ash plant. The undersize limestone separated in soda ash plant is reduced to desired size in the crusher and stacked in a storage area. The blended limestone is reclaimed and conveyed to the raw mill storage bin area. Other raw materials like blue dust and clay are trucked into the plant and conveyed to individual storage bins in the raw mill area through belt conveyor.

→ **Resource optimization/recycling and reuse**

a) Utilization of undersize limestone generated from soda ash manufacturing process

Undersize limestone generated during the sizing process is used in the Cement Plant as raw material. The undersize limestone is utilized by crushing and grinding to feed rotating kiln in cement plant. The utilization of undersize limestone helps in solid waste management and fresh limestone resource conservation.

b) Utilization of effluent solids in cement manufacturing

Effluent solids are recovered from soda ash ammonia still effluent and utilized in cement manufacturing. Thus, the cement plant, in a way, serves the purpose of waste utilization by consuming solid wastes generated in the chemical complex. Effluent solid filtration plant is first of its kind in the world. Apart from the effluent filtration, this process of effluent treatment gives benefit of conserving natural resources thereby reducing fresh limestone consumption. The reduction in fresh limestone consumption reduces the carbon emission due to decrease in transportation volume.

c) Power plant fly ash utilization

Fly ash generated from boilers is used in the cement plant, supplied to brick manufacturers, and construction of road, bund in captive salt works. Company has ensured 100% utilisation of fly ash as per Fly ash Notification.

III. Power Plant

The power plant operates on the "Total Energy Concept"– raising steam at high pressure (110 kg/cm^2), generating power out of this at Topping Turbines and supplying the exhaust steam at (30 kg/cm^2) to the various process units (Steam tube dryers and compressors in Soda Ash plant) as well as to Low Pressure Turbines. These turbines generate additional power and low-pressure steam, which are used at ammonia stills in the Soda Ash plant (at 1.5 kg/cm^2) and the Vacuum Evaporated Salt plant (at 3.5 and 1.5 kg/cm^2). The process flow diagram of captive co-generation power plant is illustrated in Figure 4.

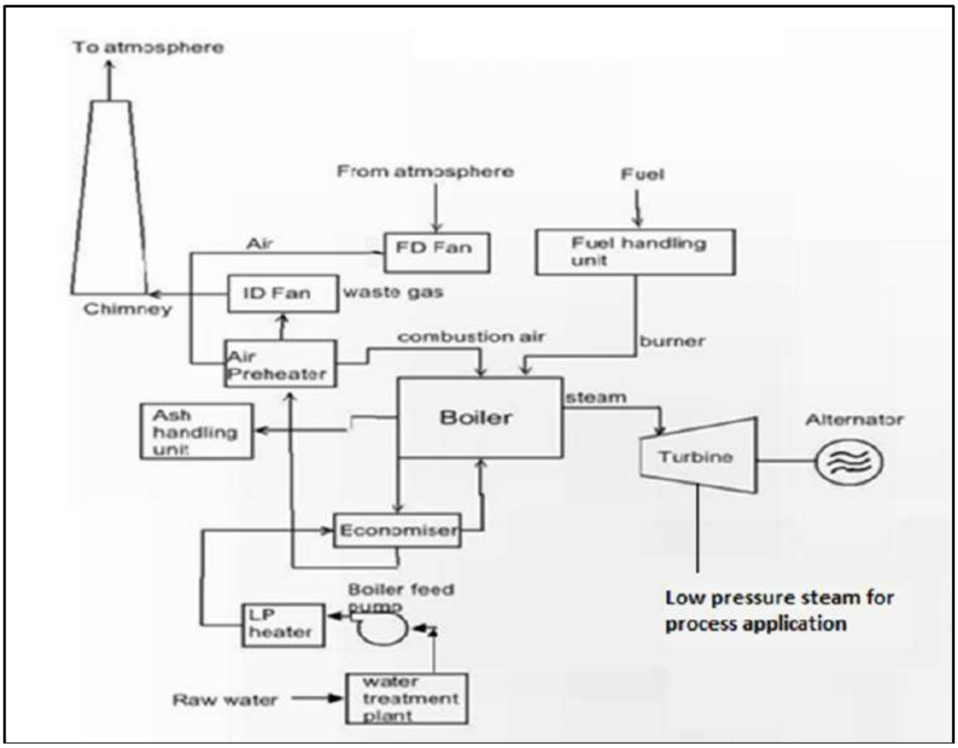


Figure 4 -Process flow diagram-Captive cogeneration power plants

IV. Fresh water and Marine water Requirements

TCL has eliminated dependence on ground water since April 2007 by adopting various in-house water conservation measures as well as management of the rain-fed lakes and innovative seawater desalination technologies. Water needs at the complex are met by seawater. Water requirements and their sources are listed in Table 2. The Company has implemented water management concepts of Reduce, Recycle, Reuse, Replace and Generate (Water). This is achieved by the following means:

- ✓ Substitution of fresh water by seawater in cooling towers
- ✓ Substitution of process water by treated seawater for brine preparation
- ✓ Water conservation initiatives within the complex
- ✓ Internal generation of water from steam jet refrigeration and waste heat desalination, RO plant
- ✓ Recycle/reuse of treated domestic sewage within the Company Township for toilet flushing and horticulture.

Table 2 - Water Requirements and Sources

Basic requirements for the project	CCA capacity (before expansion)	Additional for expansion	Total CCA capacity AWH – 129468
Fresh water (m^3/day) (Annualised average)	7,100	Nil	7,100
	Source: Rain water lake		
Sea water (m^3/day) (Annualised average)	2,46,721	29,975	2,76,696
	Source: Arabian Sea		

V. Effluent Management System

TCL Mithapur plant utilizes sea water for various applications inside the plant including for cooling applications. Concentrated brine is the raw material for production of various chemicals in the plant. The plant generates treated wastewater from its various processes which is discharged into the Gulf of Kutch, through closed pipeline and diffuser system after solids separation and dilution with return seawater from plant cooling water system.

TCL's chemical complex has implemented integrated waste management system for reuse and recycling of waste streams and utilizes sea water for its cooling requirements. Effluent streams from Chlor Caustic plant are recycled in the manufacturing process of soda ash plant. Treated waste water generated from soda ash unit, return cooling sea water and other streams from chemical complex are discharged into the sea through a single outlet as per prescribed norms (Table 3). Scheme of treated wastewater disposal is given in Figure 5.

TCL has implemented effluent management system which ensures compliance of treated wastewater quality within limit for the parameters Total Suspended Solids (TSS), pH, Ammoniacal Nitrogen, Temperature, Colour, Oil & Grease and Bioassay Test as per the Consent Order of the Gujarat Pollution Control Board (GPCB). Following process is implemented to achieve concentration of TSS in the final treated wastewater within the GPCB norms:

a) Effluent solid filtration: Effluent generated in soda ash ammonia still process is filtered in effluent solid filtration plant and the filtered solids are utilized in cement manufacturing and other purpose. Company has developed a pioneering process to use the solids recovered from the soda ash effluent in cement making.
b) Settling of suspended solids: Filtered effluent (from Effluent Solids Filtration Plant) and raw effluent (generated from Brine Purification process) is directly sent to sedimentation basins through closed pipelines to settle the suspended solids
c) Return cooling Sea Water: Other streams from RO plant, NF Plant, Bromine Plant and Clear water from ESF Plant are mixed with return cooling sea water within the complex and conveyed through closed pipeline system from Plant to Padli return cooling Sea water pond.
d) Dilution with return cooling sea water: Clear effluents after the above processes (a and b) are mixed with in return cooling sea water pond (c) and final treated wastewater is discharged into the sea through closed pipeline and diffuser system.
e) Treated Wastewater quality consent norms:

Parameters	Prescribed Norms
pH	6.5 - 9.0

Parameters	Prescribed Norms
Temperature	40^0 C
Colour (pt. co. scale) in units	100 units
Suspended Solids	500 mg/l
Oil and grease	2 mg/l
Ammoniacal Nitrogen	5 mg/l
Bio Assay Test	90% Survival of the fish after 96 hours in 100% effluent
Quantity of industrial effluent	2,40,000 m3/day

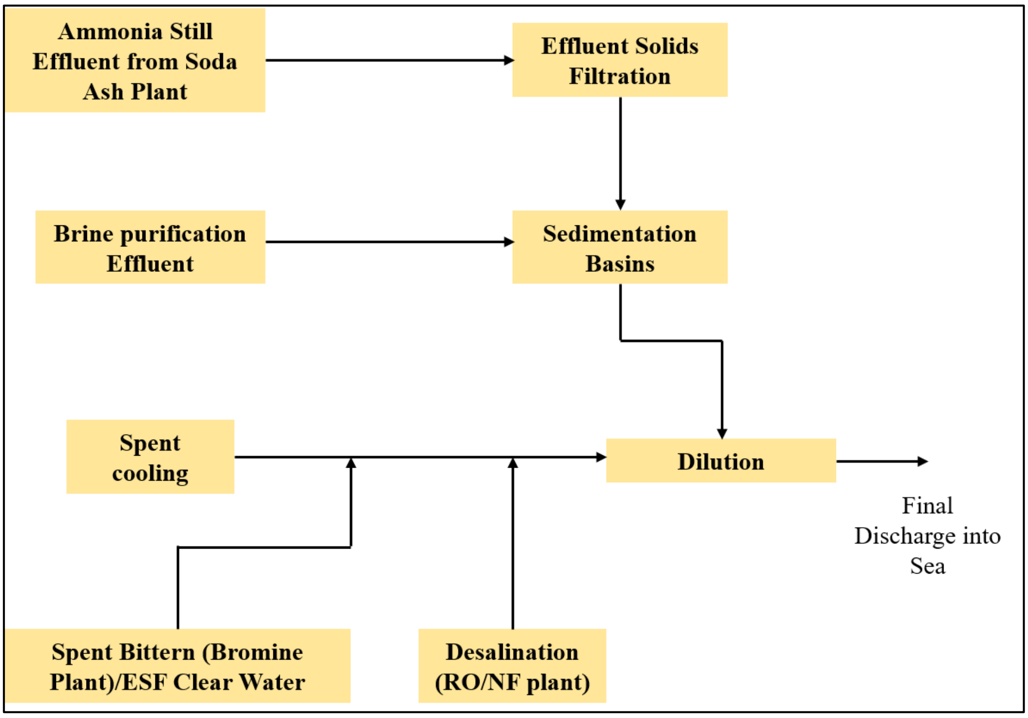


Figure 5 - Existing Effluent Management System

→ **Disposal of treated domestic wastewater**

- **Existing Sewage Treatment Plant**

  The sewage from the township is collected in the existing septic tank. Raw sewage is then pumped to the treatment plant with a capacity of 3 MLD. Treated sewage is recycled and reused for toilet flushing in the township. Any excess quantity of treated sewage is used for horticulture purposes or disposed through pipelines into the Arabian Sea. The sludge from the treatment plant is pumped to drying beds. The dried sludge is used as manure in the township gardens for horticulture/afforestation. Scheme of Domestic Treated Waste water disposal is given in Figure 6.

- **Treatment Process**

Septic tanks are used as a raw sewage sump and manual screens are provided on the upstream of the septic tank to arrest the floating matter. The raw sewage is pumped into the aeration tanks with submerged diffusers to develop the microorganisms to consume BOD. The aerated sewage flows over into the secondary clarifier- 1 where the suspended microorganisms are settling down and the clear liquid flows into the flash mixer tank. Coagulants are added to enhance suspended solids settling. Further settling takes place and clear liquid overflows from the top into the pressure filter feed sump.

The clarified sewage is then pumped from the pressure filter feed sump to the pressure sand filter where the remaining suspended solids and BOD are arrested. The outlet from the pressure filter is chlorinated and sent to the township for flushing purposes. Excess quantity of treated sewage is used for horticulture purposes or disposed through pipelines into the Arabian Sea. The solid settled in the bottom of the clarifier is recycled back into the aeration tank as return sludge. The excess sludge is periodically sent to the sludge drying bed for drying. The backwash of the pressure filter is routed back to the equalization tank. The filtrate from the sludge drying beds is pumped to the equalization tank. The dried sludge is used as manure for the gardens and other afforestation activities.

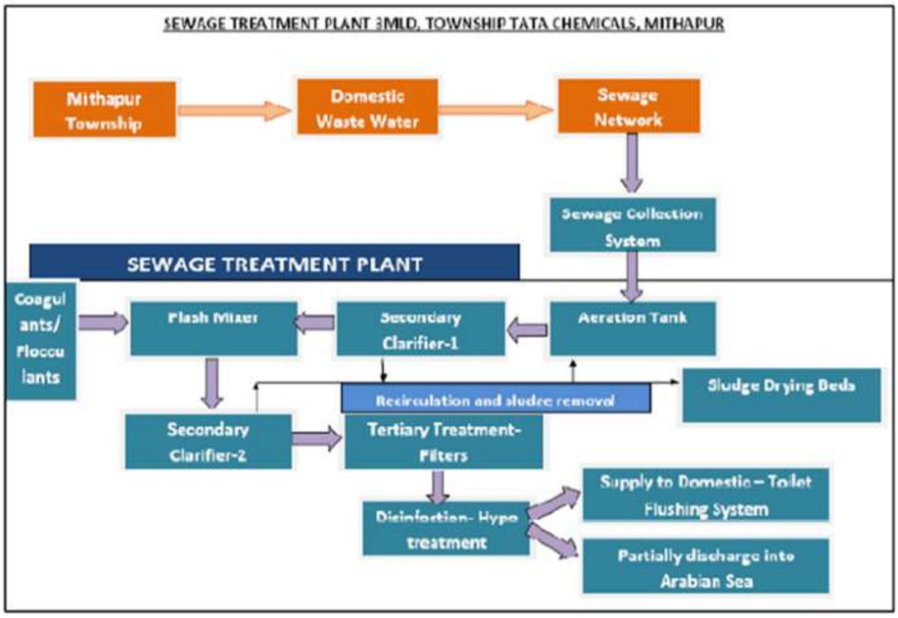


Figure 6 - Wastewater disposal scheme-Domestic

VI. Soil Classification

The quality of soil in Okhamandal Taluka is hard, sandy and saline. The base layer is made up of limestone/clay and is inherently saline in nature. Reddish and highly fossiliferous limestone (known as Dwarka beds) is exposed along the western coastline. These Dwarka beds are above the Gaj beds and limestone layers. The depth of the topsoil layer in Okhamandal varies from 2" to 36". The topsoil layer along the coastal bed is poor due to wind erosion. The soil along this belt is more or less sandy and loose. The topsoil conditions observed in Okhamandal are given in Table 3.

Table 3 - Topsoil conditions of Okha Mandal

Top Soil Features	Details
Depth of the soil	2"to 36"
Structure	Granular and Blocky
Texture	Sandy loamy/clayey
Water storage capacity	Poor to good
Penetration of water	Good to excellent
Looseness of soil	Good to excellent
Aeration	Moderate to good
Amount of organic matter present	Poor to good
Erosion factor	High
Colour	Light brown to dull black
pH	7.6-9.38
Salinity	0.002-7%

Source - http://www.gujenvis.nic.in/PDF/soil.pdf

VII. Climatic Condition

The climate in the region is broadly characterized under four seasons as follows:

Winter: December - February

Summer: March - Mid June

Monsoon: Mid June - September

Autumn: October - November

Tides:

The tides in the Mithapur Bay are mixed semi-diurnal with two unequal high and two unequal low waters occurring in each tidal day. From the recorded tides at Okha the following tidal parameters with respect to the CD are established:

Level	Range (m)
MHWS	3.47
MHWN	2.96
MSL	2.04
MLWN	1.20
MLWS	0.41

The tidal water enters the Gulf from west south-west and influences the Mithapur Bay from northwest-west. The tide pertaining to the study periods for Okha Port from Indian Tide Tables are presented.

Currents:

Current records indicate the highest current speed of about 0.9 m/s. The root mean square velocity for the entire data set is 0.56 m/s. Net u component (along-shore) is 0.05 m/s in the direction of flood which indicates the net transport into the bay. The net v component (cross-shore) of 0.05 m/s which is very small suggests dominant flow in the EW direction. The maximum u component is 0.81 m/s during flood and 0.86 m/s during ebb. However, strong ebb components occur for less duration than the strong flood components. Strong v components are also discernible with maximum offshore component of 0.77 m/s and the maximum onshore component of 0.59 m/s. This may be due to depth contours which curve in the area.

Tidal Excursion:

Tidal excursion which is useful while considering distribution of contaminants when released to marine waters is the average distance a particle travels from slack water to slack water due to tidal currents. The following excursion lengths (km) are computed based on drogue trajectories charted within the Mithapur Bay by releasing the drogue at different tidal phases.

Bathymetry:

The area between the peninsular Okha region and Bet Shankhodar is a shallow region with relatively deep-water pockets of >5 m depths while the remaining area strewn with rock outcrops. The general depths of <2 m makes the bay a tricky area for navigation for even smaller size fishing crafts.

The area between the southern tip of Shankhodar Island and Kyu Point on the southern mainland is termed as the Mithapur Bay in this report. Depths of >7 m exist in two large pockets with fewer shoals compared to the western part of the bay leading to Okha Port.

C. ENVIRONMENTAL BASELINE MONITORING

1. SAMPLES COLLECTION AND ANALYSIS METHODS

→ Date of Sampling - 17th December 2025

→ Photographs showing field sampling

Please add more photographs of field sampling on 17 December 2025

→ Marine water Sampling Locations and Maps:

Table 4 - TATA Chemicals Marine Sampling Locations

Sr. No.	Site Code	GPS Location
1	S1	22° 25' 21.79" N 69° 4' 5.00"E
2	S2	22° 24' 57.88"N 69° 4' 36.40"E
3	S3	22° 25' 0.91"N 69° 5' 18.79"E
4	S4	22° 26' 6.79"N 69° 7' 1.2"E
5	S5	22° 26' 6.79"N 69° 5' 14.60"E
6	S6	22° 26' 6.79"N 69° 5' 7.40"E
7	S7	22° 26' 6.79"N 69° 5' 0.06"E
8	S8	22° 26' 6.79"N 69° 3' 44.1"E

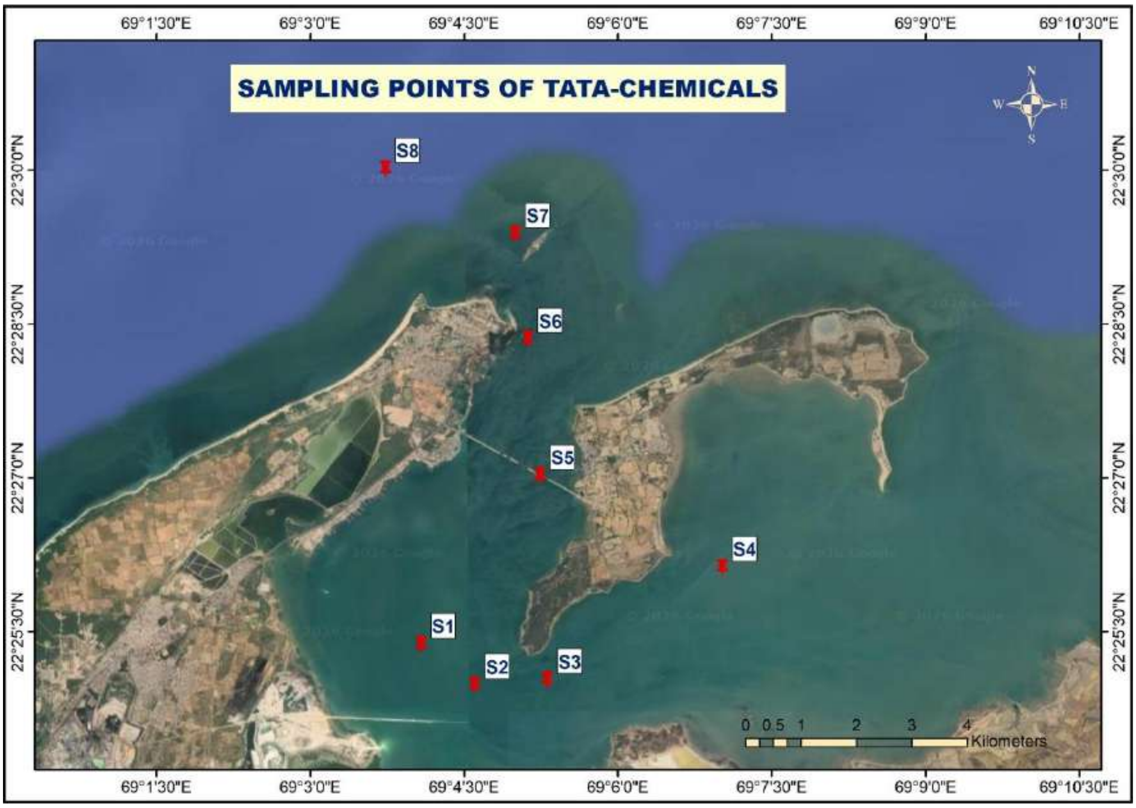


Figure 7 - TATA Chemicals Marine Sampling Locations

→ Test method used for marine water physico-chemical parameters

Sr. No.	Parameters	Method Used
1	pH	APHA: 23rd Edition 4500-H+ B
2	Conductivity	APHA: 23rd Edition 2510 B
3	Turbidity	APHA: 23rd Edition 2130 B
4	Temperature	APHA: 23rd Edition 2550 B
5	Total Suspended Solids	APHA: 23rd Edition 2540 D
6	Dissolved Oxygen	APHA: 23rd Edition 4500- O C
7	BOD (3 Days at 27 °C)	IS 3025 (Part 44): 1993
28	Salinity	APHA 23rd Edition 4500 Cl- B
10	Inorganic Phosphate PO_4 - P	APHA: 23rd Edition 4500 P - C
11	Nitrate Nitrogen	IS 3025 (Part 34) (ii): 1988
12	Nitrite Nitrogen	IS 3025 (Part 34): 1988
13	Ammoniacal Nitrogen (NH_4N)	IS 3025 (Part 34): 1988
30	Total Nitrogen	IS 3025 (Part 34) (ii): 1988
14	Arsenic	APHA 23rd Edition 3125 B
15	Cadmium	APHA 23rd Edition 3125 B
16	Hexa Chromium	APHA 23rd Edition 3125 B
17	Total Chromium	APHA 23rd Edition 3125 B
18	Copper	APHA 23rd Edition 3125 B
19	Iron	APHA 23rd Edition 3125 B
20	Lead	APHA 23rd Edition 3125 B
21	Manganese	APHA 23rd Edition 3125 B
22	Mercury	APHA 23rd Edition 3125 B
23	Nickel	APHA 23rd Edition 3125 B
24	Zinc	APHA 23rd Edition 3125 B
25	Aluminium	APHA 23rd Edition 3125 B
27	Cobalt	APHA 23rd Edition 3125 B

→ Test method used for marine water Biological Parameters

- Phytoplankton: Only surface water samples

- Phytoplankton count, major genera and generic diversity and SWDI
- Zooplankton: Only surface water samples
- Zooplankton count; volume of zooplankton, major genera of zooplankton and group diversity and SWDI.
- Microbiology counts: Total viable count, Total Coliform, *E. coli*, *Vibrio*, *Aeromonas*, *Pseudomonas* spp.

Sr. No.	Parameter	Method Used
1	Total Coliform Bacteria	APHA 23rd Edition (9221 B, C)
2	*E. Coli*	APHA 23rd Edition (9221 B, G)
3	Total Viable Count	APHA 23rd Edition (9215 A)
4	*Vibrio* Spp	APHA 23rd Edition (9260 H)
5	*Aeromonas*	APHA 23rd Edition (9260 L)
6	*Pseudomonas* sp.	APHA 23rd Edition (9217)

→ Test method used for marine sediment physico-chemical parameters

Sr. No.	Parameters	Method Used
1	Aluminium	EPA-3050B
	Arsenic	APHA 23rd Edition 3125 B
2	Chromium	EPA-3050B
3	Manganese	EPA-3050B
4	Iron	EPA-3050B
5	Nickel	EPA-3050B
6	Copper	EPA-3050B
7	Zinc	EPA-3050B
8	Lead	EPA-3050B
9	Cadmium	EPA-3050B
10	Cobalt	EPA-3050B
15	Mercury	APHA 23rd Edition 3125 B
11	Total Organic Carbon %	Walkley Black Method
12	Texture	International Pipette Method
31	Total Petroleum Hydrocarbon	USEPA 9071 B: 1998

→ Test method used for Coastal sediments Biological Parameters

Microbiology counts:

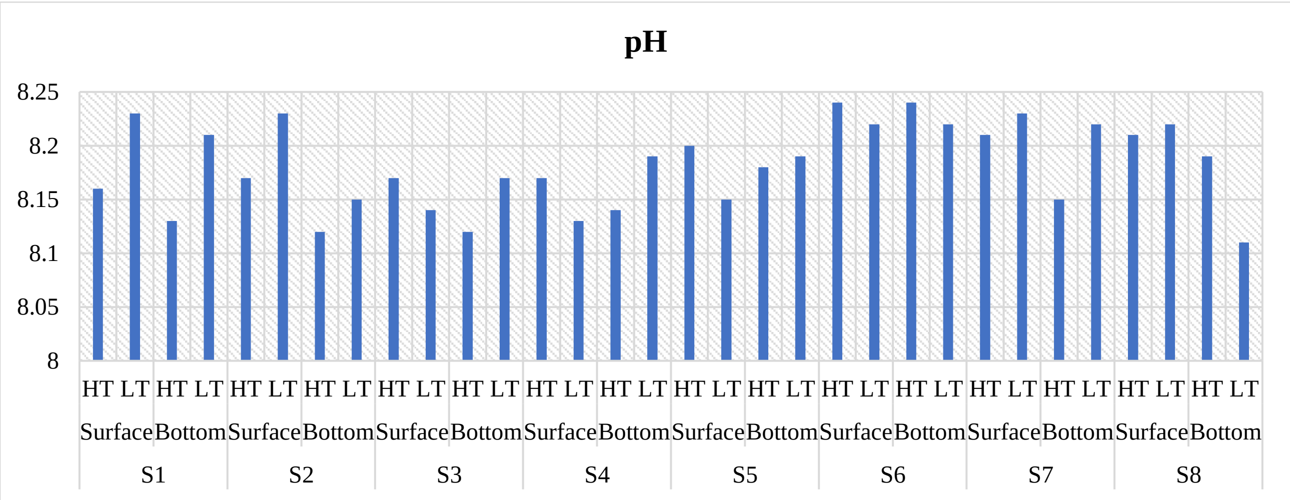
Total viable count, Total Coliform, E. coli, Vibrio spp., Aeromonas, Pseudomonas spp.

Benthic fauna: Identification of species and species diversity study

Sr. No.	Parameter	Method Used
1	Benthos Population	APHA: 10500 (23rd Edition)

2. MARINE WATER PARAMETERS

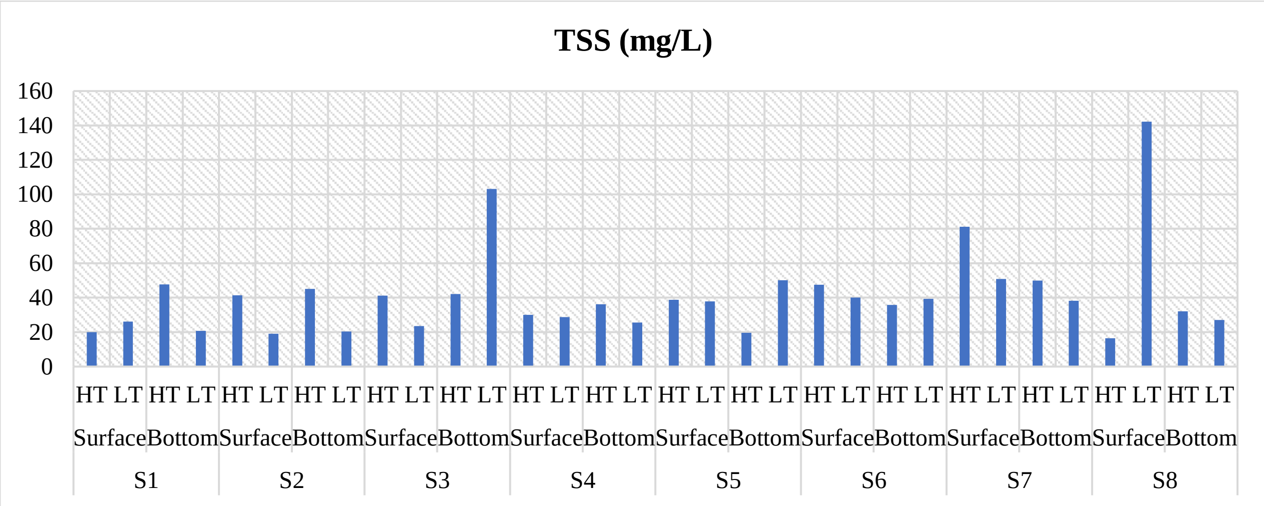
❖ Physicochemical Characteristics



Graph 1 - pH in Marine Water

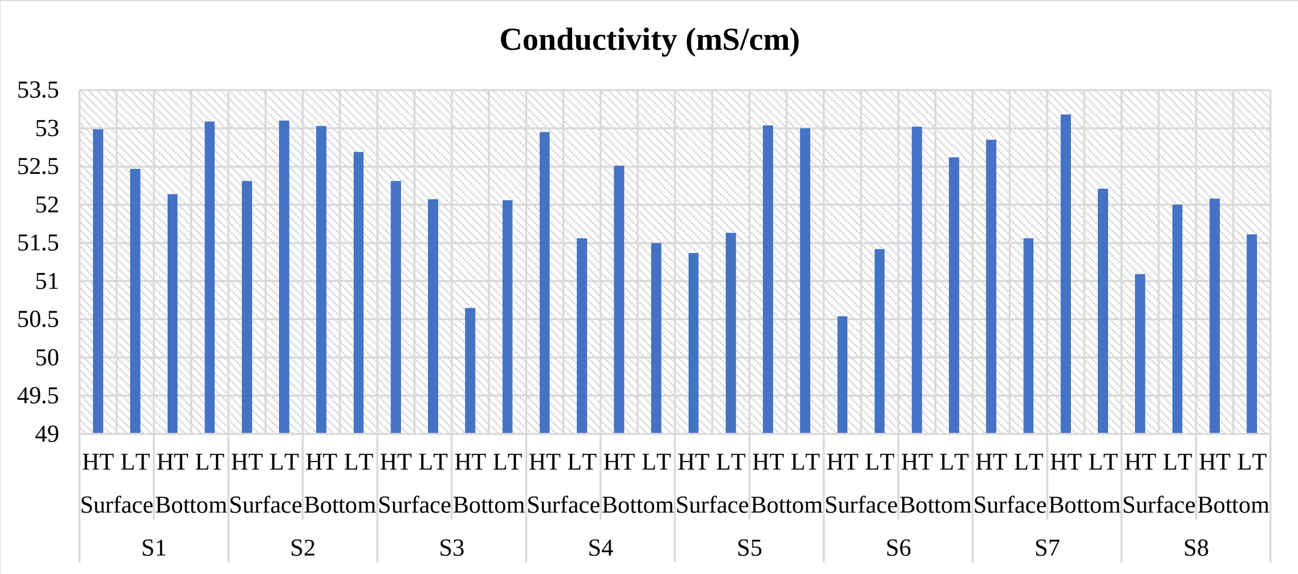
Seawater at all sampling locations exhibited pH values ranging from 8.11 to 8.24, reflecting the slightly alkaline nature characteristic of coastal marine environments. The lowest pH value (8.11) was recorded in the bottom water at Station S8, while the highest value (8.24) was observed at Station S6. Only minor differences were noted between surface and bottom waters, suggesting effective vertical mixing and stable carbonate buffering throughout the study area. The measured pH values fall well within the normal range for seawater (7.8–8.4), indicating a chemically stable aquatic environment with no evidence of significant anthropogenic disturbance or acidification.

Overall, the observed pH conditions are conducive to maintaining ecological integrity and supporting marine biological productivity.



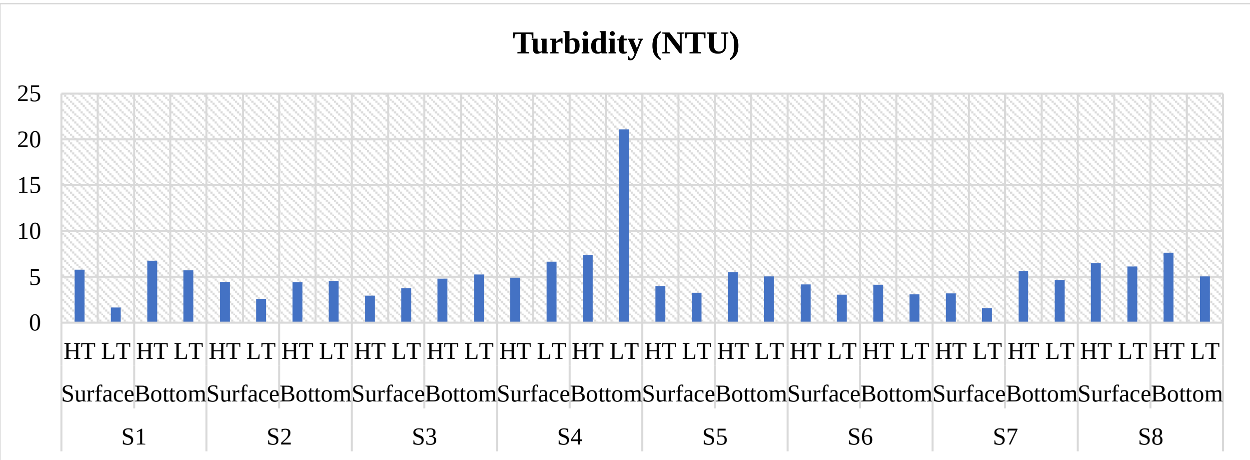
Graph 2 - TSS in Marine Water

The concentration of Total Suspended Solids (TSS) varied considerably among the sampling stations, ranging from 16.4 to 142.2 mg/L. Most stations (S1, S2, S4, S5, and S6) exhibited relatively low TSS concentrations below 50 mg/L, indicating generally stable suspended sediment conditions in the study area. However, elevated TSS levels were recorded during low tide at S3 (103.2 mg/L), S7 (81.2 mg/L), and S8 (142.2 mg/L), suggesting enhanced natural sediment resuspension driven by tidal currents in the open sea. The comparatively higher TSS concentration observed at S8 indicates a localized zone of active sediment circulation and resuspension. Overall, the spatial variation in TSS concentrations reflects the influence of tidal hydrodynamics on the transport, resuspension, and distribution of suspended sediments within the studyarea.



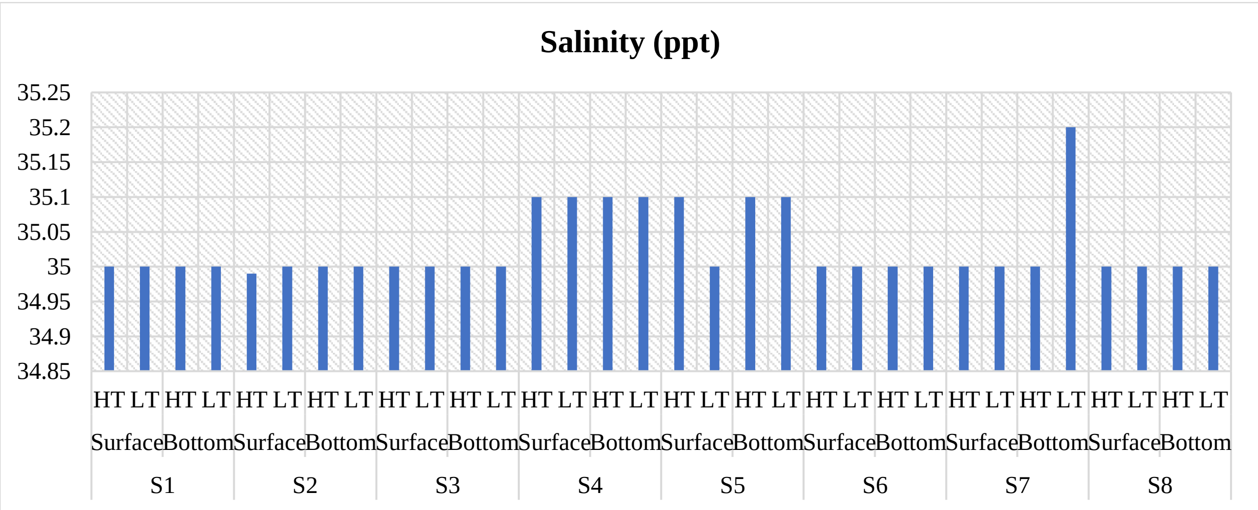
Graph 3 - Conductivity in Marine Water

The conductivity of seawater across the eight sampling stations ranged from 50.54 to 53.18 mS/cm, indicating relatively uniform marine conditions and values typical of seawater. The highest conductivity was recorded at S7 (53.18 mS/cm), while slightly lower values were observed at S3 and S6. The limited spatial variation in conductivity suggests a well-mixed water column and effective tidal exchange throughout the study area. Furthermore, only minor differences were observed between high-tide and low-tide samples, as well as between surface and bottom waters, indicating stable hydrographic conditions. Overall, the conductivity distribution reflects the predominance of marine influence with minimal freshwater intrusion during the sampling period, confirming the consistency of seawater characteristics across the study area.



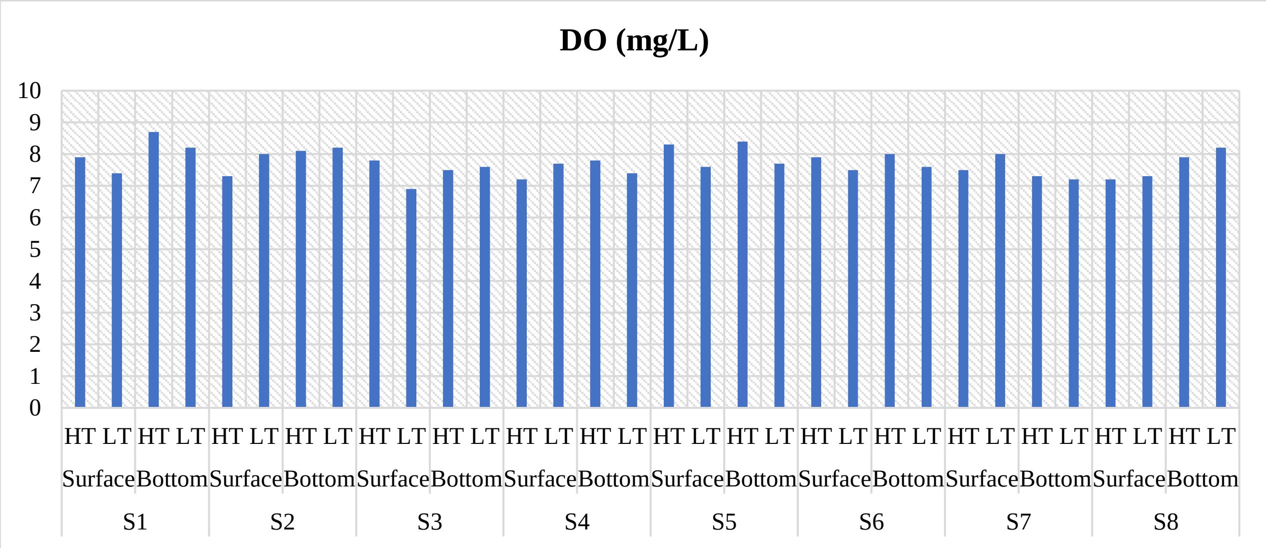
Graph 4 - Turbidity in Marine Water

The turbidity levels across the study area ranged from 1.58 to 21.10 NTU, indicating generally clear to moderately turbid coastal waters. Most sampling stations recorded turbidity values below 8 NTU, reflecting low concentrations of suspended particles and good water transparency. An isolated peak turbidity of 21.10 NTU was observed at Station S4, which may be attributed to localized sediment resuspension caused by natural tidal turbulence and hydrodynamic mixing. The lowest turbidity levels were observed at Stations S2, S6, and S7, indicating comparatively clearer water conditions. Spatial variations in turbidity were more pronounced than tidal variations, suggesting that local hydrodynamic conditions exert a greater influence on suspended particle distribution than tidal stage alone. Overall, the turbidity distribution indicates stable marine conditions throughout the study area, with the elevated value at S4 representing a localized effect of natural sediment resuspension.



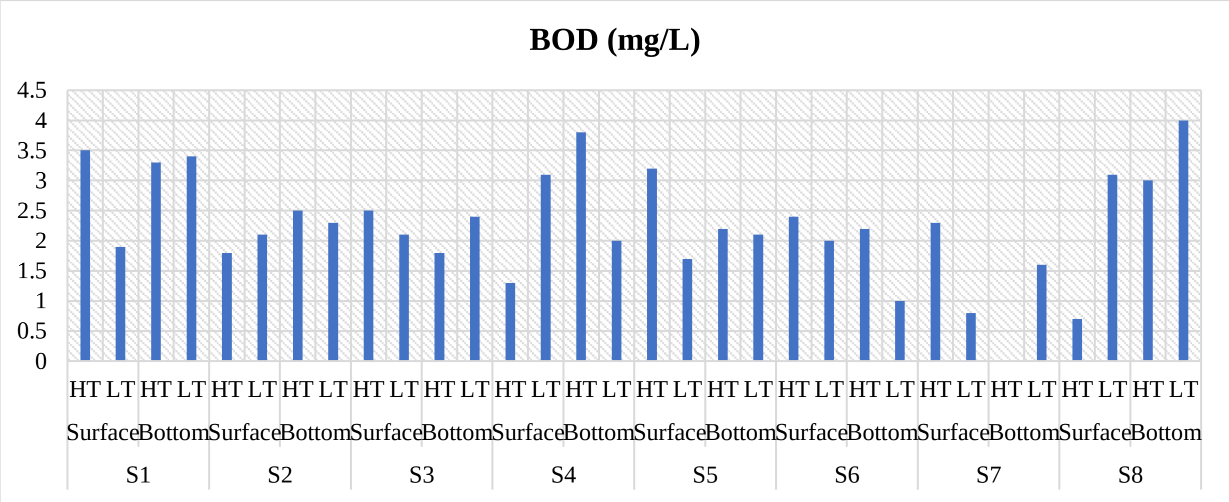
Graph 5 - Salinity in Marine Water

Salinity across the study area ranged from 34.9 to 35.2 ppt, indicating highly stable marine conditions with minimal spatial and tidal variation. Salinity values at most sampling stations were consistently close to 35.0 ppt, which is characteristic of normal coastal seawater. Slightly higher salinity values were recorded at Stations S4 (35.15 ppt) and S7 (35.2 ppt), although the overall variation remained very small. The negligible differences observed between high-tide and low-tide conditions, as well as between surface and bottom waters, suggest effective tidal mixing and a well-mixed water column throughout the study area. Overall, the salinity distribution confirms the predominance of marine influence and stable hydrographic conditions, providing a favorable environment for marine and coastal ecosystems.



Graph 6 - DO in Marine Water

Dissolved oxygen (DO) concentrations in the study area ranged from 6.9 to 8.7 mg/L, indicating consistently well-oxygenated marine waters capable of supporting aquatic life. Most sampling stations recorded DO levels between 7 and 8 mg/L, reflecting favourable water quality conditions and effective oxygen replenishment through tidal mixing and atmospheric exchange. All observed values were well above the commonly accepted minimum threshold of 5 mg/L required for the protection of marine aquatic organisms. The relatively small differences observed between high-tide and low-tide conditions, as well as between surface and bottom waters, suggest a well-mixed water column and stable hydrographic conditions throughout the study area. Overall, the distribution of dissolved oxygen indicates good ecological status and favourable water quality, supporting a healthy marine environment during the sampling period.



Graph 7 - BOD in Marine Water

Biochemical Oxygen Demand (BOD) concentrations in the study area ranged from 0.0 to 4.0 mg/L, indicating generally good coastal water quality and low to moderate levels of biodegradable organic matter. Most sampling stations recorded BOD values below 3.0 mg/L, reflecting low microbial oxygen demand and limited organic loading. Slightly elevated BOD concentrations were observed at Stations S8 (4.0 mg/L) and S4 (3.8 mg/L), which may be associated with localized natural organic matter decomposition and biological activity. In contrast, Station S7 exhibited the lowest BOD level among all sampling locations.

The observed BOD concentrations were not of a magnitude likely to cause oxygen depletion, as evidenced by the consistently high dissolved oxygen (DO) levels recorded throughout the study area. The coexistence of low BOD and adequate DO concentrations indicates a favorable balance between oxygen demand and oxygen replenishment processes. Overall, the BOD distribution suggests that the study area is characterized by good water quality and a healthy marine environment, with low organic pollution and sufficient dissolved oxygen available to support aquatic life.

Comparison of BOD and DO Trends Across Sampling Stations

The Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) results exhibit an expected inverse relationship across the study area, although the variations are relatively small and all stations indicate good water quality.

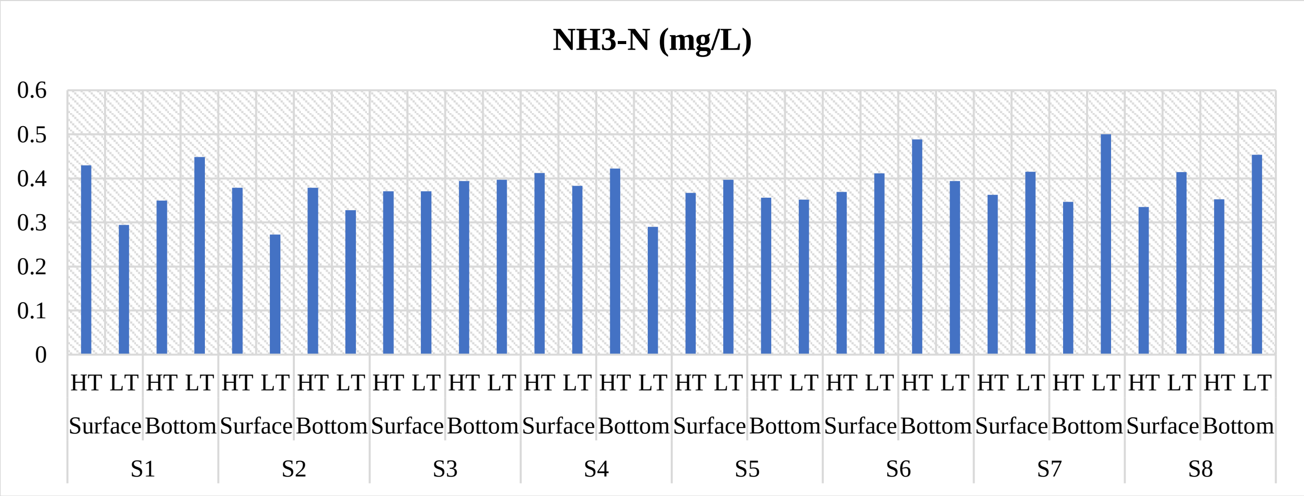
DO concentrations ranged from 6.9 to 8.7 mg/L, remaining well above the minimum level generally considered necessary for sustaining marine aquatic life.

BOD concentrations ranged from 0.0 to 4.0 mg/L, indicating low to moderate levels of biodegradable organic matter and a generally low oxygen demand.

Stations S4 and S8, which recorded the highest BOD values (3.8 mg/L and 4.0 mg/L, respectively), may reflect relatively higher organic matter decomposition and microbial activity. However, despite the slightly elevated BOD levels, dissolved oxygen concentrations remained within the healthy range, indicating that oxygen replenishment through tidal mixing and atmospheric exchange was sufficient to meet the oxygen demand.

In contrast, S7 exhibited the lowest BOD concentration, indicating minimal organic oxygen demand. Correspondingly, DO levels remained high, demonstrating favorable environmental conditions and efficient oxygenation. Across all sampling stations, the absence of low DO values together with generally low BOD concentrations suggests that organic loading was insufficient to cause oxygen depletion.

Overall, the combined BOD and DO trends indicate a well-balanced and healthy marine ecosystem, where oxygen consumption due to organic matter degradation is effectively compensated by natural aeration and tidal mixing processes. The consistently high DO concentrations, even at stations with comparatively higher BOD values, demonstrate good assimilative capacity and confirm the favorable ecological status of the study area.



Graph 8 - NH3 in Marine Water

The minor spatial variability in NH_3–N concentrations, together with the absence of corresponding deterioration in DO or BOD conditions, suggests that the coastal waters remain well mi Ammoniacal nitrogen (NH_3–N) concentrations in the study area ranged from 0.2722 to 0.5000 mg/L, indicating low to moderate nutrient levels characteristic of a healthy coastal marine environment. Most sampling stations recorded NH_3–N concentrations of ≤0.45 mg/L, suggesting limited organic nitrogen inputs and effective nutrient assimilation within the water column. Relatively higher NH_3–N concentrations were observed at Stations S6 (0.4888 mg/L), S7 (0.5000 mg/L), and S8 (0.4533 mg/L), which may be attributed to natural processes such as sediment–water nutrient exchange, organic matter mineralization, and biological regeneration within the coastal ecosystem.

Despite these localized increases, the observed ammoniacal nitrogen concentrations did not appear to adversely affect water quality or ecological conditions. This is supported by the consistently high dissolved oxygen (DO) concent xed and environmentally stable.

Overall, the distribution of ammoniacal nitrogen reflects satisfactory water quality and a healthy nutrient regime within the study area. The results indicate that marine processes continue to dominate the hydrographic and ecological characteristics of the area without evidence of significant nutrient-related stress.

Comparison of NH_3–N, BOD, and DO Trends Across Sampling Stations

The trends of ammoniacal nitrogen (NH_3–N), biochemical oxygen demand (BOD), and dissolved oxygen (DO) collectively indicate good water quality and a healthy marine environment across the study area.

- NH_3–N concentrations ranged from 0.2722 to 0.5000 mg/L, with relatively higher values observed at S6 (0.4888 mg/L), S7 (0.5000 mg/L), and S8 (0.4533 mg/L).
- BOD concentrations ranged from 0.0 to 4.0 mg/L, with the highest values recorded at S8 (4.0 mg/L) and S4 (3.8 mg/L).
- DO concentrations remained consistently high, ranging from 6.9 to 8.7 mg/L throughout the study area.

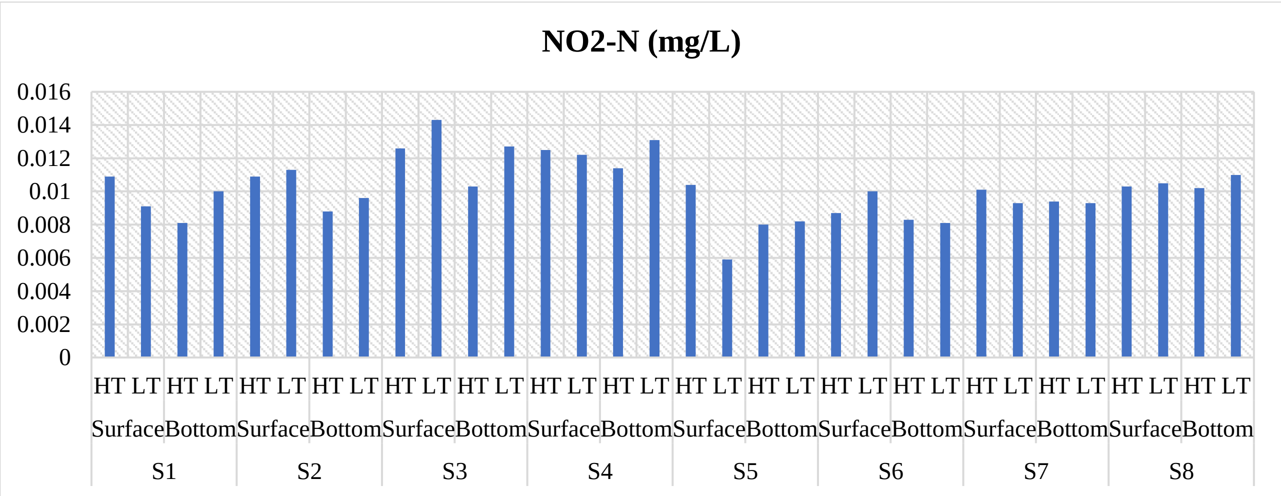
A comparison of these parameters reveals that stations exhibiting relatively elevated NH_3–N concentrations did not show correspondingly high BOD levels or reduced DO concentrations. For example, although S6, S7, and S8 recorded the highest NH_3–N concentrations, dissolved oxygen levels remained within the healthy range, indicating that the available oxygen was sufficient to support nitrification and other biological processes. Similarly, the slightly elevated BOD observed at S8 was not associated with any noticeable depletion in dissolved oxygen, suggesting effective oxygen replenishment through tidal mixing and atmospheric exchange.

The absence of a strong correlation between elevated NH_3–N and reduced DO indicates that the observed ammonia concentrations are likely associated with natural nutrient regeneration processes rather than significant organic pollution. Furthermore, the generally low BOD values across the study area suggest limited microbial oxygen demand, which is consistent with the maintenance of high DO concentrations.

Overall, the combined assessment of NH_3–N, BOD, and DO demonstrates a well-balanced coastal ecosystem, characterized by:

- Low to moderate nutrient concentrations,
- Limited organic loading,
- Low oxygen demand, and
- Adequate dissolved oxygen availability.

These findings indicate that the study area possesses good assimilative capacity and stable hydrographic conditions, with no evidence of nutrient enrichment or organic pollution adversely affecting water quality during the sampling period. The coexistence of moderate NH_3–N concentrations, low BOD levels, and consistently high DO concentrations reflects a healthy and well-oxygenated marine environment.

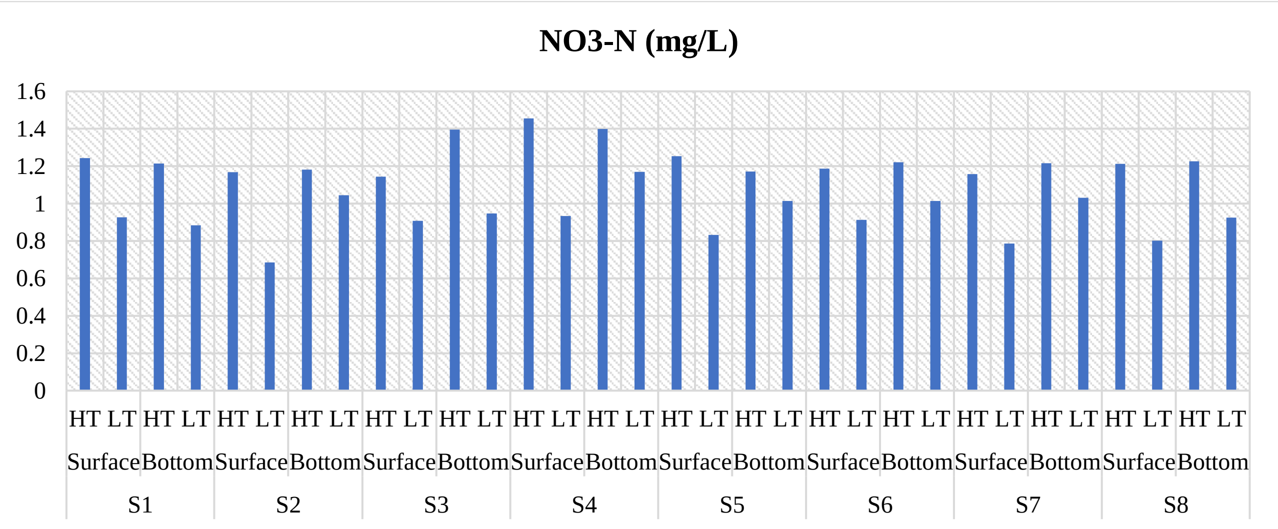


Graph 9 - NO_2 in Marine Water

Nitrite nitrogen (NO_2–N) concentrations in the study area ranged from 0.0059 to 0.0143 mg/L, indicating low nitrite levels and effective nitrogen transformation processes in the coastal waters. Most sampling stations recorded NO_2–N concentrations between 0.008 and 0.011 mg/L, which are typical of well-oxygenated marine environments where nitrite is rapidly oxidized to nitrate as part of the natural nitrogen cycle. The lowest concentration was observed at Station S5 (0.0059 mg/L), suggesting efficient nitrogen conversion processes, while slightly elevated concentrations were recorded at Stations S3 (0.0143 mg/L) and S4 (0.0131 mg/L), likely reflecting localized nitrification activity and natural variability in nutrient dynamics.

The observed nitrite concentrations are low and environmentally acceptable, indicating the absence of significant nitrogen enrichment or pollution. This interpretation is further supported by the relatively low ammoniacal nitrogen (NH_3–N) concentrations (0.2722–0.5000 mg/L), low biochemical oxygen demand (BOD) levels (0.0–4.0 mg/L), and consistently high dissolved oxygen (DO) concentrations (6.9–8.7 mg/L) recorded throughout the study area. The coexistence of low NO_2–N concentrations and high DO levels suggests that oxidative processes and nitrogen cycling are functioning effectively within a well-mixed coastal environment.

Overall, the distribution of NO_2–N reflects stable nutrient dynamics, good water quality, and healthy ecological conditions. The results indicate efficient nitrogen cycling under well-oxygenated marine conditions, with no evidence of significant nitrogen-related stress or deterioration of water quality within the study area.



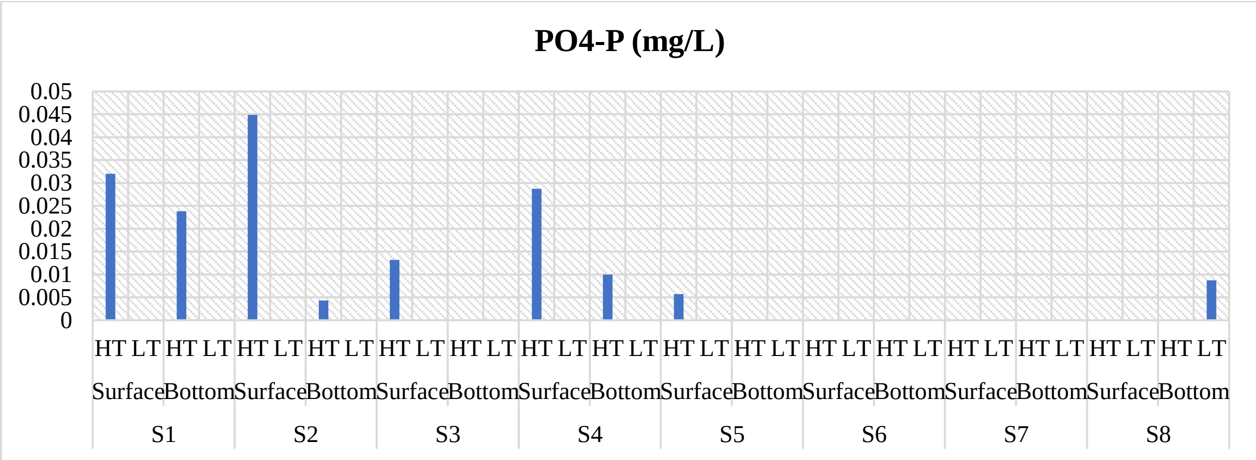
Graph 10 - NO3 in Marine Water

Nitrate nitrogen (NO_3–N) concentrations in the study area ranged from 0.6858 to 1.4557 mg/L, indicating moderate nutrient availability and active nitrogen cycling within the coastal marine environment. Most sampling stations recorded nitrate concentrations between 0.9 and 1.3 mg/L, which are characteristic of well-oxygenated coastal waters where nitrification processes efficiently convert reduced nitrogen species into nitrate. The highest nitrate concentration was observed at Station S4 (1.4557 mg/L), followed by Station S3 (1.3955 mg/L), likely reflecting localized variations in nutrient regeneration, microbial activity, and organic matter mineralization. In contrast, the lowest concentration was recorded at Station S2 (0.6858 mg/L), which may be associated with biological uptake by phytoplankton and other aquatic organisms or localized dilution effects.

The observed nitrate distribution is consistent with the patterns recorded for ammoniacal nitrogen (NH_3–N) and nitrite nitrogen (NO_2–N). Relatively low NH_3–N concentrations (0.2722–0.5000 mg/L), low NO_2–N concentrations (0.0059–0.0143 mg/L), and elevated dissolved oxygen (DO) levels (6.9–8.7 mg/L) collectively indicate efficient nitrogen transformation processes under well-oxygenated conditions. The low nitrite concentrations, coupled with moderate nitrate levels, suggest rapid conversion of intermediate nitrogen species and an active, balanced nitrogen cycle within the water column.

Furthermore, the generally low biochemical oxygen demand (BOD) values (0.0–4.0 mg/L) indicate limited organic loading and minimal oxygen stress, supporting the continued oxidation of reduced nitrogen compounds. The absence of excessive nitrate accumulation, together with stable DO and BOD conditions, suggests that nutrient dynamics are primarily governed by natural biogeochemical processes rather than anthropogenic nutrient enrichment.

Overall, the nitrate distribution reflects a well-mixed coastal marine ecosystem characterized by effective nitrogen cycling, good water quality, and stable ecological conditions. The observed concentrations do not indicate nutrient enrichment or eutrophication risk and are consistent with a healthy marine environment supporting balanced nutrient transformation processes.



Graph 11 - PO4 in Marine Water

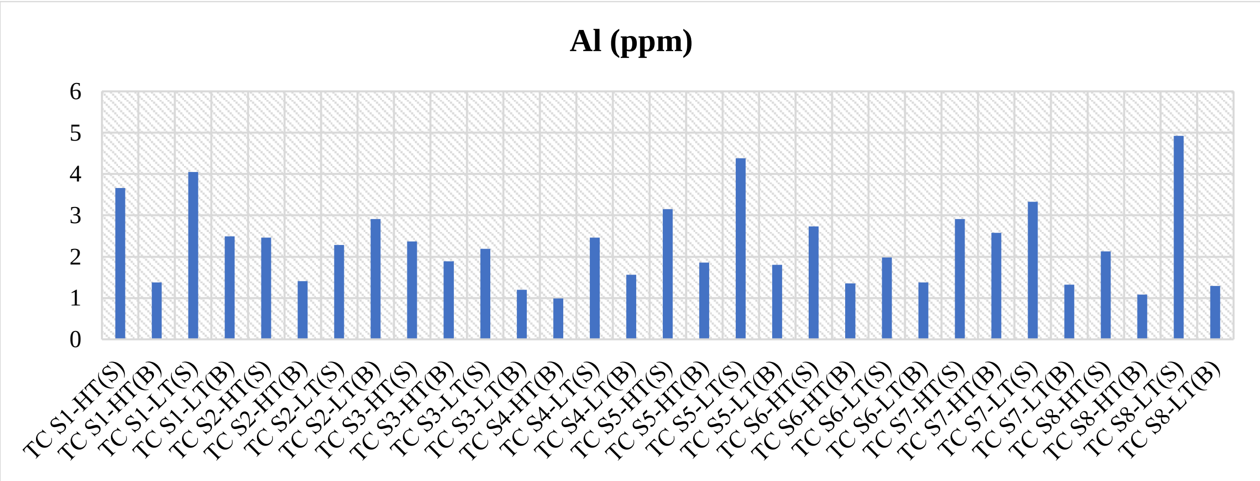
Orthophosphate phosphorus (PO_4–P) concentrations in the study area ranged from below detection limit (BDL) to 0.0449 mg/L, indicating very low phosphorus availability and generally favorable nutrient conditions throughout the coastal waters. Most sampling stations recorded phosphate concentrations below the analytical detection limit, suggesting effective biological uptake and limited external phosphorus inputs. Detectable phosphate concentrations were observed at Stations S1 (0.0320 mg/L), S2 (0.0449 mg/L), and S4 (0.0287 mg/L), which may be associated with natural processes such as nutrient regeneration, organic matter decomposition, and sediment–water nutrient exchange.

The highest PO_4–P concentration was recorded at Station S2 (0.0449 mg/L); however, the overall phosphate levels remained low and within the range typically observed in healthy coastal marine environments. The low phosphorus concentrations, together with moderate inorganic nitrogen levels (NH_3–N, NO_2–N, and NO_3–N), indicate a balanced nutrient regime without evidence of excessive nutrient enrichment.

Furthermore, the nutrient status is supported by consistently high dissolved oxygen (DO) concentrations (6.9–8.7 mg/L) and low biochemical oxygen demand (BOD) values (0.0–4.0 mg/L), which indicate good water quality, limited organic loading, and the absence of oxygen stress. The concurrence of low phosphate concentrations, moderate nitrogen availability, high DO, and low BOD suggests that nutrient cycling processes are functioning efficiently without promoting excessive biological productivity or eutrophication.

Overall, the spatial distribution of PO_4–P reflects a well-mixed and well-flushed coastal marine system with good ecological health and satisfactory water quality. The low phosphorus concentrations, coupled with balanced nitrogen dynamics and favorable oxygen conditions, indicate minimal nutrient enrichment and no evidence of phosphorus-driven eutrophication within the study area during the sampling period.

❖ **Marine Water Metallic Characteristics**



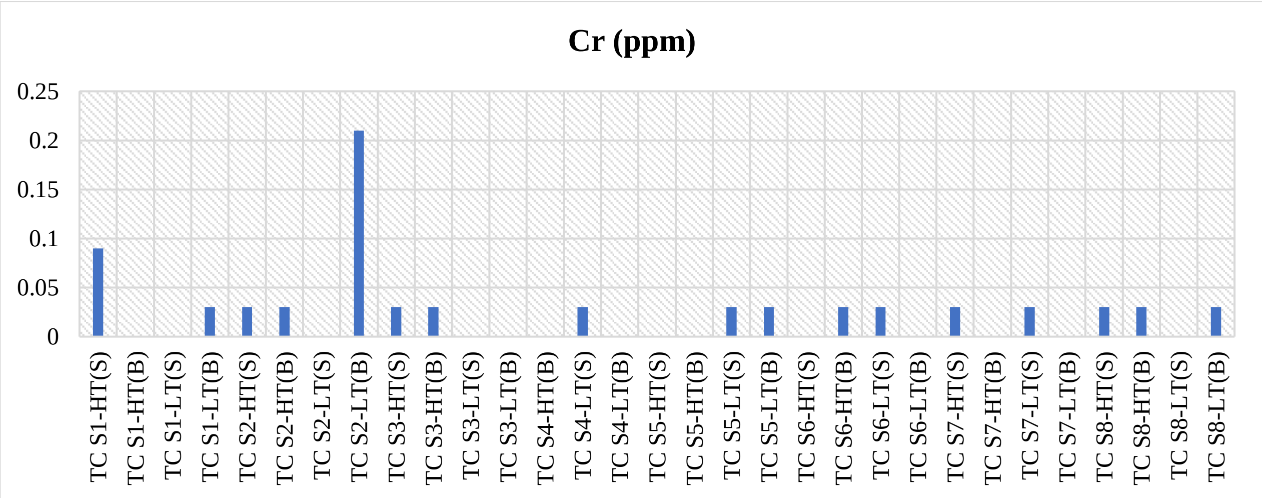
Graph 12 - Al in Marine Water

Aluminium (Al) concentrations in the study area exhibited noticeable spatial variability across the eight sampling stations (S1–S8) under both High Tide (HT) and Low Tide (LT) conditions. Aluminium is one of the most abundant elements in the Earth's crust and commonly occurs in coastal waters through natural processes such as weathering of aluminosilicate minerals, erosion of rocks, sediment resuspension, and transport of suspended particulates. The measured Al concentrations ranged from 0.99 mg/L at Station S4-HT(B) to 4.92 mg/L at Station S8-LT(S).

The generally moderate range of aluminium concentrations observed across the study area suggests that its distribution is primarily controlled by natural sediment dynamics and hydrodynamic processes. Relatively higher concentrations at certain locations, particularly at S8 during low tide, may reflect localized sediment resuspension and the influence of tidal currents on particulate transport. In contrast, lower concentrations recorded at stations such as S4 indicate comparatively reduced suspended sediment inputs or more stable local hydrodynamic conditions.

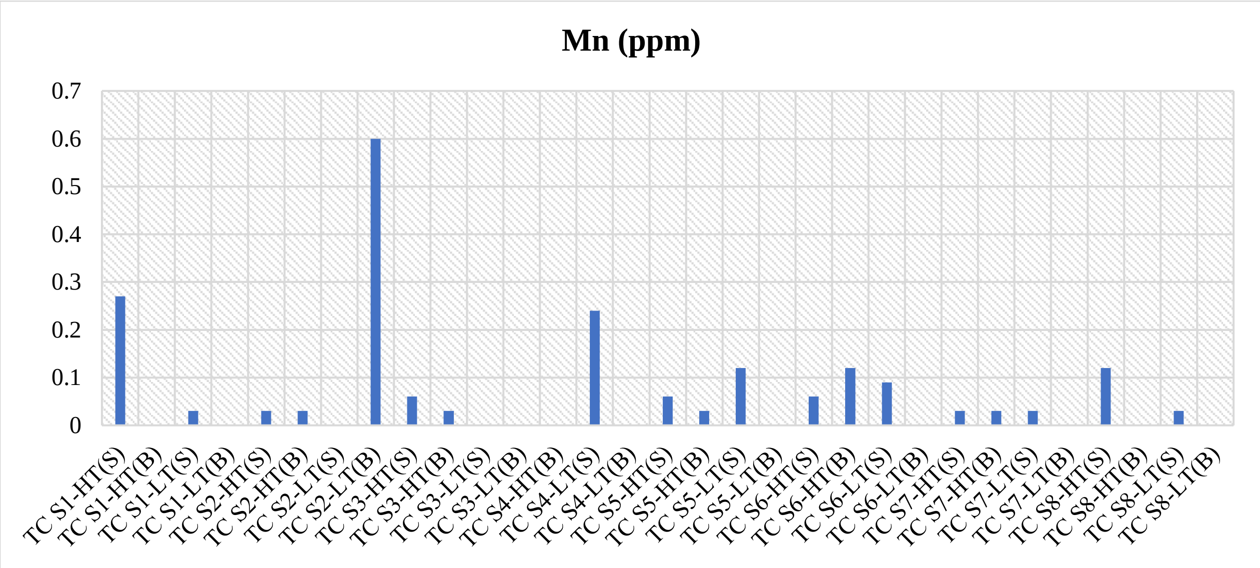
The observed spatial variations are consistent with the behavior of aluminium as a predominantly particulate-associated element, whose distribution is closely linked to suspended sediment concentrations. This interpretation is supported by the variability observed in Total Suspended Solids (TSS), where localized increases in suspended particulate matter were also noted at selected stations.

Overall, the aluminium distribution reflects the influence of natural sediment transport pathways and tidal hydrodynamics within a well-mixed coastal marine environment. The measured concentrations do not indicate any unusual accumulation pattern and are consistent with the natural geochemical characteristics of coastal waters influenced by sediment circulation and resuspension processes.



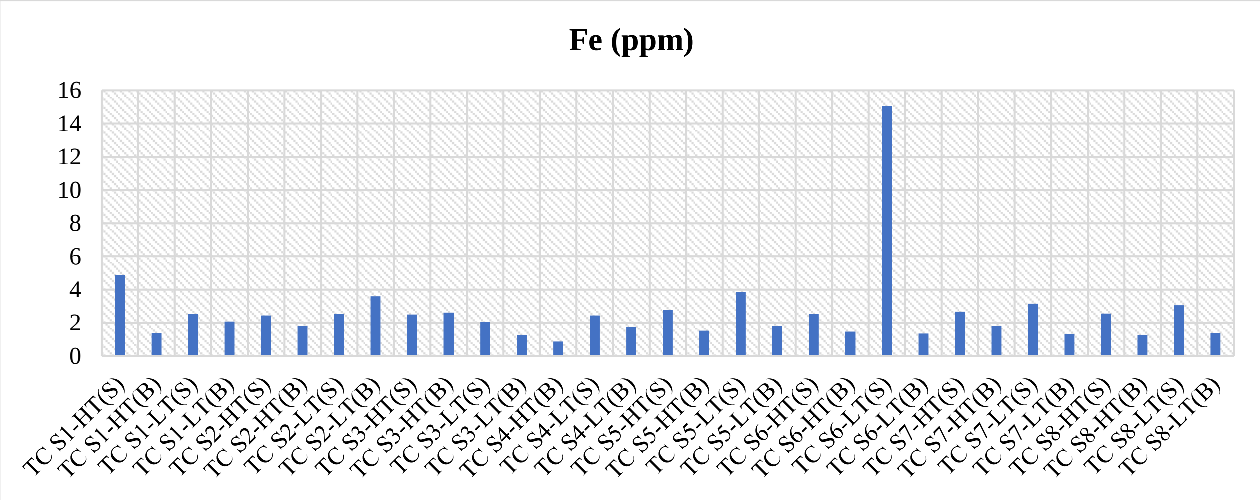
Graph 13 - Cr in Marine Water

The distribution of chromium (Cr) concentrations across the eight sampling sites (S1–S8) indicated that chromium levels were generally very low, with several samples recording concentrations below the detection limit (BDL). Detectable chromium concentrations were observed only at a few locations, ranging from BDL (0.00 mg/L) to 0.21 mg/L. Spatial variation in chromium concentrations across the study area was minimal, as most sampling sites exhibited a concentration of approximately 0.03 mg/L. These results suggest a relatively uniform distribution of chromium, with only localized occurrences of slightly elevated concentrations.



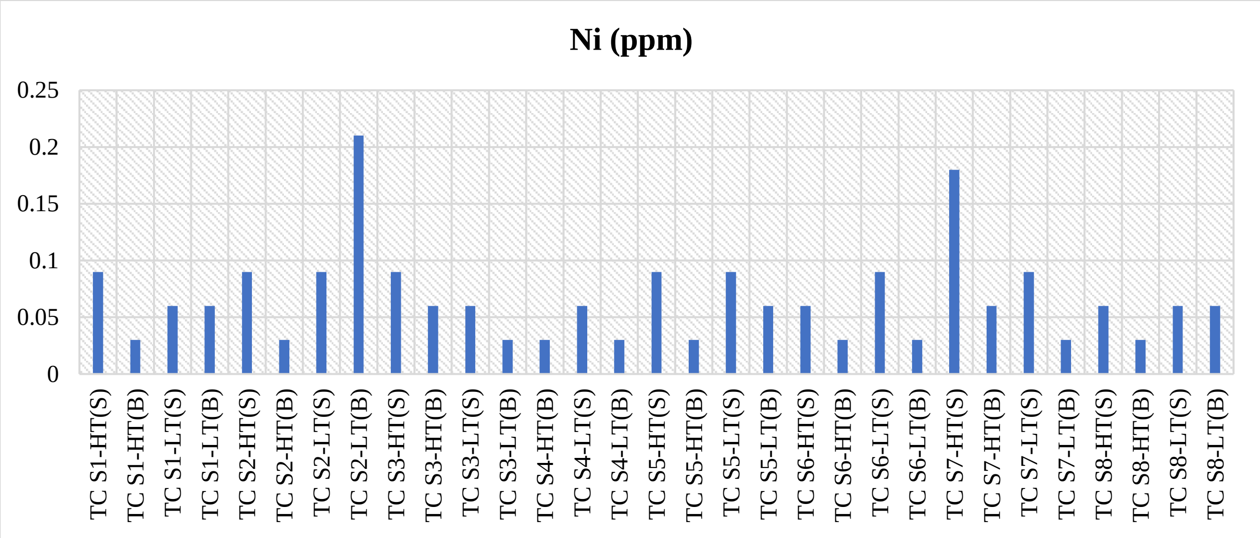
Graph 14 - Mn in Marine Water

The spatial distribution of manganese (Mn) concentrations across the eight sampling stations (S1–S8) indicated that manganese levels were generally low, with several samples recording concentrations below the detection limit (BDL). Detected Mn concentrations ranged from BDL (0.00 mg/L) to 0.60 mg/L, while the majority of samples exhibited concentrations between BDL and 0.12 mg/L. Only a few isolated locations showed relatively elevated manganese levels, with concentrations approaching 0.60 mg/L. Overall, the distribution pattern suggests that manganese is predominantly present at background levels across the study area, with localized enrichment observed at a limited number of sampling stations.



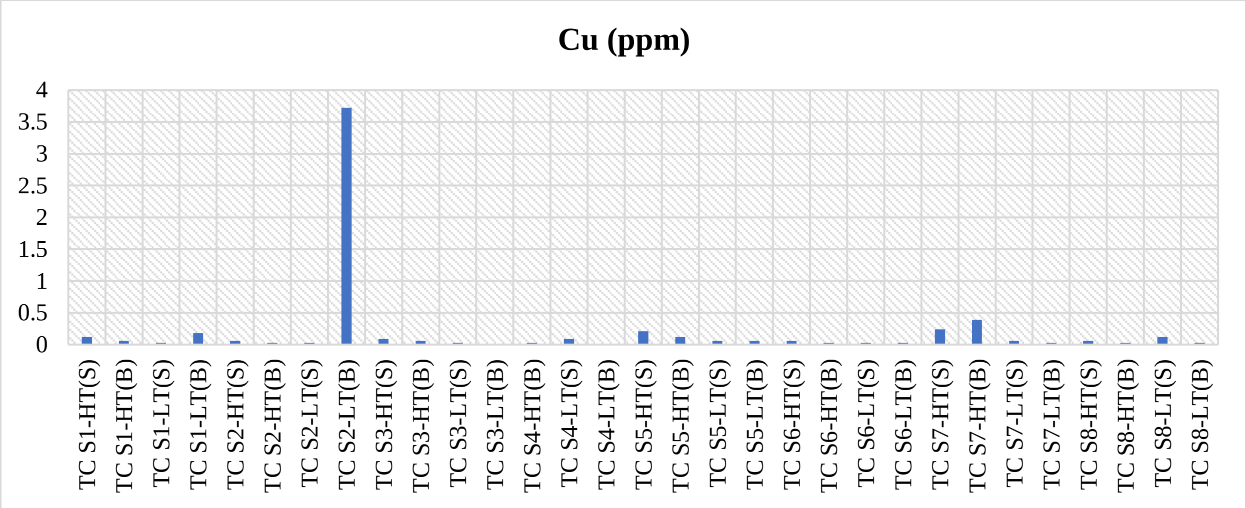
Graph 15 - Fe in Marine Water

The spatial distribution of iron (Fe) concentrations across the eight sampling stations (S1–S8) indicated generally low to moderate iron levels throughout most of the study area, with one station exhibiting a notably elevated concentration. Iron is a naturally occurring trace element in coastal marine environments and is typically introduced through weathering of rocks, soil erosion, riverine inputs, and sediment resuspension processes. The measured iron concentrations ranged from 0.87 mg/L at S4-HT(B) to 15.06 mg/L at S6-LT(S). Most sampling locations recorded concentrations between 1 and 4 mg/L, suggesting relatively consistent background levels of iron across the study area. However, the substantially higher concentration observed at S6-LT(S) represents a localized enrichment and may be attributable to site-specific environmental conditions or natural sedimentary influences. Overall, the distribution pattern indicates limited spatial variability in iron concentrations, except for the isolated elevated value recorded at S6-LT(S).



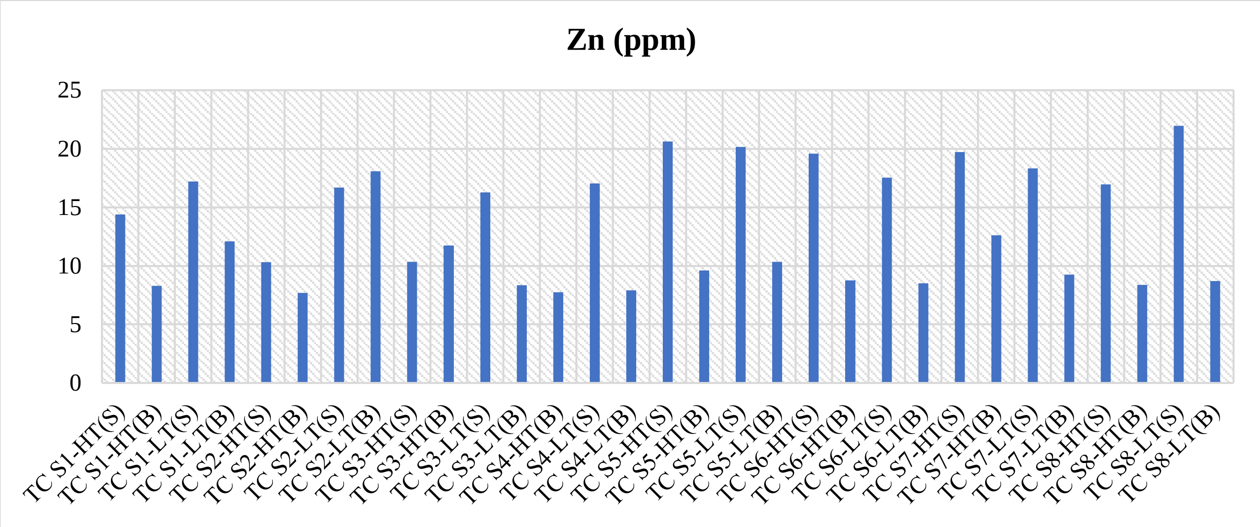
Graph 16 - Ni in Marine Water

The spatial distribution of nickel (Ni) concentrations across the eight sampling stations (S1–S8) indicated generally low nickel levels throughout the study area, with only a few locations exhibiting comparatively elevated concentrations. Nickel is a naturally occurring trace metal in marine environments and is introduced through natural processes such as rock weathering, sediment erosion, and riverine transport. The measured nickel concentrations ranged from 0.03 mg/L to 0.21 mg/L, with most samples recording values between 0.03 and 0.09 mg/L. The relatively narrow concentration range observed across the majority of sampling sites suggests limited spatial variability and reflects background nickel levels within the study area. Although localized enrichment was observed at a few stations, the overall distribution pattern indicates minimal nickel contamination and generally low nickel concentrations throughout the coastal environment.



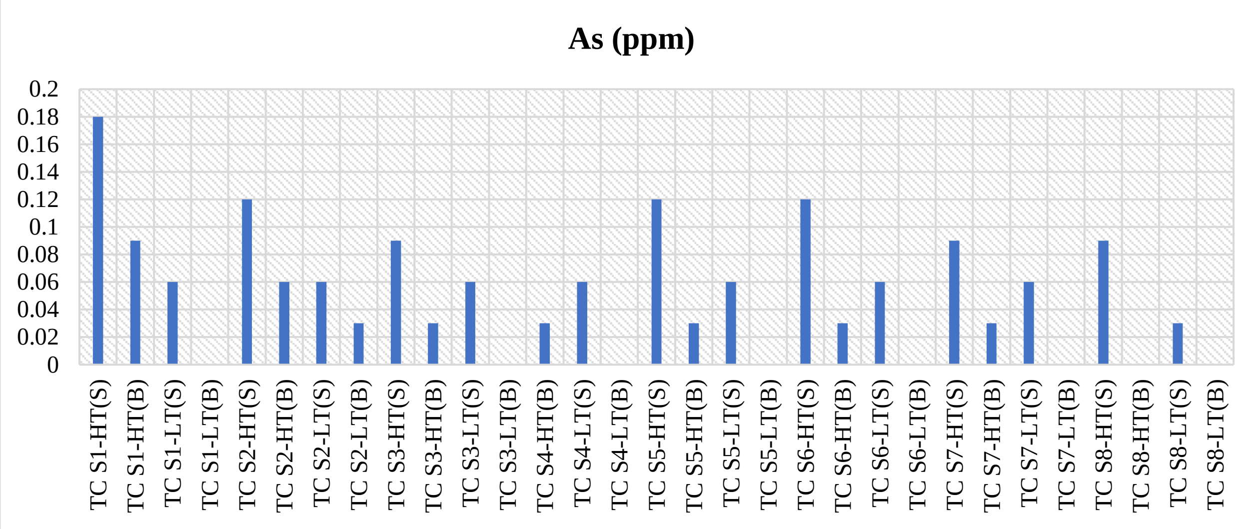
Graph 17 - Cu in Marine Water

The spatial distribution of copper (Cu) concentrations across the eight sampling stations (S1-S8) indicated that copper was generally present at very low concentrations throughout the study area. Copper is a naturally occurring trace metal in marine environments and is commonly introduced through weathering of rocks, sediment transport, riverine inputs, and coastal processes. The measured copper concentrations ranged from below the detection limit (BDL; 0.00 mg/L) to 3.72 mg/L. However, the majority of samples exhibited concentrations between 0.03 and 0.24 mg/L, indicating relatively low and consistent background levels across most sampling locations. The isolated occurrence of elevated copper concentration at a limited number of sites suggests localized enrichment rather than a widespread increase throughout the study area. Overall, the distribution pattern reflects minimal spatial variability in copper concentrations, with generally low levels prevailing across the coastal environment.



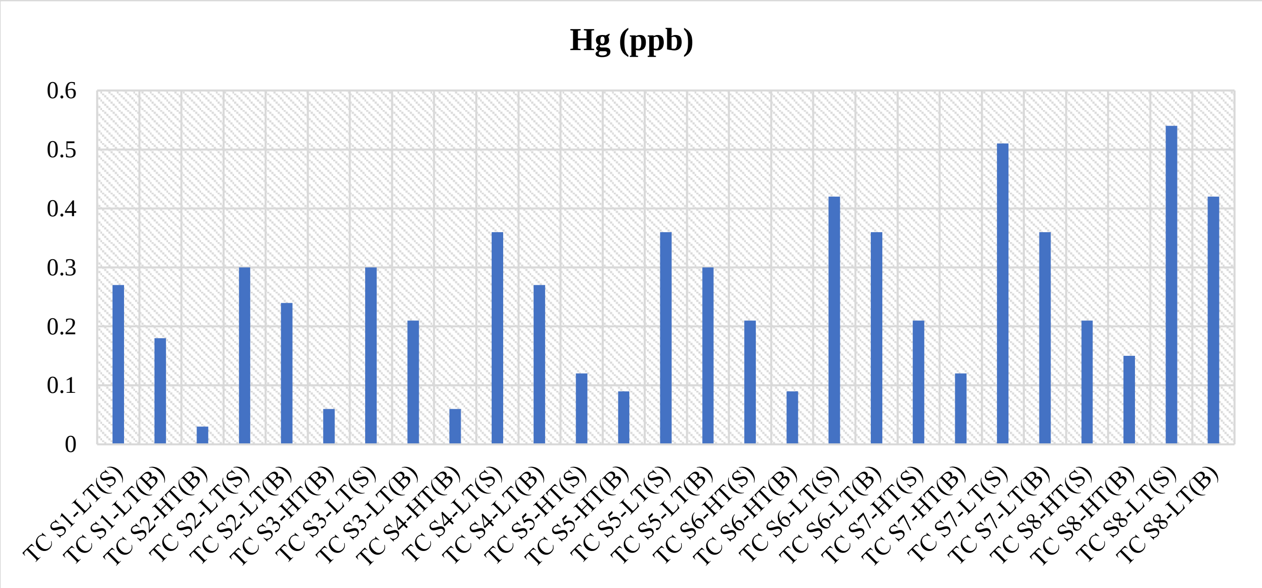
Graph 18 - Zn in Marine Water

The spatial distribution of zinc (Zn) concentrations across the eight sampling stations (S1–S8) revealed moderate zinc levels throughout the study area, with distinct spatial variability and consistently higher concentrations during High Tide (HT) compared to Low Tide (LT) conditions. Zinc is a naturally occurring trace element in coastal and marine environments and may be influenced by both natural geochemical processes and hydrodynamic conditions. The measured Zn concentrations ranged from 7.68 mg/L at S2-LT(B) to 21.96 mg/L at S8-HT(S). In general, Zn concentrations in HT samples were notably higher than those recorded during the corresponding LT periods. This pattern suggests that tidal exchange, seawater intrusion, and associated sediment–water interactions play a significant role in governing the distribution of zinc within the study area. Overall, the observed distribution indicates moderate spatial variability, with tidal influences emerging as a key factor controlling zinc concentrations.



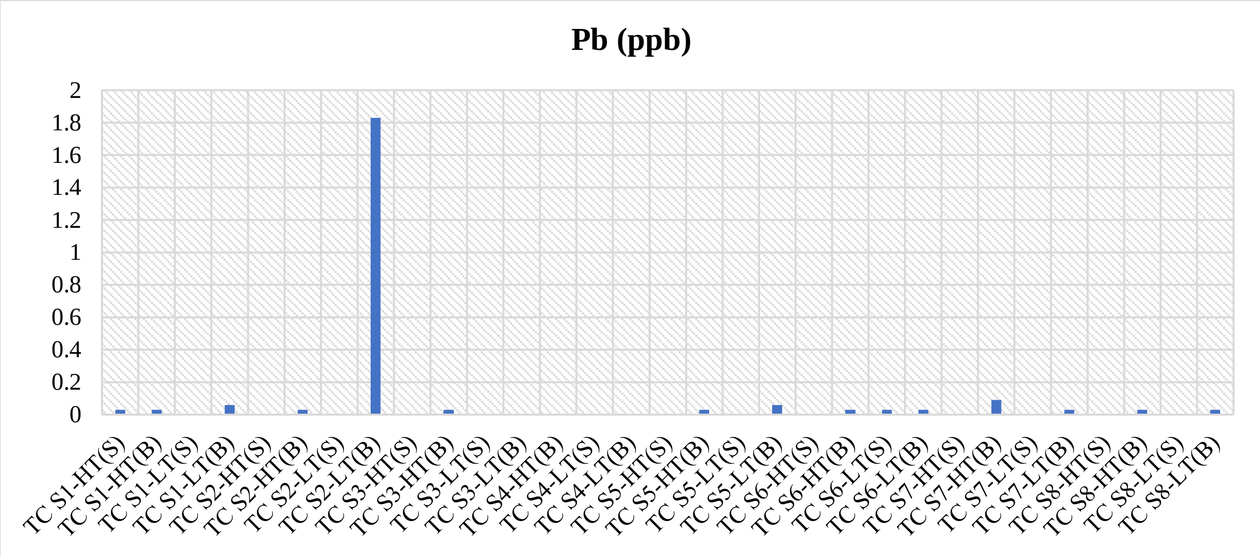
Graph 19 - As in Marine Water

The spatial distribution of arsenic (As) concentrations across the eight sampling stations (S1–S8) indicated generally low arsenic levels throughout the study area, with several samples recording concentrations below the analytical detection limit (BDL). Arsenic is a naturally occurring metalloid in coastal environments and is introduced into marine waters through natural processes such as weathering of arsenic-bearing minerals, riverine inputs, and sediment–water interactions. The measured arsenic concentrations ranged from BDL (0.00 mg/L) to 0.18 mg/L, while the majority of samples exhibited concentrations between 0.03 and 0.09 mg/L. The relatively narrow range of concentrations observed across most sampling locations suggests limited spatial variability and reflects background arsenic levels within the study area. Overall, the distribution pattern indicates low arsenic abundance and minimal enrichment across the monitored coastal environment.



Graph 20 - Hg in Marine Water

Mercury (Hg) concentrations measured at the eight sampling locations (S1–S8) varied between 0.03 and 0.54 µg/L. The minimum concentration was recorded at S2-HT(B), while the maximum concentrations were observed at S8-LT(S) and S7-LT(S). The spatial distribution demonstrates moderate variability across the study area, indicating localized differences in mercury occurrence. Despite the presence of elevated concentrations at a few stations, the overall Hg levels remained within a relatively narrow range, suggesting that mercury is not uniformly distributed but is influenced by localized environmental factors, including tidal conditions, sediment characteristics, and water circulation patterns. The spatial distribution of mercury (Hg) concentrations across the eight sampling stations (S1–S8) indicated moderate spatial variability throughout the study area. Mercury is a naturally occurring trace metal that enters coastal environments through natural processes such as weathering of rocks, atmospheric deposition, and sediment-water interactions. The observed concentration range suggests generally low mercury levels across the study area, with localized zones exhibiting relatively elevated concentrations. Overall, the distribution pattern reflects moderate spatial heterogeneity, likely influenced by site-specific hydrodynamic and geochemical conditions.



Graph 21 - Pb in Marine Water

The spatial distribution of lead (Pb) concentrations across the eight sampling stations (S1–S8) indicated generally low lead levels throughout the study area. Measured Pb concentrations in seawater ranged from below the analytical detection limit (BDL) to 1.83 µg/L, with most sampling locations exhibiting concentrations between 0.03 and 0.09 µg/L or values below the detection limit. A single elevated concentration of 1.83 µg/L was recorded at S2-LT(B) during the low-tide sampling event, suggesting a localized source or enrichment process. However, both Low Tide (LT) and High Tide (HT) samples generally exhibited consistently low Pb concentrations, indicating minimal tidal influence on the distribution of dissolved lead. The predominance of trace-level and non-detectable concentrations across the study area reflects low background lead levels and limited spatial variability. Overall, the distribution pattern demonstrates good seawater quality with respect to lead and suggests the absence of significant or widespread Pb contamination within the monitored coastal environment.

❖ **Marine Water Biological Characteristics**

1. <u>Chlorophyll A and Pheophytin:</u>

Chlorophyll is the primary photosynthetic pigment responsible for capturing solar energy and converting it into chemical energy during photosynthesis. Through this process, carbon dioxide and water are transformed into carbohydrates and oxygen, forming the basis of primary productivity in aquatic ecosystems. Consequently, chlorophyll concentration is widely used as an indicator of phytoplankton biomass and biological productivity. Phaeophytin-a, a degradation product of chlorophyll-a, serves as an indicator of phytoplankton senescence and organic matter decomposition. The concentrations of chlorophyll-a and phaeophytin observed at all sampling stations are presented in the table below. Chlorophyll-a concentrations were below the analytical detection limit at all stations throughout the study area, indicating very low phytoplankton biomass during the sampling period. In contrast, phaeophytin concentrations ranged from 0.002 to 0.015 mg/L, reflecting the presence of degraded phytoplankton pigments at low levels. The observed chlorophyll-a and phaeophytin concentrations are characteristic of normal biological conditions in coastal seawater and suggest the absence of significant phytoplankton blooms or excessive organic enrichment within the study area.

Table 5 - Chlorophyll and Pheophytin

Sampling Sites	Tides	Chlorophyll (a) mg/l	Pheophytin (a) mg/l
S-1	HT	BDL	0.006
	LT	BDL	0.003
S-2	HT	BDL	0.005
	LT	BDL	0.006
S-3	HT	BDL	0.009
	LT	BDL	0.006
S-4	HT	BDL	0.011
	LT	BDL	0.011
S-5	HT	BDL	0.002
	LT	BDL	0.003
S-6	HT	BDL	0.012
	LT	BDL	0.002
S-7	HT	BDL	0.010
	LT	BDL	0.004
S-8	HT	BDL	0.015
	LT	BDL	0.006

2. Plankton Study

Phytoplankton

Table 6 - Phytoplankton

Sr. No.	Name of Species	S-1		S-2		S-3		S-4		S-5		S-6		S-7		S-8	
		HT	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**
1	*Cylindrotheca closterium*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Gyrosigma	+	-	+	-	-	-	-	-	-	+	+	-	+	-	-	-
3	*Cosinodiscus*	+	+	-	+	+	+	+	+	+	+	-	+	-	+	+	+
4	*Bacillaria* sp.	+	++	+	+	+	+	+	+	+	++	+	+	+	+	-	+
5	Pleurosigma	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	*Navicula*	+	+	+	-	-	-	+	-	-	-	+	-	+	-	+	-
7	*Nitzschia*	+	+	+	-	-	+	-	+	-	+	+	+	-	-	+	-
8	*Rhizosolenia* sp.	-	+	-	-	-	-	-	+	+	+	-	-	-	-	+	-
9	*Eucampia* sp.	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	*Synedra* sp.	-	-	+	-	-	-	-	-	+	-	+	+	+	+	+	+
11	*Phormidium*	-	-	+	-	-	+	+	-	-	+	-	-	-	-	-	-
12	*Closterium steaceum*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
13	*Planktothrix*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
14	*Pseudonitzschia*	-	-	-	+	-	-	-	-	-	+	+	+	-	-	-	-
15	*Dinophysis* sp.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
16	*Pinnularia*	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-
17	*Fragilarila*	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-
18	Unidentified 1	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
19	Unidentified 2	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
20	*Chaetoceros* sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
21	*Leptocylindrus* sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-
22	Unidentified 3	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
	Species Diversity	**7**	**6**	**6**	**5**	**3**	**5**	**6**	**5**	**4**	**10**	**7**	**5**	**5**	**3**	**6**	**3**
	SWDI	**1.82**	**0.85**	**1.74**	**1.48**	**0.98**	**1.43**	**0.87**	**0.85**	**1.10**	**1.33**	**1.28**	**0.80**	**1.40**	**0.83**	**1.70**	**1.06**

(- Indicates 0) (+ indicates 1-25) (++ indicates 26-50) (+++ indicates 51- 75)

The phytoplankton community observed across the eight sampling stations (S1–S8) comprised a total of 22 species, predominantly represented by diatoms. Commonly occurring taxa included Bacillaria sp., Coscinodiscus sp., Navicula sp., and Nitzschia sp., which are characteristic of productive coastal and nutrient-rich marine environments. Species richness varied from 3 to 10 species per station, with the highest richness recorded at S5 during Low Tide (LT) and the lowest at S3 during High Tide (HT) and S7 during Low Tide (LT). The Shannon–Wiener diversity index (H′) ranged from 0.80 to 1.82, indicating low to moderate phytoplankton diversity across the study area. Generally, higher diversity values were observed during high tide conditions, likely reflecting enhanced species mixing and dispersion resulting from tidal exchange. Overall, the phytoplankton assemblage exhibited moderate diversity and a clear influence of tidal dynamics on community structure, suggesting that hydrodynamic processes play an important role in shaping phytoplankton distribution within the study area.

The dominance of diatom species such as Bacillaria, Coscinodiscus, Navicula, and Nitzschia indicates favorable conditions for phytoplankton growth and reflects the typical ecological characteristics of coastal marine waters. The observed range of species richness (3–10 species) and Shannon–Wiener diversity index values (0.80–1.82) suggests a moderately diverse phytoplankton community with variable species composition among sampling stations. Higher diversity during high tide conditions highlights the influence of tidal mixing in promoting species dispersal and enhancing community evenness. Overall, the phytoplankton assemblage reflects a stable coastal ecosystem with moderate biological diversity and a strong tidal influence on community composition and distribution patterns.

Figure 8 - Phytoplankton

Zooplankton

Table 7 - Zooplankton

Sr. No.	Name of Species	S-1		S-2		S-3		S-4		S-5		S-6		S-7		S-8	
		HT	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**	**HT**	**LT**
1	*Euterpina* sp.	+	-	++	+	+	-	++	+	+	+	+	+	+	-	No data found	+
2	Larval euphasid	+	-	-	-	-	-	-	-	-	-	-	-	-	-		-
3	*Calanidae* sp.	+	+	++	+	+	+	++	+	+	+	+	+	+	++		+
4	*Centropagidae* sp.	+	-	+	-	-	+	-	-	-	-	-	-	+	+		-
5	*Corycaeus* sp.	+	++	+	++	+	+++	+	++	+	+	++	+	+	++		+
6	*Pontellidae* sp.	+	+	-	-	+	-	+	+	-	-	-	-	+	-		+
7	*Acartidae* sp.	+	-	+	+	+	+	++	+	+	+	+	+	+	+		+
8	Calanoida nauplis	+	-	-	-	-	-	-	+	-	-	-	-	-	-		-
9	Zoea larva	+	-	+	-	-	-	-	-	+	-	-	-	-	-		+
10	Mysid	+	-	+	-	-	-	-	-	+	-	-	-	-	-		+
11	Isopoda (Idotea)	-	+	-	-	-	-	-	-	-	-	-	-	-	-		-
12	Pseudodiaptomidae sp.	-	+	-	-	+	-	-	-	-	-	-	-	+	-		-
13	Oncaea sp.	-	+	+	+	-	-	-	+	-	-	-	-	-	-		-
14	Oithona sp.	-	+	-	-	-	-	-	-	-	-	+	-	-	-		-
15	Unidentified	-	-	+	-	-	+	-	-	-	-	-	-	-	-		-
16	Microstella nauplis	-	-	+	-	+	-	-	-	-	-	-	-	-	-		-
17	Forminifera sp.	-	-	-	+	+	-	-	-	-	-	-	-	-	-		-
18	Mitis sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-		-
19	Larval polecheate	-	-	-	-	-	-	-	-	-	+	-	-	-	-		-
20	Microstella sp.	-	-	-	-	-	-	-	-	+	-	+	+	-	-		-
21	Clausocalanidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+		-
22	Euclanidae sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+		-
23	Cyclopoida sp.	-	-	-	+	-	-	+	-	+	+	-	-	+	+		+

Species Diversity	**10**	**7**	**10**	**7**	**8**	**6**	**6**	**7**	**8**	**7**	**7**	**5**	**9**	**7**		**8**
SWDI	**2.10**	**1.30**	**1.74**	**1.56**	**1.96**	**1.43**	**1.52**	**1.77**	**1.89**	**1.49**	**1.50**	**1.58**	**2.06**	**1.81**		**1.81**

(- Indicates 0) (+ indicates 1-10) (++ indicates 11-20) (+++ indicates 21- 30)

The zooplankton community recorded across the eight sampling stations (S1–S8) comprised a total of 23 species and was predominantly represented by copepods. Frequently occurring taxa included Euterpina sp., Calanidae sp., Corycaeus sp., Acartiidae sp., and Cyclopoid copepods, which are characteristic of productive coastal and estuarine ecosystems. Species richness ranged from 5 to 10 species, with the highest richness observed at S1 (HT) and S2 (HT), while the lowest richness was recorded at S6 (LT). The Shannon–Wiener diversity index (H′) varied from 1.30 to 2.10, indicating moderate to high zooplankton diversity across the study area. Generally, diversity values were higher during high tide conditions, suggesting enhanced species evenness and distribution resulting from tidal mixing and seawater exchange. Overall, the zooplankton assemblage reflects a moderately to highly diverse coastal ecosystem, with tidal dynamics playing a significant role in shaping community structure and spatial distribution.

The dominance of copepod taxa, including Euterpina, Corycaeus, Acartiidae, Calanidae, and Cyclopoid forms, indicates favourable environmental conditions and adequate food availability within the study area. The observed species richness (5–10 species) and Shannon–Wiener diversity index values (1.30–2.10) demonstrate a relatively healthy and diverse zooplankton community. Higher diversity during high tide periods highlights the influence of tidal exchange in promoting species dispersal, reducing dominance by individual taxa, and enhancing community evenness. The overall distribution pattern suggests a productive coastal environment with moderate to high biological diversity and a strong tidal influence on zooplankton community composition and structure.

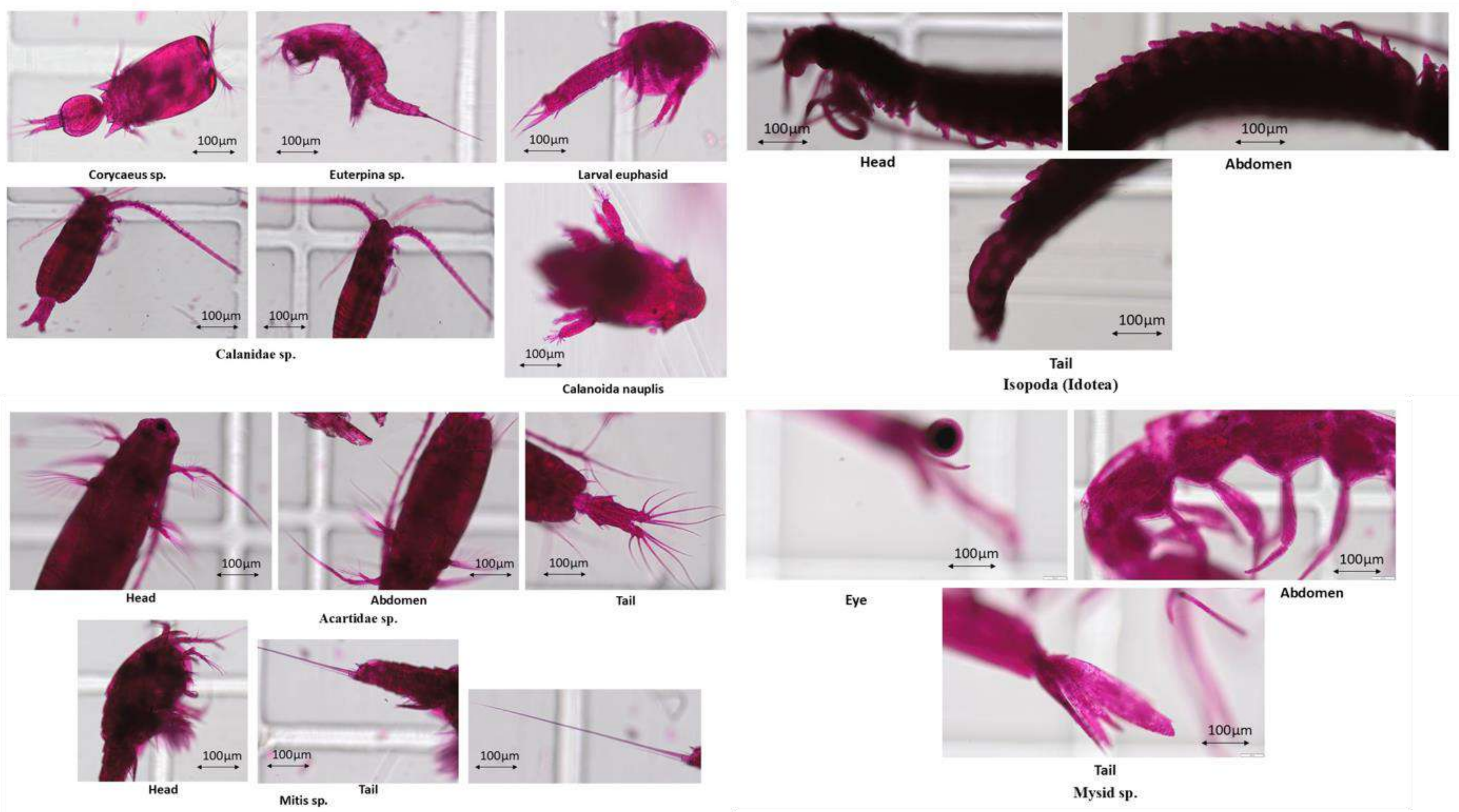


Figure 9 – Zooplankton 1

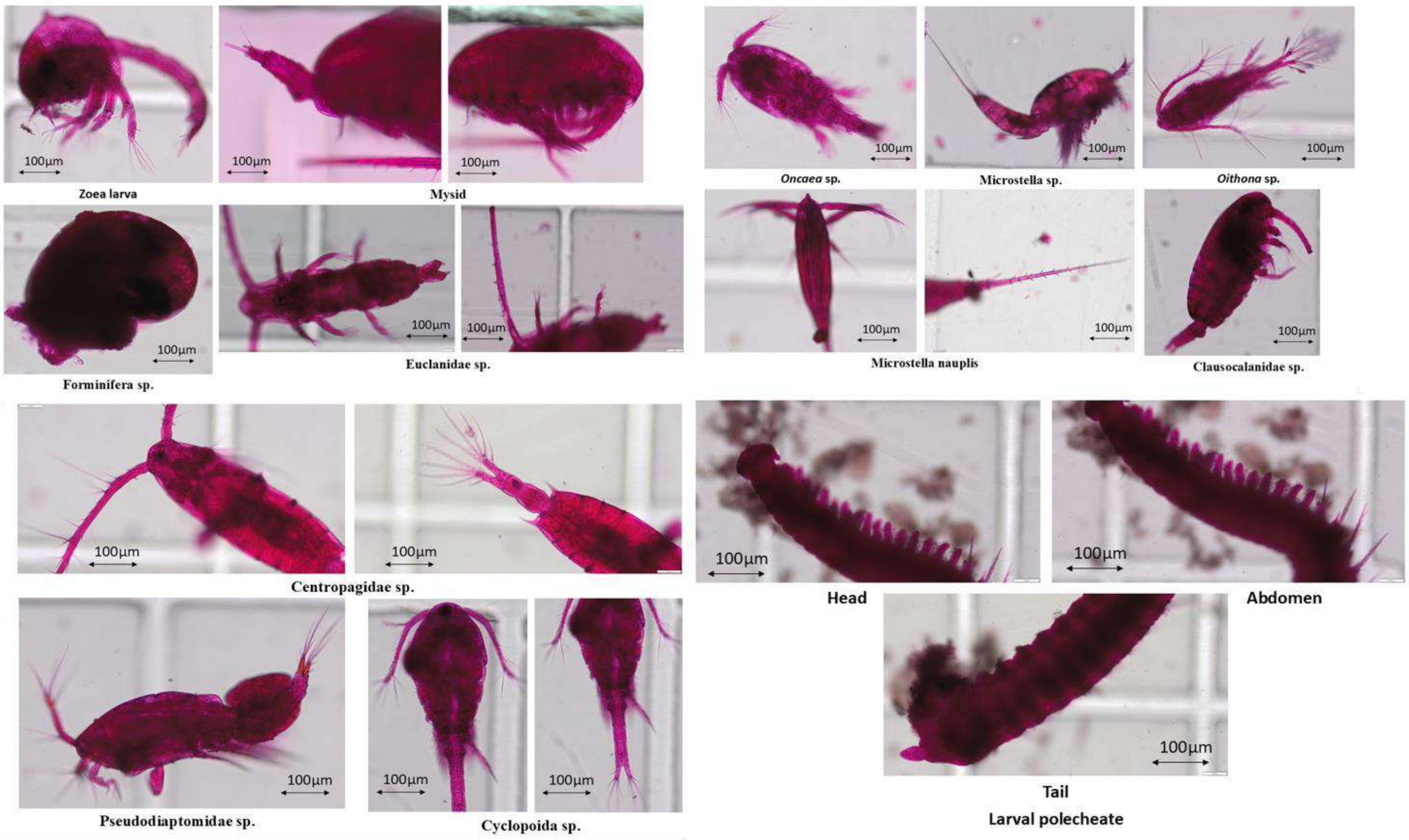


Figure 10 - Zooplankton 2

Microbiology Study

Table 8 - Water Microbiology

Sample Station	TCBS	Ma C.	Mac. S	Aeromonas A.	Pseudomonas A.	ZMA
S1	134 Y + 0 G = 134 (1.34 × 10^3)	NG	NG	0 Op. + 1 D.G = 1 (1.0 × 10^1)	NG	2720 (2.720 × 10^4)
S2	31 Y + 0 G = 31 (3.1 × 10^2)	NG	NG	NG	NG	3160 (3.160 × 10^4)
S3	170 Y + 0 G = 170 (1.70 × 10^3)	NG	NG	3 Op. + 0 D.G = 3 (3.0 × 10^1)	NG	4920 (4.920 × 10^4)
S4	TNTC.Y + 12 G = TNTC	NG	NG	29 Op. + 3 D.G = 32 (3.2 × 10^2)	30 (3.0 × 10^2)	2800 (2.800 × 10^4)
S5	NG	NG	NG	NG	NG	180 (1.80 × 10^3)
S6	1Y + 0 G = 1 (1.0 × 10^1)	NG	NG	NG	NG	290 (2.90 × 10^3)
S7	NG	NG	NG	NG	NG	160 (1.60 × 10^3)
S8	NG	NG	NG	NG	NG	240 (2.40× 10^3)

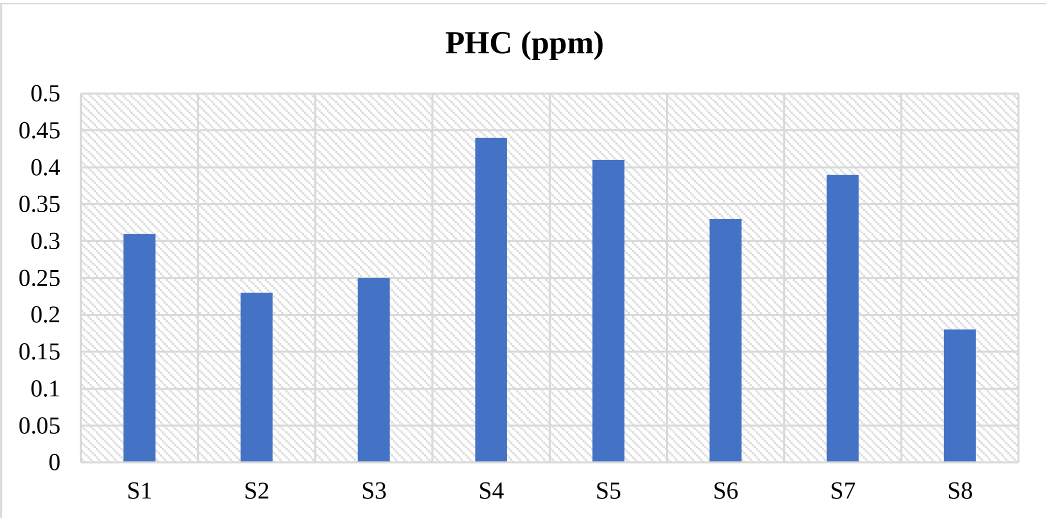
Media	Colony Description
TCBS	(Y) yellow: Vibrio cholerae, V. fluvialis; (G) green: V. parahaemolyticus, V. vulnificus
Ma C	(P/R) pink/red: Escherichia coli, Enterobacter aerogenes; (C/Y) colourless/yellow: Enterococcus fecalis, Klebsiella spp.;
Mac. S	(P) pink: Escherichia coli, Salmonella Typhi; (C/Y) colourless/yellow: Shigella flexneri
ZMA	Regular colonies: unknown; swarms(s): probably proteus spp. Total count is mentioned inclusive of regular colonies as well as swarms considered as single CFU
Aeromonas A.	Dark green/ opaque (DG): Aeromonas hydrophila
Pseudomonas A.	Pseudomonas spp.

Microbial load both in the non-selective and selective media do not have any tresses of sewage of other types of pollution. All the pathogenic bacteria isolated in the respective selective media were negligible. This report normal coastal microbial loads.

3. MARINE SEDIMENT PARAMETERS

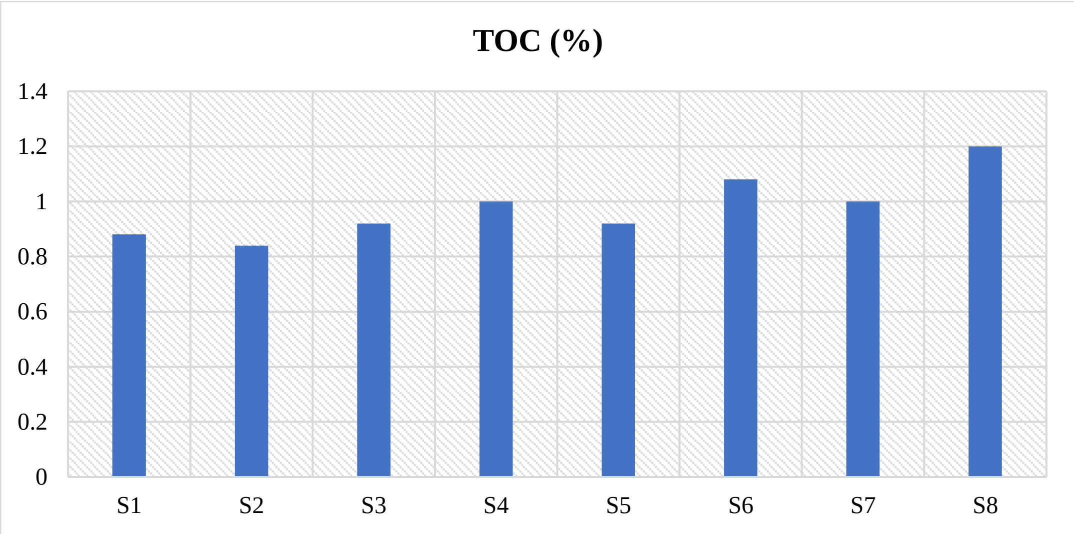
As repositories of Earth's geological and climatic history, habitats for benthic creatures, and stores of nutrients, carbon, and commercially valuable minerals, marine sediments are essential elements of the marine environment. They are essential for monitoring maritime pollution and environmental impact assessments since they also serve as markers of environmental contamination. Therefore, sustainable coastal management, the use of marine resources, biodiversity conservation, and the preservation of marine ecosystems all depend on an understanding of the physical, chemical, and biological properties of marine sediments.

❖ **Physicochemical Characteristics**



Graph 22 - PHC in Sediment

The spatial distribution of Petroleum Hydrocarbons (PHC) in marine sediments indicated generally low concentrations across the study area, with measured values ranging from 0.18 to 0.44 ppm. The relatively narrow concentration range and the absence of markedly elevated values suggest limited spatial variability in PHC levels among the sampling locations. Although slight enrichment was observed at a few stations, most sites exhibited comparable PHC concentrations, indicating that hydrocarbon accumulation in the sediments is generally low. The localized increases may be attributed to minor site-specific inputs or sediment depositional characteristics; however, there is no evidence of widespread petroleum hydrocarbon contamination. Overall, the observed PHC distribution reflects good sediment quality and suggests that the marine sediments are only minimally influenced by hydrocarbon pollution, representing acceptable environmental conditions within the study area.

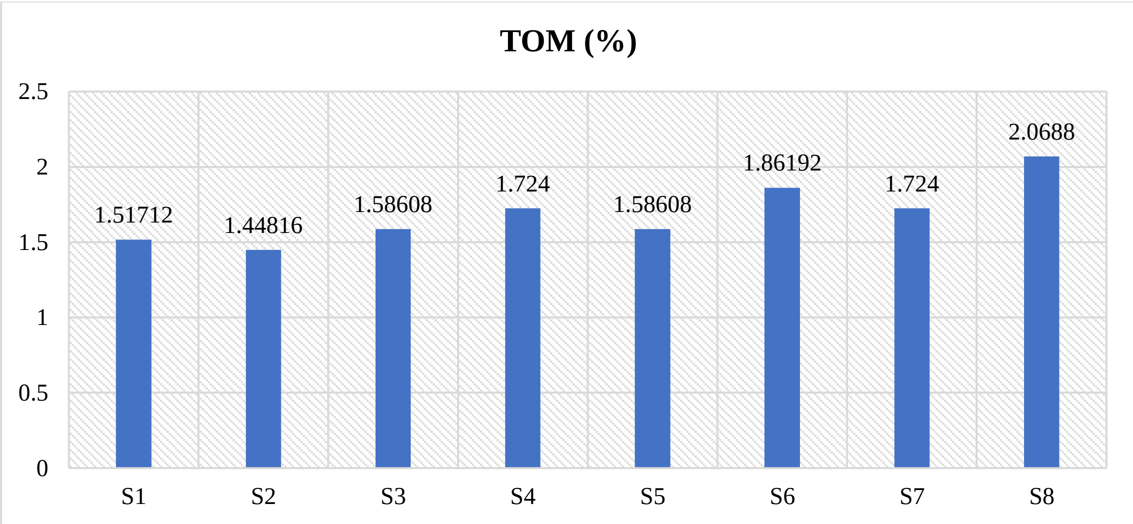


Graph 23 - TOC in Sediment

Total Organic Carbon (TOC) concentrations in the marine sediments ranged from 0.84% to 1.20%, indicating moderate organic matter content and generally productive environmental conditions across the study area. The spatial distribution revealed relatively higher TOC levels at stations S6, S7, and S8, suggesting localized enhancement of organic matter accumulation, potentially influenced by sediment texture, depositional characteristics, and biological productivity. Overall, the measured TOC levels indicate moderately organic-rich sediments that provide favourable conditions for nutrient recycling, microbial activity, and benthic ecosystem functioning.

A comparison of TOC and Petroleum Hydrocarbon (PHC) concentrations revealed that stations with relatively elevated TOC levels also tended to exhibit slightly higher PHC concentrations. This relationship suggests that organic-rich sediments may promote the adsorption and retention of hydrocarbons owing to the strong affinity of petroleum compounds for organic matter. However, despite this association, PHC concentrations throughout the study area remained low (0.18–0.44 ppm), indicating minimal hydrocarbon accumulation and limited anthropogenic influence.

Consequently, the observed TOC–PHC relationship primarily reflects the natural geochemical behaviour of sedimentary organic matter rather than significant hydrocarbon contamination. Overall, the combined TOC and PHC data indicate good sediment quality, with natural organic matter playing a dominant role in controlling sediment geochemistry and supporting benthic ecological processes within the study area.



Graph 24 - TOM in Sediment

The Total Organic Matter (TOM) content in marine sediments ranged from 1.45% to 2.07%, indicating moderately organic-rich sediments and generally productive environmental conditions across the study area. The observed TOM levels do not suggest excessive organic enrichment and are characteristic of healthy coastal marine ecosystems. Spatially, TOM exhibited moderate variability, with the highest value recorded at S8 (2.07%), followed by S6 (1.86%), while the lowest concentration was observed at S2 (1.45%). Elevated TOM levels at stations S6, S7, and S8 indicate enhanced organic matter accumulation, which may be associated with higher biological productivity, finer sediment texture, and/or inputs of terrestrial organic material. Overall, the TOM distribution suggests favourable sediment conditions that support nutrient cycling, microbial activity, and benthic ecosystem functioning. The moderate TOM concentrations further indicate a stable sedimentary environment with adequate organic matter availability to sustain biological processes without evidence of excessive organic loading.

❖ Marine Sediment Biological Characteristics

Microbiological Study

Table 9 - Microbiology in Sediment

Sample Station	TCBS	Ma C.	Mac. S	Aeromonas A.	Pseudomonas A.	ZMA
S1	NG	NG	NG	NG	NG	90 (9.0 × 10^2)
S2	1 Y + 0 G = 1 (1.0 × 10^1)	NG	NG	NG	NG	190 (1.90 × 10^3)
S3	0 Y + 1 G = 1 (1.0 × 10^1)	NG	NG	NG	NG	200 (2.00 × 10^3)
S4	5 Y + 1 G = 6 (6.0 × 10^1)	NG	NG	1 Op. + 0 D.G = 1 (1.0 × 10^1)	NG	260 (2.60 × 10^3)
S5	43 Y + 31 G = 74 (7.4 × 10^2)	NG	NG	6 Op. + 4 D.G = 10 (1.0 × 10^2)	NG	950 (9.50 × 10^3)
S6	NG	NG	NG	NG	NG	110 (1.10 × 10^3)
S7	NG	NG	NG	NG	NG	210 (2.10 × 10^3)
S8	NG	NG	NG	NG	NG	170 (1.70 × 10^3)

Media	Colony Description
TCBS	(Y) yellow: Vibrio cholerae, V. fluvialis; (G) green: V. parahaemolyticus, V. vulnificus
MaC	(P/R) pink/red: Escherichia coli, Enterobacter aerogenes; (C/Y) colourless/yellow: Enterococcus fecalis, Klebsiella spp.;
Mac. S	(P) pink: Escherichia coli, Salmonella Typhi; (C/Y) colourless/yellow: Shigella flexneri
ZMA	Regular colonies: unknown; swarms(s): probably proteus spp. Total count is mentioned inclusive of regular colonies as well as swarms considered as single CFU
Aeromonas A.	Dark green/ opaque (DG): Aeromonas hydrophila
Pseudomonas A.	Pseudomonas spp.

4. ECOLOGICAL ASSESSMENT

Methodology For Floral and Faunal Survey

Vegetation sampling

During 19–21 May 2026, an extensive field survey was carried out at the marine discharge site of Tata Chemicals, Mithapur, Gujarat, to document floral diversity in different habitat types using stratified random sampling. The vegetation was sampled, stratified randomly, by laying out 8 transects of 200 meters in 24 quadrats of 10 m x 10 m each. In each quadrat, all the trees (dbh > 1 cm) were identified, and their number and diameter at breast height (dbh) were recorded with the help of a slide caliper.

Where DBH measurement was not possible, girth at breast height (GBH) was measured using a meter tape. The shrubs, climbers, and tree saplings (< 1 cm dbh, height > 30 cm) were sampled in two 5 m x 5 m quadrats, and herbs, including tree seedlings (< 1 cm dbh, height < 30 cm), were sampled by laying four 1 m x 1 m quadrats nested within each 10 m x 10 m quadrat. Plant specimens were collected, and identification of the unknown species was done by consulting the regional flora of Gujarat.

For each tree individual, the species name, number of individuals, and girth at breast height (GBH) measured at 1.3 m above ground level were recorded. GBH values were converted to Diameter at Breast Height (DBH) using the formula DBH = GBH / π.

The number and size of quadrats were selected to adequately represent the vegetation of the study area.

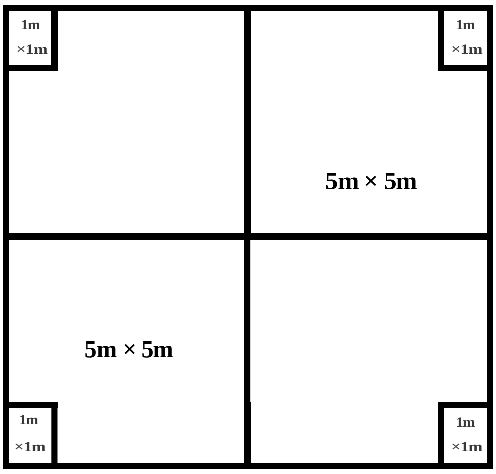


Figure 11 - The layout of the quadrat plot design (main plot and the attached subplots)

Source - Diagrammatical representation of quadrate design as per (Ganguli & Joshi, 2021)

Note:

- ❖ 10 m × 10 m plot: Trees
- ❖ 5 m × 5 m subplot: Tree regeneration, shrubs and climbers
- ❖ 1 m × 1 m subplot: Herbs

Sampling locations of Vegetation diversity

Table below gives the GPS coordinates of each quadrat of vegetation that was thought to have been recorded during the vegetation survey in Mithapur, Gujarat.

Table 10 - GPS coordinates of the quadrat sampled during the vegetation survey

Sr. No.	No. of Transect	No. of Quadrant	GPS Coordinates	
			N	E
1.	1	1.1	22.4097	69.10356
2.		1.2	22.40891	69.1041
3.	2	2.1	22.3942	69.09602
4.		2.2	22.39486	69.09566
5.		2.3	22.395	69.0954
6.		2.4	22.39572	69.09446
7.	3	3.1	22.38823	69.07802
8.		3.2	22.38855	69.0781
9.		3.3	22.38933	69.0783
10.	4	4.1	22.39256	69.06128
11.		4.2	22.39241	69.06347
12.		4.3	22.39252	69.06393
13.	5	5.1	22.40346	69.05905
14.		5.2	22.40358	69.05906
15.		5.3	22.40358	69.05901
16.	6	6.1	22.42579	69.04538
17.		6.2	22.42434	69.04638
18.		6.3	22.42382	69.04615
19.	7	7.1	22.43778	69.09083
20.		7.2	22.43755	69.0916
21.		7.3	22.43731	69.09262
22.	8	8.1	22.43128	69.09451
23.		8.2	22.43144	69.09381
24.		8.3	22.43164	69.09344

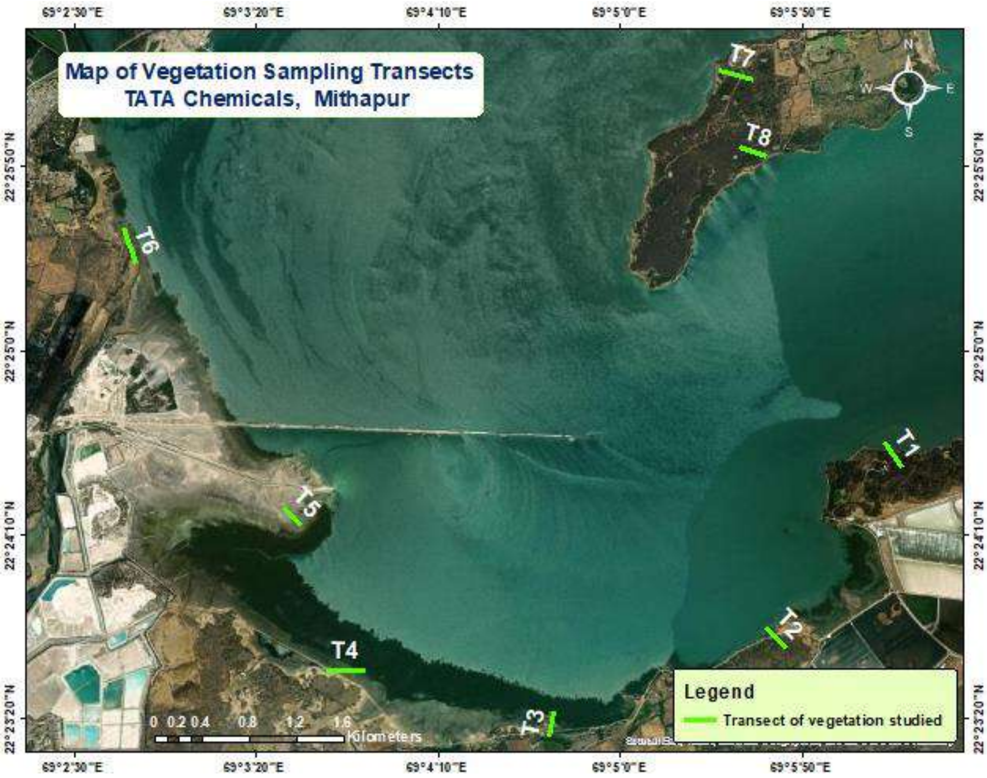


Figure 12 - Study Area Showing Vegetation Survey Sampling Sites in the Tata Chemicals Project, Mithapur

Avifaunal Sampling

Table 11 - Table of Avifaunal Sampling Locations at Mithapur

Stations	Latitude	Longitude
S1	22°24'14.4"N	69°03'30.3"E
S2	22°23'27.9"N	69°03'48.1"E
S3	22°23'16.5"N	69°04'42.7"E
S4	22°23'42.5"N	69°05'41.5"E
S5	22°24'32.9"N	69°06'10.9"E
S6	22°25'33.7"N	69°02'35.3"E
S7	22°25'52.3"N	69°05'41.6"E
S8	22°26'18.1"N	69°05'30.5"E

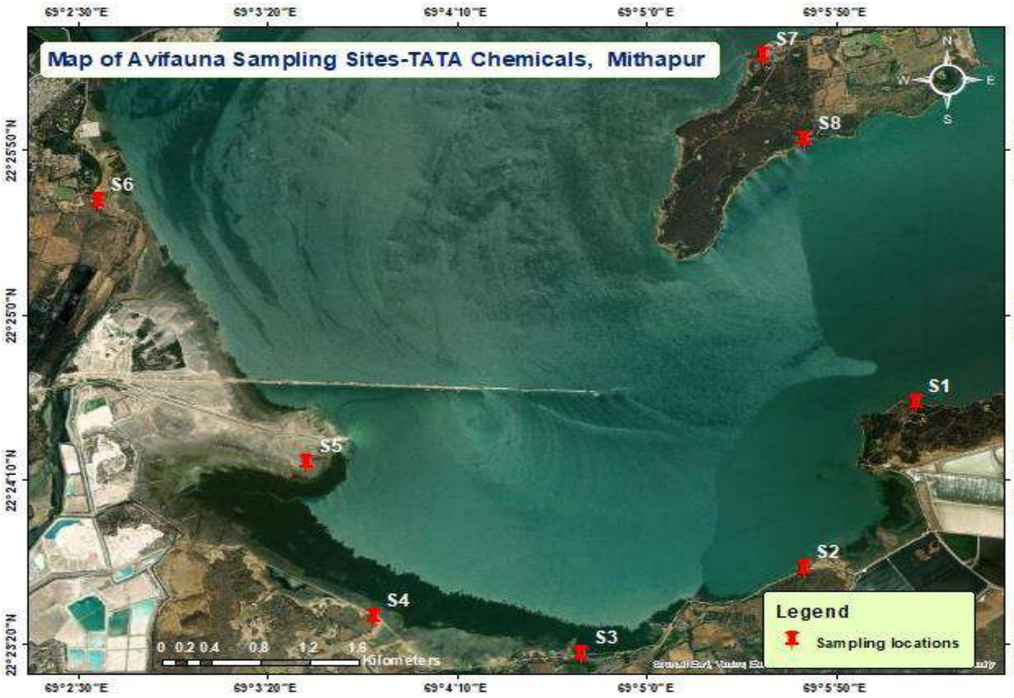


Figure 13 - Study Area Showing Avifaunal Sampling Sites in the TATA Chemicals Project, Mithapur

The diversity of the bird species was done using an integration of the line transect and point count methods in the coastal areas of Mithapur. Two kilometre long transects were considered at each sampling location to obtain the best representation of habitat variability. The fieldwork was done early in the morning from 06:00 to 09:00 A.M and in the evening from 4:00 to 7:00 P.M, the hours when most birds are active (de Deus et al., 2023). Four to five points counts were set up at equal distance on each transect to reduce overlapping detections. At each point count location, the observational study of bird species was done for ten minutes. This included all individuals seen or heard in that particular sampling location. Birds that were detected in the process of sampling through the transect lines were also noted.

The survey involved point count and transect walks across habitat types (shoreline and near Mangrove cover). Bird observations were done using field binoculars and confirmed using the field guide (Birds of Indian Subcontinent), Merlin Bird ID software was used for acoustic detections (WAYIRAWO, 2025).

Ecological Characteristics of study area

The analysis of floral and avifaunal diversity at eight sampling locations (S1-S8), it becomes evident that there is quite variation in the habitat composition at the Tata Chemicals study area that includes coastal mudflats, mangroves, salt marshes, scrublands, saline wastelands, and habitats associated with human activities. In vegetation sampling, 27 different plant species were found to occur, of which there were 10 tree species, 5 shrub/climber species, and 12 herbaceous species. There were 40 different species of birds with a total count of 637 individuals found in the avifaunal sampling.

Floral Assessment

From the vegetation survey, the data shows that *Neltuma juliflora* is the dominant tree species within the site, due to its invasive nature and adaptability. The *Avicennia marina* is predominantly found on the coast and in salty environments, suggesting that there are good mangroves patches that help in stabilizing the coastline and provide nursing habitats. There are moderate shrubs, *Ziziphus nummularia* and *Pentatropis capensis* being xerophytes. The herb layer comprises salty grasses such as *Aeluropus lagopoides*, Sporobolus spp., and *Tecticornia indica*. In general, the diversity values show good species diversity with a balanced community structure (Tree H' = 1.48; Herb H' = 1.66).

Diversity Indices

Tree Species Diversity

The tree community comprised 10 species and 594 individuals. The Shannon–Wiener Diversity Index (H′ = 1.48) and Simpson's Diversity Index (1 − D = 0.68) indicate moderate species diversity. The Effective Number of Species (ENS = 4.40) implies that the diversity is equivalent to about four species with the same abundance. Pielou’s Evenness Index (J′ = 0.64) indicates moderate evenness with a few tree species being dominant. The results are presented in Table.

Shrubs and Climbers Diversity

The shrub and climber community consisted of 5 species and 42 individuals. The diversity indices ($H' = 1.42$, $ENS = 4.12$, $J' = 0.87$, and $1 - D = 0.71$) suggested a moderate level of diversity with high species evenness. The high evenness value indicated that individuals were relatively evenly distributed among the recorded species, with limited dominance of any specific species. The results are presented in Table.

Herbaceous Species Diversity

The herbaceous layer was composed of 12 species and 376 individuals with moderate to high species diversity indices (H'=1.66, ENS=5.28, J'=0.67, and 1-D=0.74). The herbaceous community had a moderate evenness with a few dominant species and several less abundant species that contributed to the overall community diversity. The results are presented in Table.

Overall Interpretation

Species diversity of the vegetation community of the study area is moderate to high in all the vegetation layers. A few species are well represented in the tree layer, but the shrub, climber, and herb layers are relatively even and balanced in their species distribution. The recorded vegetation is ecologically important in terms of providing shelter, soil stabilization, nutrient recycling, and supporting local biodiversity. In the vegetation survey area, no serious problems were detected regarding the conservation of flora. Therefore, implementation of the proposed project with appropriate mitigation measures is unlikely to result in significant long-term impacts to the existing vegetation.

Table 12 - Vegetation Structure of Trees Species

Sr. No.	Name of Species	Family	Common Name	Site No.	No. of Ind. (ni)	Freq . (%)	Den. (Trees/h a)
1.	*Avicennia marina* (Forssk.) Vierh.	Acanthaceae	Cher	5.3, 4.2, 4.3, 3.2, 3.3, 2.4, 1.1, 6.1.	156	33.3	650.00
2.	*Azadirachta indica* A.Juss.	Meliaceae	Neem	6.2, 6.3.	7	8.33	29.17
3.	*Capparis decidua* (Forssk.) Edgew.	Capparaceae	Kedo	2.1, 6.2, 6.3, 7.2.	12	16.7	50.00
4.	*Commiphora wightii* (Arn.) Bhandari	Burseraceae	Gugal	1.2, 6.2, 6.3, 8.1,	37	29.2	154.17
				7.1, 7.2, 7.3.			
5.	*Euphorbia neriifolia* L.	Euphorbiace ae	Vad Thor	1.2, 6.2, 8.1, 8.2, 8.3, 7.1, 7.2.	65	29.2	270.83
6.	*Gymnosporia montana* (Roth) Benth.	Celastraceae	Vikaro	6.3, 6.3, 7.1, 7.3.	10	16.7	41.67
7.	*Limonia acidissima* L.	Rutaceae	Kotha	7.3.	1	4.17	4.17
8.	*Neltuma juliflora* (Sw.) Raf.	Fabaceae	Gando Baval	2.1, 2.2, 2.3, 1.2, 6.2, 6.3, 8.1, 8.2, 8.3, 7.1, 7.2, 7.3.	282	50.0	1175.00
9.	*Salvadora persica* L.	Salvadoracea e	Piludi	1.2, 7.1, 7.2.	6	12.5	25.00
10.	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.	Fabaceae	Deshi Baval	2.1, 1.2, 8.3, 7.1, 7.2, 7.3.	18	25.0	75.00
	Total				**594**	**225**	**2475**

Table 13 - Diversity Index Calculations

Sr. No.	Name of Species	No. of Ind. (ni)	Shannon-Weiner Diversity Index	Simpson's Species Diversity Index
			Pi ln (Pi)	Pi^2
1.	*Avicennia marina* (Forssk.) Vierh.	156	-0.35	0.07
2.	*Azadirachta indica* A.Juss.	7	-0.05	0.00
3.	*aris decidua* (Forssk.) Edgew.	12	-0.08	0.00
4.	*Commiphora wightii* (Arn.) Bhandari	37	-0.17	0.00
5.	*Euphorbia neriifolia* L.	65	-0.24	0.01
6.	*Gymnosporia montana* (Roth) Benth.	10	-0.07	0.00
7.	*Limonia acidissima* L.	1	-0.01	0.00
8.	*Neltuma juliflora* (Sw.) Raf.	282	-0.35	0.23
9.	*Salvadora persica* L.	6	-0.05	0.00
10.	*Vachellia nilotica* (L.) P.J.H.Hurter & Mabb.	18	-0.11	0.00
	Total	**594**	**-1.48**	**0.31**

Table 14 - Summary of Diversity Indices

Sr. No.	Parameter	Value
1.	Total number of species	10
2.	Total number of individuals	594
3.	Shannon–Wiener Index (H′)	1.48
4.	Effective number of species	4.40
5.	Pielou's Evenness Index (J′)	0.64
6.	Simpson's Diversity Index (1 − D)	0.68

Table 15 - Vegetation Structure of Shrubs and Climbers Species

Sr. No.	Name of Species	Family	Common Name	Site No.	No. of Ind. (ni)	Fre q. (%)	Den. (Tree s/ha)	Abund.	IVI
1.	*Cocculus hirsutus* (L.) W.Theob.	Menisper maceae	Vevati	2.2.1, 2.3.1.	4	4.17	0.02	2.00	39.81
2.	*Lantana camara* L.	Verbena ceae	Gandhari	8.3.1	3	2.08	0.01	3.00	34.72
3.	*Pentatropi s capensis* (L.f.) Bullock	Apocyna ceae	Salt Killer Vine	1.2.1, 1.2.2, 6.3.1, 7.1.1.	10	10.4 2	0.05	2.00	77.31
4.	*Senna auriculata* (L.) Roxb.	Fabaceae	Aval	7.1.1, 7.1.2.	7	4.17	0.02	3.50	50.93

Sr. No.	Name of Species	Family	Common Name	Site No.	No. of Ind. (ni)	Freq. (%)	Den. (Trees/ha)	Abund.	IVI
5.	*Ziziphus nummulari a* (Burm.f.) Wight & Arn.	Rhamnac eae	Chani Bor	6.2.1, 6.2.2, 6.3.1, 6.3.2, 7.3.1, 7.3.2.	18	12.50	0.06	3.00	97.22
	Total				**42**	**33.3**	**0.17**	**13.5**	**300**

Table 16 - Diversity Index Calculations

Sr. No.	Name of Species	No. of Ind. (ni)	Shannon-Weiner Diversity Index	Simpson's Species Diversity Index
			Pi ln (Pi)	**Pi^2**
1	*Cocculus hirsutus* (L.) W.Theob.	4	-0.22	0.0091
2	*Lantana camara* L.	3	-0.19	0.0051
3	*Pentatropis capensis* (L.f.) Bullock	10	-0.34	0.0567
4	*Senna auriculata* (L.) Roxb.	7	-0.30	0.0278
5	*Ziziphus nummularia* (Burm.f.) Wight & Arn.	18	-0.36	0.1837
	Total	**42**	**-1.42**	**0.2823**

Table 17 - Summary of Diversity Indices

Sr. No.	Parameter	Value
1.	Total number of species	5
2.	Total number of individuals	42
3.	Shannon–Wiener Index (H′)	1.42
4.	Effective number of species (ENS) =EXP (H')	4.12
5.	Pielou's Evenness Index (J′)	0.87
6.	Simpson's Diversity Index (1 − D)	0.71

Table 18 - Vegetation Structure of Herbs Species

Sr. No.	Name of Species	Family	Common Name	Site No.	No. of Ind. (ni)	Freq. (%)	Den. (Trees/ha)	Abund.	IVI
1	*Aeluropus lagopoides* (L.) Thwaites	Poaceae	Khariyu ghas	2.2.3, 2.2.4, 2.3.1, 2.3.3, 2.3.4, 6.3.4.	146	6.25	0.0025	24.33	56.26
2	*Barleria prionitis* L.	Acanthaceae	Vajradanti	7.1.1, 7.2.3, 7.2.4, 7.3.3, 7.3.4.	10	5.21	0.0021	2.00	24.65
3	*Blepharis sp.*	Acanthaceae	-	2.1.1, 2.2.2, 6.2.2, 6.3.1, 6.3.2, 6.3.3, 6.3.4.	27	7.29	0.0029	3.86	35.80
4	*Cynodon dactylon* (L.) Pers.	Poaceae	Dharo	3.1.1.	18	1.04	0.0004	18.00	26.34

Sr. No.	Name of Species	Family	Common Name	Site No.	No. of Ind. (ni)	Freq. (%)	Den. (Trees/ha)	Abund.	IVI
5	*Desmostachya bipinnata* (L.) Stapf	Poaceae	Dabhado	6.2.1, 6.2.2, 6.2.3, 6.2.4.	11	4.17	0.0017	2.75	21.12
6	*Senna tora* (L.) Roxb.	Fabaceae	Kuvadio	2.1.1, 2.1.2, 2.1.3, 2.1.4.	17	4.17	0.0017	4.25	22.95
7	*Sporobolus sp.*	Poaceae	-	3.1.1, 2.3.1, 2.3.4, 1.2.1, 1.2.2, 1.2.3, 1.2.4.	111	7.29	0.0029	15.86	50.40
8	*Suaeda maritima* (L.) Dumort.	Amaranthaceae	Luno	5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.2.1, 5.2.2.	1	1.04	0.0004	1.00	5.66

Sr. No.	Name of Species	Family	Common Name	Site No.	No. of Ind. (ni)	Freq. (%)	Den. (Trees/ha)	Abund.	IVI
9	*Tecticornia indica* (Willd.) K.A.Sheph.	Amaranthaceae	Bholado	6.3.1.	28	6.25	0.0025	4.67	32.34
	& Paul G.Wilson								
10	*Trichodesma indicum* (L.) Sm.	Boraginaceae	Undhanphuli	6.3.1.	1	1.04	0.0004	1.00	5.66
11	*Tridax procumbens* L.	Asteraceae	Pardesi Bhangaro	6.3.1.	3	1.04	0.0004	3.00	8.09
12	*Triumfetta rotundifolia* Lam.	Malvaceae	Zipti	2.1.3, 7.2.4.	3	2.08	0.0008	1.50	10.71
	Total				**376**	**46.88**	**0.01875**	**82.21**	**300**

Table 19 - Diversity Index Calculations

Sr. No.	Name of Species	No. of Ind. (ni)	Shannon-Weiner Diversity Index	Simpson's Species Diversity Index
			Pi ln (Pi)	**Pi^2**
1	*Aeluropus lagopoides* (L.) Thwaites	146	-0.36732	0.150775
2	*Barleria prionitis* L.	10	-0.09646	0.000707
3	*Blepharis sp.*	27	-0.18913	0.005156
4	*Cynodon dactylon* (L.) Pers.	18	-0.14549	0.002292

Sr. No.	Name of Species	No. of Ind. (ni)	Shannon-Weiner Diversity Index	Simpson's Species Diversity Index
			Pi ln (Pi)	**Pi^2**
5	*Desmostachya bipinnata* (L.) Stapf	11	-0.10332	0.000856
6	*Senna tora* (L.) Roxb.	17	-0.14	0.002044
7	*Sporobolus sp.*	111	-0.36018	0.087151
8	*Suaeda maritima* (L.) Dumort.	1	-0.01577	7.07E-06
9	*Tecticornia indica* (Willd.) K.A.Sheph. & Paul G.Wilson	28	-0.19342	0.005545
10	*Trichodesma indicum* (L.) Sm.	1	-0.01577	7.07E-06
11	*Tridax procumbens* L.	3	-0.03855	6.37E-05
12	*Triumfetta rotundifolia* Lam.	3	-0.03855	6.37E-05
	Total	**376**	**-1.66541**	**0.254668**

Table 20 - Summary of Diversity Indices

Sr. No.	Parameter	Value
1.	Total number of species	12
2.	Total number of individuals	376
3.	Shannon–Wiener Index (H′)	1.66
4.	Effective number of species	5.28
5.	Pielou's Evenness Index (J′)	0.67
6.	Simpson's Diversity Index (1 − D)	0.74

Figure 14 - a) Avicennia marina;(b) and (c) Commiphora wightii;(d) Ipomoea sp. (e) Tecticornia indica; (f) Quadrate

Dominant plant species

Based on observations during the survey of Wildlife conservation plan expert found that Avicenna marina, *Prosopis juliflora*, *Acasia nilotica* in trees, *Zizyphus numularia* and *Euphorbia neriifolia* in shrubs and *Sporolobus maderaspatensiss* & *Apluda mutica* in grasses and *Urochloa reptans* and *Metanuse marginatus* in herbs are the most dominant species in the region.

Avifaunal Assessment

This bird community included 40 species totalling 637 birds which occupied wetlands, shores, grasslands, scrublands, and urban areas. Diversity in species richness was high among the various sites visited. This is because of the presence of diverse habitats in the area. The largest number of birds (315) was observed at site S5 due to the presence of Greater Flamingos. Site S4 had the highest number of migratory shorebirds. Common Tailorbird was the most common resident bird that was found in six sites. Wetlands were home to specialist birds like Eurasian Curlew, Great Thick-knee, Little Tern, and Common Sandpiper.

Migratory Bird Species Recorded

The study confirmed the occurrence of several migratory species, emphasizing the ecological importance of the Mithapur coastal ecosystem along the Central Asian Flyway.

Migratory Species	**Scientific Name**	**Migration Status in India**	**Primary Breeding Range**	**Ecological Significance**	**Site(s) Recorded**
Greater Flamingo	*Phoenicopterus roseus*	Winter Migrant	Southern Europe, Central Asia, West Asia	Forms large wintering flocks in saline wetlands and mudflats; filter feeder indicating productive coastal ecosystems.	S5
Eurasian Curlew	*Numenius arquata*	Winter Migrant	Northern Europe and Siberia	Long-distance migratory shorebird dependent on intertidal mudflats for feeding on benthic invertebrates.	S2, S6
Common Sandpiper	*Actitis hypoleucos*	Winter Migrant / Passage Migrant	Europe and Northern Asia	Utilizes tidal flats and coastal wetlands during migration and wintering periods.	S4
Little Tern	*Sternula albifrons*	Seasonal Migrant (Local and Winter Visitor)	Northern Eurasia and parts of Central Asia	Coastal piscivorous bird utilizing sandy beaches, mudflats and estuarine habitats.	S4, S5, S8
Red-necked Phalarope	*Phalaropus lobatus*	Passage and Winter Migrant	Arctic regions of Europe, Asia and North America	Pelagic migratory shorebird using coastal waters during migration.	S1
Barn Swallow	*Hirundo rustica*	Winter Migrant	Europe, Central Asia and Siberia	Aerial insectivore arriving in India during winter months.	S1, S3, S6
Tibetan Plover	*Anarhynchus atrifrons*	Winter Migrant	Tibetan Plateau and Central Asia	Coastal shorebird utilizing mudflats and sandy beaches during the non-breeding season.	S4

Note - (Birds of the World. Cornell Lab of Ornithology; Birds of the World. Cornell Lab of Ornithology; IUCN Red List of Threatened Species. (2025))

Osprey (Intermediate area of sites) (19/05/26)

White-eared Bulbul (21/05/26)

Brown Crake (19/05/26)

Painted Stork (20/05/26)

Yellow-backed Oriole (20/05/26)

Indian Silverbill (21/05/26)

Figure 15 -(a) Red-necked Phalarope; (b) Greater Flamingo; (c) Tibetan Plover; (d) Eurasian Curlew

Avifaunal structure of respective sites

Table 21 - Avifauna

Date	Time	Site	Tidal Condition	Name of species	Scientific Name	No. of Individuals	IUCN Category	Relative Abundance (%)	SWDI	Feeding Preference	Major Food Selection
20/05/26	**7:47 AM**	**S1**	**Low Tide**	Great Thick-knee	*Esacus recurvirostris*	1	NT	3.85	0.13	Carnivore	Crabs, insects, molluscs
				Black-winged Stilt	*Himantopus himantopus*	2	LC	7.69	0.20	Carnivore	Aquatic insects, crustaceans
				Red-wattled Lapwing	*Vanellus indicus*	1	LC	3.85	0.13	Insectivore	Beetles, termites, worms
				Black Drongo	*Dicrurus macrocercus*	5	LC	19.23	0.32	Insectivore	Flying insects, beetles
				Red-necked Phalarope	*Phalaropus lobatus*	6	LC	23.08	0.34	Omnivore	Plankton, aquatic insects, crustaceans
				Common Tailorbird	*Orthotomus sutorius*	6	LC	23.08	0.34	Insectivore	Caterpillars, spiders, insects
				Barn Swallow	*Hirundo rustica*	5	LC	19.23	0.32	Insectivore	Flying insects
						26			**1.76**		
20/05/26	**6:00 AM**	**S2**	**Ebb Tide**	House Sparrow	*Passer domesticus*	3	LC	7.5	0.19	Granivore	Seeds, grains; insects during breeding
				Black Drongo	*Dicrurus macrocercus*	6	LC	15	0.28	Insectivore	Flying insects, beetles

Date	Time	Site	Tidal Condition	Name of species	Scientific Name	No. of Individuals	IUCN Category	Relative Abundance (%)	SWDI	Feeding Preference	Major Food Selection
				Black-headed Ibis	*Threskiornis melanocephalus*	4	LC	10	0.23	Carnivore	Fish, frogs, insects, molluscs
				Indian Robin	*Copsychus fulicatus*	2	LC	5	0.15	Insectivore	Beetles, ants, caterpillars, termites
				Greater Coucal	*Centropus sinensis*	3	LC	7.5	0.19	Carnivore	Insects, reptiles, eggs, snails
				Common Tailorbird	*Orthotomus sutorius*	4	LC	10	0.23	Insectivore	Caterpillars, spiders, insects
				White-eared Bulbul	*Pycnonotus leucotis*	5	LC	12.5	0.26	Omnivore	Fruits, berries, insects, nectar
				Red-wattled Lapwing	*Vanellus indicus*	4	LC	10	0.23	Insectivore	Beetles, termites, worms
				Jungle Babbler	*Argya striata*	7	LC	17.5	0.31	Omnivore	Insects, berries, grains
				Eurasian Curlew	*Numenius arquata*	2	NT	5	0.15	Carnivore	Crabs, worms, molluscs
						40			**2.23**		
19/05/26	**7:06 PM**	**S3**	**Ebb Tide**	Barn Swallow	*Hirundo rustica*	3	LC	5.36	0.16	Insectivore	Flying insects
				Common Tailorbird	*Orthotomus sutorius*	2	LC	3.57	0.12	Insectivore	Caterpillars, spiders, insects
				Ashy Prinia	*Prinia socialis*	3	LC	5.36	0.16	Insectivore	Small insects, caterpillars

Date	Time	Site	Tidal Condition	Name of species	Scientific Name	No. of Individuals	IUCN Category	Relative Abundance (%)	SWDI	Feeding Preference	Major Food Selection
				Black-headed Ibis	*Threskiornis melanocephalus*	2	LC	3.57	0.12	Carnivore	Fish, frogs, insects, molluscs
				Little Cormorant	*Microcarbo niger*	3	LC	5.36	0.16	Piscivore	Fish
				Crested lark	*Galerida cristata*	20	LC	35.71	0.37	Insectivore–Granivore	Insects, grass seeds, grains
				Asian Green Bee-eater	*Merops orientalis*	2	LC	3.57	0.12	Insectivore	Flying insects, bees, dragonflies
				Paddyfield Pipit	*Anthus rufulus*	3	LC	5.36	0.16	Insectivore	Grass insects, beetles
				Yellow-backed Oriole	*Icterus chrysater*	15	LC	26.79	0.35	Omnivore	Fruits, nectar, insects
				White-eared Bulbul	*Pycnonotus leucotis*	3	LC	5.36	0.16	Omnivore	Fruits, berries, insects, nectar
						56			**1.86**		
19/05/26	**5:30 PM**	**S4**	**Ebb Tide**	Tibetan plover	*Anarhynchus atrifrons*	37	LC	49.33	0.35	Insectivore	Aquatic insects, worms, crustaceans
				Indian Robin	*Copsychus fulicatus*	3	LC	4.00	0.13	Insectivore	Beetles, ants, caterpillars, termites
				Gray Francolin	*Ortygornis pondicerianus*	4	LC	5.33	0.16	Omnivore	Seeds, grains, insects, shoots
				Common babbler	*Argya caudata*	4	LC	5.33	0.16	Insectivore	Insects, larvae, spiders

Date	Time	Site	Tidal Condition	Name of species	Scientific Name	No. of Individuals	IUCN Category	Relative Abundance (%)	SWDI	Feeding Preference	Major Food Selection
				Brahminy starling	*Sturnia pagodarum*	3	LC	4.00	0.13	Omnivore	Fruits, nectar, insects
				Asian Green Bee-eater	*Merops orientalis*	2	LC	2.67	0.10	Insectivore	Flying insects, bees, dragonflies
				Little Tern	*Sternula albifrons*	4	LC	5.33	0.16	Piscivore	Small fishes, aquatic invertebrates
				Common Sandpiper	*Actitis hypoleucos*	10	LC	13.33	0.27	Carnivore	Aquatic insects, worms, molluscs
				Yellow-wattled Lapwing	*Vanellus malabaricus*	6	LC	8.00	0.20	Insectivore	Beetles, termites, grasshoppers
				Painted Stork	*Mycteria leucocephala*	1	LC	1.33	0.06	Piscivore/Carnivore	Fish, frogs, molluscs
				Brown Crake	*Zapornia akool*	1	LC	1.33	0.06	Omnivore	Aquatic insects, seeds, molluscs
						75			**1.76**		
19/05/26	**9:30 AM**	**S5**	**Flood Tide**	Crested lark	*Galerida cristata*	37	LC	11.75	0.25	Insectivore–Granivore	Insects, grass seeds, grains
				Delicate prinia	*Prinia lepida*	22	LC	6.98	0.19	Insectivore	Small insects, spiders, larvae
				Little egret	*Egretta garzetta*	4	LC	1.27	0.06	Piscivore/Carnivore	Fish, crustaceans, frogs, aquatic insects

Date	Time	Site	Tidal Condition	Name of species	Scientific Name	No. of Individuals	IUCN Category	Relative Abundance (%)	SWDI	Feeding Preference	Major Food Selection
				Little Tern	*Sternula albifrons*	2	LC	0.63	0.03	Piscivore	Small fishes, aquatic invertebrates
				Greater Flamingo	*Phoenicopterus roseus*	250	LC	79.37	0.18	Filter feeder	Algae, diatoms, crustaceans, molluscs
						315			**0.71**		
20/05/26	**4:30 PM**	**S6**	**High Tide**	White-throated Kingfisher	*Halcyon smyrnensis*	2	LC	5.26	0.15	Carnivore	Fish, frogs, insects, lizards
				Rufous-fronted Prinia	*Prinia buchanani*	8	LC	21.05	0.33	Insectivore	Small insects, spiders
				Red-wattled Lapwing	*Vanellus indicus*	3	LC	7.89	0.20	Insectivore	Beetles, termites, worms
				Yellow-wattled Lapwing	*Vanellus malabaricus*	3	LC	7.89	0.20	Insectivore	Beetles, termites, grasshoppers
				Eurasian Curlew	*Numenius arquata*	3	NT	7.89	0.20	Carnivore	Crabs, worms, molluscs
				Little egret	*Egretta garzetta*	5	LC	13.16	0.27	Piscivore/Carnivore	Fish, crustaceans, frogs, aquatic insects
				Common Tailorbird	*Orthotomus sutorius*	3	LC	7.89	0.20	Insectivore	Caterpillars, spiders, insects
				Indian Silverbill	*Euodice malabarica*	4	LC	10.53	0.24	Granivore	Grass seeds, cereal grains

Date	Time	Site	Tidal Condition	Name of species	Scientific Name	No. of Individuals	IUCN Category	Relative Abundance (%)	SWDI	Feeding Preference	Major Food Selection
				Indian Robin	*Copsychus fulicatus*	4	LC	10.53	0.24	Insectivore	Beetles, ants, caterpillars, termites
				Barn Swallow	*Hirundo rustica*	3	LC	7.89	0.20	Insectivore	Flying insects
						38			**2.23**		
21/05/26	**7:50 AM**	**S7**	**Ebb Tide**	Indian Robin	*Copsychus fulicatus*	2	LC	3.13	0.11	Insectivore	Beetles, ants, caterpillars, termites
				Great Thick-knee	*Esacus recurvirostris*	2	NT	3.13	0.11	Carnivore	Crabs, insects, molluscs
				Laughing Dove	*Spilopelia senegalensis*	4	LC	6.25	0.17	Granivore	Seeds, grains, small shoots
				Grey Heron	*Ardea cinerea*	2	LC	3.13	0.11	Piscivore/Carnivore	Fish, amphibians, crustaceans
				Asian Green Bee-eater	*Merops orientalis*	4	LC	6.25	0.17	Insectivore	Flying insects, bees, dragonflies
				Common Myna	*Acridotheres tristis*	5	LC	7.81	0.20	Omnivore	Fruits, insects, grains, food scraps
				Common Tailorbird	*Orthotomus sutorius*	4	LC	6.25	0.17	Insectivore	Caterpillars, spiders, insects
				Gray Francolin	*Ortygornis pondicerianus*	1	LC	1.56	0.06	Omnivore	Seeds, grains, insects, shoots
				Black Drongo	*Dicrurus macrocercus*	6	LC	9.38	0.22	Insectivore	Flying insects, beetles

Date	Time	Site	Tidal Condition	Name of species	Scientific Name	No. of Individuals	IUCN Category	Relative Abundance (%)	SWDI	Feeding Preference	Major Food Selection
				White-eared Bulbul	*Pycnonotus leucotis*	27	LC	42.19	0.36	Omnivore	Fruits, berries, insects, nectar
				Indian Silverbill	*Euodice malabarica*	4	LC	6.25	0.17	Granivore	Grass seeds, cereal grains
				House Sparrow	*Passer domesticus*	3	LC	4.69	0.14	Granivore	Seeds, grains; insects during breeding
						64			**2.01**		
21/05/26	**6:30 AM**	**S8**	**Ebb Tide**	Common Tailorbird	*Orthotomus sutorius*	4	LC	17.39	0.30	Insectivore	Caterpillars, spiders, insects
				Little Cormorant	*Microcarbo niger*	1	LC	4.35	0.14	Piscivore	Fish
				Red-wattled Lapwing	*Vanellus indicus*	2	LC	8.70	0.21	Insectivore	Beetles, termites, worms
				Grey Heron	*Ardea cinerea*	1	LC	4.35	0.14	Piscivore/Carnivore	Fish, amphibians, crustaceans
				Little Tern	*Sternula albifrons*	2	LC	8.70	0.21	Piscivore	Small fishes, aquatic invertebrates
				House Crow	*Corvus splendens*	5	LC	21.74	0.33	Omnivore	Carrion, insects, fruits, food waste
				Rock Pigeon	*Columba livia*	5	LC	21.74	0.33	Granivore	Seeds, grains
				Gray Francolin	*Ortygornis pondicerianus*	3	LC	13.04	0.27	Omnivore	Seeds, grains, insects, shoots
						23			**1.93**		

The avifaunal survey conducted across the eight sampling stations (S1–S8) demonstrates that the coastal ecosystem surrounding the long-term disposal area continues to support a rich and ecologically significant bird community. A total of 637 individual birds representing 40 species were recorded, indicating moderate to high biodiversity and highlighting the ecological importance of the study area. The observed Shannon–Wiener Diversity Index (H′) values ranging from 0.71 to 2.23, together with species richness of up to 11 species at individual stations, reflect the availability of diverse habitats capable of supporting a wide range of avian feeding guilds and ecological niches.

The presence of heterogeneous habitats, including coastal mudflats, intertidal zones, shallow waters, and wetland-associated environments, has contributed to sustaining a diverse assemblage of resident and migratory bird species. The occurrence of migratory species such as Greater Flamingo (Phoenicopterus roseus), Eurasian Curlew (Numenius arquata), Common Sandpiper (Actitis hypoleucos), Tibetan Plover (Anarhynchus atrifrons), Red-necked Phalarope (Phalaropus lobatus), Little Tern (Sternula albifrons), and Barn Swallow (Hirundo rustica) further emphasizes the ecological significance of the Mithapur coastal area as an important habitat within the Central Asian Flyway (CAF).

Notably, Station S5, located in the vicinity of the long-term disposal area, recorded the highest bird abundance (315 individuals), predominantly due to the occurrence of Greater Flamingos. Although species diversity at this location was comparatively lower because of the dominance of a single species, the exceptionally high abundance of flamingos indicates that the habitat continues to provide suitable feeding and resting conditions.

Importantly, no discernible reduction in avifaunal diversity, species richness, or habitat utilization was observed at locations adjacent to the disposal area. The continued occurrence of both resident and migratory species, coupled with the overall moderate to high biodiversity recorded during the study, suggests that the long-term disposal activities have not resulted in any measurable adverse impact on the avifaunal community or the ecological integrity of the surrounding coastal habitats.

Overall, the findings indicate that the long-term disposal area is situated within a biologically productive and environmentally healthy coastal ecosystem that continues to support rich biodiversity and important ecological functions. The study area remains an important habitat for both resident and migratory bird populations, demonstrating ecological resilience and conservation value.

Osprey (Intermediate area of sites) (19/05/26)

White-eared Bulbul (21/05/26)

Brown Crake (19/05/26)

Painted Stork (20/05/26)

Yellow-backed Oriole (20/05/26)

Indian Silverbill (21/05/26)

Figure 16 - Avifauna 1

Grey Heron (21/05/26)

Great Thick-knee (19/05/26)

Crested lark (19/05/26)

Gray Francolin (21/05/26)

Ground nesting of Yellow wattled lapwing (19/05/26)

Sea anemone at Mithapur (19/05/26)

Figure 17 - Avifauna 2

Correlative Ecological Characteristics and Significance of each sampling station

Site	Floral Characteristics	Avifaunal Characteristics	Ecological Interpretation
S1	Sparse coastal vegetation with *Avicennia marina* and scattered *Neltuma juliflora*. Presence of halophytic herbs adapted to saline conditions.	Shorebird assemblage including Great Thick-knee, Black-winged Stilt, Red-necked Phalarope and Barn Swallow.	Intertidal feeding habitat supporting migratory waders during tidal exposure with moderate vegetation cover.
S2	Dominated by *Neltuma juliflora* with patches of *Avicennia marina* and halophytic grasses.	Mixed terrestrial and wetland bird community comprising House Sparrow, Black-headed Ibis, Eurasian Curlew and Jungle Babbler.	Transitional habitat connecting scrub vegetation with coastal wetlands, supporting both resident and migratory species.
S3	Coastal scrub vegetation interspersed with mangrove patches. Moderate herbaceous diversity.	Dominance of Crested Lark, Yellow-backed Oriole, Little Cormorant and Black-headed Ibis.	Represents an ecotonal habitat between terrestrial scrubland and coastal ecosystem supporting diverse feeding guilds.
S4	Coastal vegetation associated with mangrove patches and saline herbs.	Tibetan Plover dominated assemblage with Little Tern, Common Sandpiper, Painted Stork and Brown Crake.	Highly productive intertidal habitat supporting migratory shorebirds and piscivorous species.
S5	Herbaceous vegetation characterized by salt-tolerant species (*Suaeda maritima*) with comparatively sparse woody vegetation.	Highest abundance recorded due to Greater Flamingo (250 individuals), along with Crested Lark, Delicate Prinia, Little Egret and Little Tern.	Ecologically important mudflat and saline wetland despite its proximity to the disposal point, indicating continued habitat suitability for migratory waterbirds.
S6	Mixed scrub vegetation dominated by *Neltuma juliflora*, *Ziziphus nummularia* and drought-tolerant shrubs.	Eurasian Curlew, Yellow-wattled Lapwing, Little Egret and White-throated Kingfisher.	Natural scrub habitat supporting insectivorous and wetland-associated birds.
S7	Highest woody vegetation density with *Neltuma juliflora*, *Vachellia nilotica* and *Commiphora wightii*.	White-eared Bulbul dominant with Great Thick-knee, Grey Heron and Black Drongo.	Structurally complex habitat supporting woodland and scrub bird communities.
S8	Mixed scrub vegetation with *Euphorbia neriifolia* and *Commiphora wightii*.	Common Tailorbird, Little Tern, Grey Heron, House Crow and Rock Pigeon.	Habitat influenced by both natural vegetation and anthropogenic activities, supporting adaptable resident species.

Station S5 situated close to the disposal point featured the greatest abundance of birds (315 individuals) due to the presence of 250 Greater Flamingos, Little Egret, Little Tern, Delicate Prinia, and Crested Lark. At the same time, the vegetation was comprised mostly of halophytes, namely, *Suaeda maritima*, which is associated with the adaptation to the salty coastal environment. It is important to note that the high bird abundance in the study area is associated with the concentration of one species, namely, flamingos,. This suggests that the current habitat can provide adequate food sources for filter feeders and shorebirds.

Conclusions from the comparative analysis show that the coastal habitat at Tata Chemicals harbours an ecosystem with moderate diversity and resilience with varied vegetation communities and a high population of resident and migratory birds. The mangroves, saline grassland, scrub, and intertidal mudflats together make provision for different ecological niches and serve as a source of nutrition and rest to the migratory birds.

Despite being located close to the discharge location, no evidence of negative impacts of industrial activities on either the flora or the use of this location by migratory birds was found during the current investigation.

Mudflat restoration plan:

Diversified birds including waders were identified in the present study. They have different feeding habit and also both migratory and resident bards were identified. This signifies the suitable habitat for the birds. Natural mangrove growth (*Avicennia* spp.) was recorded. TCL has conducted Mangrove plantation activities as per Rehabilitation plan approved by the Chief Wildlife Warden, Government of Gujarat, Gandhinagar.

Mangrove Rehabilitation and Wildlife Conservation Measures

As part of compliance with the conditions stipulated in the approvals for laying treated waste water pipeline through Marine Sanctuary area, a Detailed Plan for ***Rehabilitation of the existing effluent discharge area through mangrove plantation was prepared and duly approved by the Chief Wildlife Warden, Government of Gujarat, Gandhinagar***.

The mangrove plantation activities were proposed and implemented during FY 2019–20, 2020–21, 2021–22, 2022–23, 2023–24, and 2024–25, and have been successfully completed in consultation with the field staff of the Marine National Park, Dwarka Range. In addition, Tata Chemicals Limited (TCL) has deposited an amount of ₹11.45 crore with the Gujarat Marine National Park and Marine Sanctuary Conservation Society towards habitat improvement and wildlife conservation activities.

Satellite Imagery showing dense mangrove ecosystem surrounding of effluent discharge area

SEAGRASS STATUS

Seagrasses are seed-bearing, flowering, rooted plants, which grow submerged, exclusively in marine coastal waters and coastal wetlands (Figure 18). Like grasses in terrestrial habitats, they form meadows on the bed of coastal seas. They are dependent on light for photosynthesis, and therefore, seagrass generally grows only in clear and shallow waters in estuaries and coastal seas. Seagrass cannot survive exposure out of water, so often survives behind shelter from a sand bar or coral reef. Seagrasses possesses the vascular system for transport of food and water. Similarly, possesses specialized reproductive structures, such as flowers and fruits, and roots. Seagrasses are the only flowering plants that have adapted to a completely submerged life in the tidal and sub-tidal marine environment, where they must withstand the wave energy of the sea and sub-marine pollination. Air-filled tissues in the leaves facilitate gas exchange with the environment. The underground rhizomes and roots anchor the plants; sugars and oxygen are produced during photosynthesis. Seagrasses need more sunlight than algae, which do not have underground components.

Seagrass meadows constitute ecologically and economically important habitats for many edible fish, and also act as nurseries for many commercial fish and shellfish species. Seagrass meadows prevent coastal erosion and pollution and sedimentation of coastal waters, stabilize the floor of coastal seas, are primary producers in coastal ecosystems, support coastal biodiversity, enrich nutrients in coastal waters, and may be monitored as an indicator of coastal ecosystem health. They also act as filters for coastal waters, slowing water currents and trapping inorganic particles, organic nutrients and pollutants washed from inland waters to coastal areas.

The Gulf of Kachchh is diversified with various marine habitats, influenced by semi-diurnal tidal amplitude and heavy sedimentation. There are few published studies on seagrasses in the Gulf of Kachchh MNP&S, but the distribution of seagrass has been recorded by various agencies working among the mangroves, coral reefs and other habitats. Jagtap (1991) reported the occurrence of four species of seagrass from Gulf of Kachchh: *Halophila beccarii* was reported to be common while *Halodule uninervis*, *Halophila ovalis* and *Halophila ovata* were very rare. The status of seagrass was reported to be degraded. Nair (2002) reported three species, *Halodule univervis*, *Halophila ovate* and *Halophila beccari* on sandy regions of Narara and Kalubhar reefs. A comprehensive study on biodiversity and management issues of the MNP&S by Singh et al. (2004) indicates the status of seagrass in different locations. Maximum abundance was observed at Paga Reef, Chandri Reef, Noru Reef, Bhural Chank Reef, Kalubhar Reef, Narara Reef, Boria Reef, Mangunda Reef, Goose Reef and Pirotan Island. Low density seagrass meadows were reported at Meetha Chusna Island, Bhaidar Island, Chank Island, Ajad Island, Jindra Island, Chhad Island and Poshitra reef. Areas without seagrass included Bet Dwarka Island, Khara Chusna Island, Dedeka Island, Mundeka Island, Okha Village and Arambhda Village. Singh et al. (2004) reported only three species of seagrass from the intertidal reef areas of Gulf of Kachchh MNP&S compared with the six species reported by SAC (2010).

Thalassia hermprichii and algae were mapped on the coastal side of the reef flats of Bural Chank and Paga Reefs, Kalubhar Island, Narara Reef and Pirotan Island. Common seagrasses found growing on the muddy substrate of the seaward side of reef flats are *Halophilaovalis, Halophila beccarii and Zostrea marina* (SAC, 2010). Seagrass is one of the key habitats in Gulf of Kutch with the predominant diversity of *Halophila ovalis, Halodule uninervis,* and *Thalassia hemprichii*. The seagrass is subjected to be at risk than any other habitats due to naturaland human impacts. Strategies need to be developed to conserve seagrass patches of inhospitable environments like Gulf of Kutch, which demands the present feasibility study on seagrass restoration. Adhavan et al. (2022) reported in his study, the occurrence of seagrass habitats in Pirotan, Narara, and Mithapur reef areas of the Gulf of Kutch. *Halophila ovalis* showed the most extensive coverage in all the studied sites during the study period ($62.11 \pm 5.60/m^2$ in Pirotan; $60.70 \pm 7.24/m^2$ in Mithapur and $59.32 \pm 5.45/m^2$ in Narara sites). Likewise, *Thalassia hemprichii* showed the least cover in all the three studied sites ($25 \pm 6.28/m^2$ at Narara; $28.93 \pm 3.54/m^2$ in Pirotan and $31.78 \pm 4.16/m^2$ in Mithapur sites). Site-specific strategies have been attempted to develop a successful seagrass restoration nursery for *Ha. ovalis* and *H. uninervis* in the GoK region.

During ground truthing, no seagrass species were found in the Poshitra Bay.

Figure 18 - Thalassia Hemprichii

SAKURAEOLIS GUJARATICA

Sakuraeolis Gujaratica is an aeolid opisthobranch belonging to family facelinidae (Figure 27). The species was described by Rudman in 1980 based on his collection from Adatara reef and Okha in Gulf of Kachchh in 1972. After its discovery, the species was not recorded in any of the study till BNHS reported it during surveys of 2008-09 from Poshitra. As the species is not reported from any other place in the world, it is considered to be endemic to Poshitra in Gulf of Kachchh. Further, Vadher et al. (2020) reported various studies that were undertaken w.r.t. *Sakuraeolis Gujaratica* occurance in Gulf of Kachchh (Apte et al. 2010; GEER 2014a,b; Poriya et al. 2015; Apte & Desai 2017); Poshitra Reef, Ashaba Island (Parasharya 2012); Diu (Poriya et al. 2015); Gujarat (Venkataraman et al. 2015; Raghunathan et al. 2016). Currently BNHS is working on the population ecology of the species and its habitat characteristics.

During ground truthing, the species *'Sakuraeolis Gujaratica'* was not found in the Poshitra Bay. However, the area is home to this beautifully coloured, endemic aeolid species (Hornbill April-June, 2018).

Figure 19 - Sakuraeolis Gujaratica (Source: BHNS website)

Figure 20 - Sakuraeolis Gujaratica (Source: Vadher et al. 2020)

ANTEAEOLIDIELLA POSHITRA

Anteaeolidiella Poshitra is a species of sea slugs, an aeolid nudibranch. It is a marine gastropod mollusc in the family Aeolidiidae (Figure 29). This species was described from specimens collected under coral rubble at Poshitra, Gujarat, India. The body of *Anteaeolidiella Poshitra* is translucent white, with a bracket-shaped orange mark on the front of the head. Behind the rhinophores is an orange diamond-shaped mark, and the pericardium is translucent with an orange circle. The rhinophores are orange with white tips, and the oral tentacles are translucent white with a hint of orange. Black eyes are visible through the skin just behind the bases of the rhinophores. The cerata are long and swollen and extend from the rear of the rhinophores to the tail leaving a bare zone over the back. The cerata contain orange digestive gland and have a white tip. The cerata are arranged in as many as 6 rows with as many as 6 cerata in the anterior rows and as few as 2 in the last rows. The animals were only 8 mm in length (Carmona et al. 2014).

During ground truthing, the species *'Anteaeolidiella Poshitra'* was not found in the Poshitra Bay.

Figure 21 - Anteaeolidiella Poshitra (Source: https://uk.inaturalist.org/photos/60112485)

NEW EFFLUENT DISCHARGE SYSTEM- IN OPERATION

TCL has fully commissioned and operationalised the closed pipeline and diffuser system for discharge of treated effluent into the marine outfall point, in line with the recommendations of the National Institute of Oceanography (NIO) and the revised effluent discharge standards prescribed for the soda ash industry (S. No. 75 - Solvay Process). The new pipeline and diffuser system is operational as per GPCB CCA No. AWH-138320 dated 30.05.2026.

Figure 22 - Effluent Discharge systems- Operational

OLD EFFLUENT DISCHARGE SYSTEM- DISCONTINUED

TCL has permanently closed the operation of existing open Channel for discharge of treated wastewater and initiated activities for restoration to its original condition, as directed by the board vide GPCB directions GPCB Directions (Outward No. 902320) dated 29 May 2026.

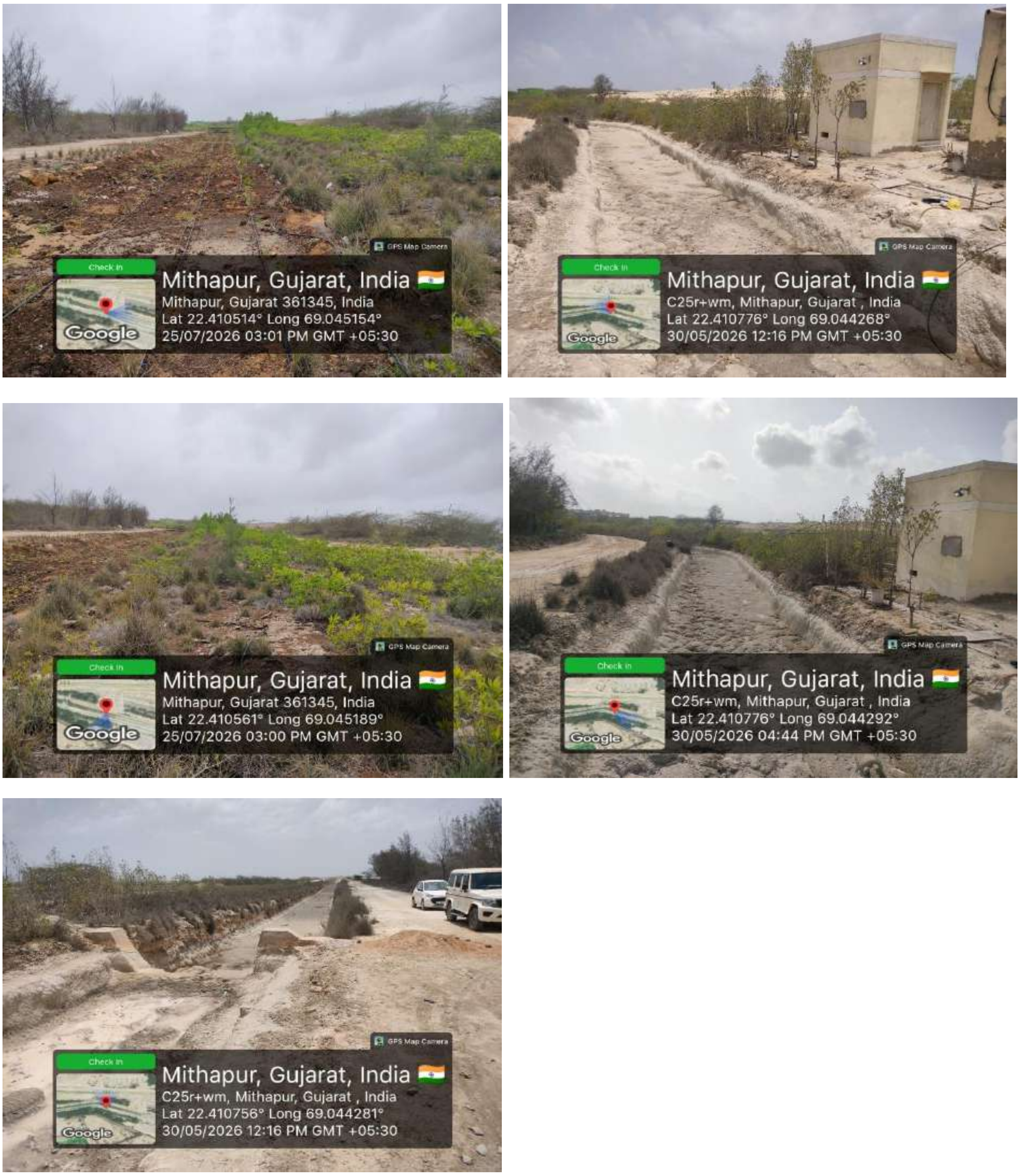


Figure 23 - Photographs showing open channel discharge into Sea- discontinued

Photographs showing field visits and ecology surrounding of discharge area


GPS Map Camera
Check In
Google
Hamusar, Gujarat, India
Hamusar, Gujarat, India, Hamusar,
Gujarat , India
Lat 22.3974° Long 69.054588°
09/04/2026 10:32 AM GMT +05:30


GPS Map Camera
Check In
Google
Hamusar, Gujarat, India
Hamusar, Gujarat, India, Hamusar,
Gujarat , India
Lat 22.3974° Long 69.054588°
09/04/2026 10:32 AM GMT +05:30

D. CONCLUSION

The comprehensive assessment of seawater quality across the study area demonstrates that the marine environment is in a healthy, stable, and ecologically favorable condition. All key physicochemical and nutrient parameters exhibited characteristics typical of a well-mixed coastal marine ecosystem and remained within ranges generally associated with good environmental quality.

The pH values (8.11–8.24) confirmed the naturally alkaline nature of seawater and indicated a chemically stable environment with no evidence of acidification or significant anthropogenic influence. Conductivity (50.54–53.18 mS/cm) and salinity (34.9–35.2 ppt) showed very limited spatial and tidal variation, reflecting strong marine influence, effective tidal exchange, and a well-mixed water column throughout the study area.

Although Total Suspended Solids (TSS) showed localized elevations at certain stations, particularly during low tide, the observed variations are attributable to natural hydrodynamic processes such as tidal currents and sediment resuspension rather than any identifiable deterioration in environmental quality. These findings highlight the dynamic nature of the coastal system while confirming the continued predominance of natural sediment transport mechanisms.

Biological and oxygen-related parameters further demonstrated the good ecological status of the study area. Dissolved Oxygen (DO) concentrations remained consistently high (6.9–8.7 mg/L), well above levels required to sustain aquatic life, while Biochemical Oxygen Demand (BOD) values were generally low (0.0–4.0 mg/L), indicating limited organic loading and low oxygen stress. The coexistence of low BOD and high DO concentrations reflects an efficient balance between oxygen consumption and replenishment through natural aeration and tidal mixing processes.

The nutrient assessment also indicated a healthy and balanced marine ecosystem. Ammoniacal nitrogen, nitrite nitrogen, and nitrate nitrogen concentrations were within ranges expected in productive coastal waters and exhibited patterns consistent with active and efficient nitrogen cycling.

The absence of nutrient accumulation, oxygen depletion, or any indication of eutrophication suggests that nutrient dynamics within the study area are primarily governed by natural biogeochemical processes.

Overall, the integrated evaluation of pH, TSS, conductivity, salinity, DO, BOD, ammoniacal nitrogen, nitrite nitrogen, and nitrate nitrogen confirms that the study area possesses good assimilative capacity, effective tidal mixing, stable hydrographic conditions, and favorable ecological characteristics. The findings provide strong evidence that the coastal waters remain environmentally sound, well oxygenated, and capable of supporting marine biodiversity and biological productivity. No signs of significant organic pollution, nutrient-related stress, or adverse impacts on water quality were observed during the study period, indicating that the marine ecosystem is functioning in a healthy and sustainable manner.

The assessment of heavy metal concentrations in seawater across the study area indicates that the coastal marine environment is in a good chemical and ecological condition. The concentrations of the analyzed metals exhibited limited spatial variation and remained within levels typically observed in natural coastal marine waters, suggesting the absence of significant heavy metal contamination.

The overall distribution pattern of metals reflects the influence of natural geochemical processes, seawater circulation, and sediment–water interactions rather than any substantial anthropogenic enrichment. The relatively uniform concentrations observed across the sampling stations indicate effective dilution, dispersion, and mixing processes within the study area, which contribute to maintaining stable water quality conditions.

No evidence of localized heavy metal accumulation or elevated concentrations indicative of environmental stress was observed during the study period. Furthermore, the generally favorable physicochemical conditions—including stable pH, salinity, dissolved oxygen, and low organic loading—provide an environment that minimizes the potential mobility and bioavailability of metals, thereby supporting ecological stability.

When evaluated alongside other water quality parameters, the heavy metal results are consistent with the overall findings of good environmental quality and healthy ecosystem functioning. The absence of significant metal enrichment, coupled with adequate dissolved oxygen levels, balanced nutrient dynamics, and low organic pollution, suggests that the coastal waters retain a strong assimilative capacity and are capable of sustaining marine biological productivity.

Overall, the heavy metal assessment confirms that the study area represents a well-maintained and environmentally stable marine ecosystem, with no indication of adverse impacts from heavy metal contamination during the monitoring period. The observed concentrations are indicative of a healthy coastal environment that continues to support ecological integrity and marine life.

The combined assessment of physicochemical characteristics, suspended solids, oxygen dynamics, nutrient status, and heavy metal concentrations demonstrates that the study area is characterized by good water quality, stable hydrographic conditions, effective tidal mixing, balanced nutrient cycling, and a healthy ecological status. The results collectively indicate that natural marine processes remain the dominant influence on water quality, with no evidence of significant organic pollution, eutrophication, acidification, or heavy metal-related stress. Consequently, the coastal waters in the study area provide a favorable environment for sustaining marine biodiversity, ecological functions, and long-term biological productivity.

The biological assessment of the marine environment indicates that the study area is characterized by a healthy, ecologically balanced, and biologically productive coastal ecosystem. The combined evaluation of chlorophyll-a, phaeophytin, phytoplankton, and zooplankton communities demonstrates that the biological processes operating within the study area are being governed primarily by natural marine and tidal influences.

Chlorophyll-a concentrations remained below the analytical detection limit at all sampling stations, indicating low phytoplankton biomass during the sampling period. The low phaeophytin concentrations (0.002–0.015 mg/L) further suggest limited phytoplankton degradation and the absence of excessive organic enrichment. Together, these findings indicate that the study area was free from algal bloom conditions and nutrient-induced biological stress during the period of investigation. The observed pigment concentrations are consistent with normal coastal seawater conditions and reflect a stable and environmentally sound marine ecosystem.

The phytoplankton community comprised 22 species, dominated by diatoms such as Bacillaria, Coscinodiscus, Navicula, and Nitzschia, which are widely recognized as indicators of productive and healthy coastal waters. The observed species richness and Shannon–Wiener diversity index values indicate a moderately diverse phytoplankton community with balanced ecological functioning. The occurrence of higher diversity during high tide conditions highlights the beneficial role of tidal exchange in promoting species dispersal, community mixing, and ecological connectivity across the study area. Overall, the phytoplankton assemblage reflects favourable environmental conditions and an active primary producer community capable of supporting higher trophic levels.

Similarly, the zooplankton assemblage exhibited good diversity, comprising 23 species predominantly represented by copepods, including Euterpina, Calanidae, Corycaeus, Acartiidae, and Cyclopoid forms. These taxa are characteristic of productive coastal ecosystems and indicate the availability of adequate food resources and favourable habitat conditions. The moderate to high Shannon–Wiener diversity index values (1.30–2.10) demonstrate a well-established and ecologically stable zooplankton community. Higher diversity observed during high tide periods further emphasizes the positive influence of tidal mixing in enhancing species distribution, reducing dominance, and maintaining community balance.

The coexistence of a diverse phytoplankton assemblage, a healthy zooplankton community, low pigment degradation levels, and the absence of bloom-forming conditions suggests that the coastal waters support balanced ecological interactions and efficient energy transfer through the marine food web. These biological observations are also consistent with the favourable physicochemical conditions recorded during the study, including high dissolved oxygen levels, stable salinity, low organic loading, and balanced nutrient concentrations.

Overall, the biological characteristics of the study area confirm the presence of a stable, well-functioning, and environmentally healthy coastal marine ecosystem. The observed biological communities reflect good ecological quality, effective tidal mixing, balanced nutrient availability, and the absence of significant anthropogenic stress. The marine environment possesses the necessary ecological attributes to sustain biodiversity, support aquatic productivity, and maintain long-term ecosystem health and resilience.

The sediment quality assessment demonstrates that the study area is characterized by good environmental conditions, stable sediment geochemistry, and healthy benthic habitat characteristics. The combined evaluation of Petroleum Hydrocarbons (PHC), Total Organic Carbon (TOC), and Total Organic Matter (TOM) indicates that natural sedimentary processes are the predominant factors controlling sediment quality across the study area.

Petroleum Hydrocarbon (PHC) concentrations were consistently low, ranging from 0.18 to 0.44 ppm, with only limited spatial variation among sampling stations. The absence of markedly elevated PHC concentrations indicates that the sediments have not been subjected to significant hydrocarbon contamination. Although minor localized increases were observed at certain stations, these variations are likely associated with natural depositional processes and sediment characteristics rather than widespread anthropogenic hydrocarbon inputs. Overall, the PHC distribution confirms that the sediments are largely free from petroleum-related pollution and represent environmentally acceptable conditions.

Total Organic Carbon (TOC) concentrations ranged from 0.84% to 1.20%, while Total Organic Matter (TOM) content varied from 1.45% to 2.07%, indicating moderately organic-rich sediments throughout the study area. These levels are characteristic of productive coastal marine environments and reflect the availability of sufficient organic matter to support nutrient cycling, microbial activity, and benthic ecological processes. The relatively higher TOC and TOM concentrations observed at Stations S6, S7, and S8 suggest localized enhancement of organic matter accumulation, likely influenced by natural sediment depositional patterns, biological productivity, and sediment texture.

The observed relationship between TOC and PHC concentrations further indicates that organic-rich sediments possess a natural capacity to adsorb and retain small amounts of hydrocarbons. However, despite this association, PHC concentrations remained consistently low across all stations, demonstrating that organic matter accumulation has not resulted in significant hydrocarbon enrichment. Consequently, the TOC–PHC relationship reflects normal sediment geochemical behaviour rather than evidence of contamination.

The moderate concentrations of organic carbon and organic matter, coupled with low petroleum hydrocarbon levels, indicate a balanced sedimentary environment with no evidence of excessive organic loading, degradation, or ecological stress. These conditions are favourable for sustaining benthic organisms, supporting nutrient regeneration processes, and maintaining overall sediment ecosystem health.

Overall, the sediment quality evaluation confirms that the marine sediments within the study area are environmentally sound, moderately productive, and ecologically stable. The low petroleum hydrocarbon concentrations, together with moderate TOC and TOM levels, demonstrate that natural organic matter dynamics dominate sediment geochemistry and that the area remains largely unaffected by hydrocarbon pollution. The sediments provide favourable conditions for benthic ecosystem functioning, nutrient cycling, and long-term ecological sustainability, reflecting good sediment quality and healthy marine environmental conditions.

Integrated Sediment and Water Quality Perspective: When considered together with the favourable water quality, balanced nutrient dynamics, high dissolved oxygen levels, healthy plankton communities, and stable hydrographic conditions observed during the study, the sediment quality results further reinforce the conclusion that the study area represents a well-functioning, resilient, and environmentally healthy coastal marine ecosystem. Both the water column and sediment compartments exhibit characteristics consistent with good ecological quality, strong assimilative capacity, and the absence of significant environmental stress, thereby supporting sustainable marine biodiversity and ecosystem productivity.

The marine ecological assessment conducted across the study area indicates the presence of a diverse, ecologically functional, and environmentally stable coastal ecosystem. The survey documented a variety of terrestrial and coastal habitats, including mangrove patches, coastal mudflats, salt marshes, scrublands, saline wastelands, and anthropogenically influenced areas, collectively supporting a rich assemblage of flora and avifauna. The observed habitat heterogeneity contributes significantly to the ecological integrity and biodiversity value of the region.

Floral Diversity and Vegetation Structure: The vegetation survey recorded a total of 27 plant species comprising 10 tree species, 5 shrub/climber species, and 12 herbaceous species, reflecting moderate to high floral diversity. Diversity indices for trees ($H' = 1.48$), shrubs/climbers ($H' = 1.42$), and herbs ($H' = 1.66$) indicate a balanced vegetation community with moderate species richness and relatively even species distribution. The vegetation assemblage is ecologically significant in supporting habitat stability, nutrient cycling, soil conservation, and biodiversity maintenance.

The occurrence of Avicennia marina along coastal and saline zones is particularly noteworthy, as it reflects the presence of healthy mangrove patches that provide essential ecological services, including shoreline stabilization, sediment trapping, nursery grounds for aquatic organisms, and habitat for wildlife. Dominant species such as Avicennia marina, Acacia nilotica, Prosopis juliflora, Ziziphus nummularia, and salt-tolerant grasses demonstrate strong adaptation to local environmental conditions and contribute to ecosystem resilience. Overall, the vegetation composition and diversity indicate a stable and well-established plant community with no significant conservation concerns identified during the survey.

Avifaunal Diversity: The avifaunal survey recorded 40 bird species comprising 637 individuals, demonstrating the ecological importance of the study area as a habitat for coastal and terrestrial bird communities. The diversity and abundance of bird species indicate the availability of suitable feeding, nesting, roosting, and sheltering habitats across the various ecosystem types present within the region. The coexistence of mangroves, mudflats, salt marshes, and scrub habitats provides a mosaic of ecological niches that support a wide range of avian species.

The substantial avifaunal richness observed during the study reflects favourable habitat conditions, adequate food resources, and minimal ecological disturbance. The recorded bird diversity further indicates that the existing habitats continue to perform important ecological functions in sustaining local biodiversity and maintaining ecosystem connectivity within the coastal landscape.

Ecological Significance and Overall Assessment: The combined floral and faunal observations demonstrate that the study area supports a well-functioning coastal ecosystem characterized by moderate to high biodiversity and healthy habitat conditions. The dominance of native coastal and salt-tolerant vegetation, healthy mangrove presence, balanced community structure, and substantial avifaunal diversity collectively indicate good ecological status and ecosystem stability.

Furthermore, no rare, endangered, or ecologically sensitive habitat degradation issues were identified during the assessment, and no major conservation concerns relating to the existing vegetation communities were observed. The diversity indices suggest that ecosystem functions such as primary production, habitat provision, nutrient recycling, and food-web support remain intact and effective.

Overall Ecological Conclusion: The ecological assessment confirms that the study area represents a biologically rich and environmentally stable coastal ecosystem with healthy vegetation communities, ecologically important mangrove habitats, and diverse avifaunal populations. The observed floral and faunal assemblages reflect good habitat quality, strong ecological resilience, and functional ecosystem processes. The findings indicate that the area continues to support biodiversity conservation, shoreline stabilization, nutrient cycling, and wildlife habitat functions. The overall ecological condition of the region is considered favourable, sustainable, and supportive of long-term ecosystem health and biodiversity conservation.

The avifaunal assessment undertaken across the eight sampling stations demonstrates that the Mithapur coastal ecosystem supports a diverse, productive, and ecologically significant bird community, reflecting the overall health and stability of the coastal environment. The recording of 637 individual birds belonging to 40 species highlights the importance of the study area as a habitat for both resident and migratory avifauna and underscores its ecological value within the coastal landscape.

The observed bird assemblage occupied a wide variety of habitats, including coastal mudflats, intertidal zones, wetlands, shallow marine waters, grasslands, scrublands, and anthropogenically influenced areas. This habitat heterogeneity has contributed to the moderate to high species diversity recorded during the survey, with Shannon–Wiener diversity index values ranging from 0.71 to 2.23. The availability of diverse habitat types provides feeding, roosting, nesting, and resting opportunities for multiple avian guilds, thereby enhancing the ecological resilience of the area.

A notable finding of the study is the occurrence of several migratory bird species, including Greater Flamingo (Phoenicopterus roseus), Eurasian Curlew (Numenius arquata), Common Sandpiper (Actitis hypoleucos), Tibetan Plover (Anarhynchus atrifrons), Red-necked Phalarope (Phalaropus lobatus), Little Tern (Sternula albifrons), and Barn Swallow (Hirundo rustica). The presence of these migratory species confirms the ecological significance of the Mithapur coastline as an important stopover, feeding, and resting habitat along the Central Asian Flyway (CAF). The continued utilization of the area by migratory birds indicates the maintenance of suitable habitat quality and ecological conditions.

The ecological importance of individual sampling stations was also evident. Intertidal mudflats and shallow coastal waters supported large populations of shorebirds and waders, while mangroves, scrublands, and saline grasslands provided critical habitat for resident bird communities. In particular, Station S5, located in the vicinity of the long-term disposal area, recorded the highest bird abundance owing to the presence of a large congregation of Greater Flamingos. The occurrence of large numbers of flamingos and other wetland-dependent species indicates the continued availability of suitable feeding resources and habitat conditions, particularly for filter-feeding and migratory waterbirds.

Importantly, the comparative ecological assessment revealed no evidence of adverse effects on avifaunal diversity, species richness, abundance, or habitat utilization in areas adjacent to the disposal site. The continued presence of ecologically sensitive wetland birds, migratory species, and habitat specialists demonstrates that the ecological functions of the coastal environment remain intact. The diversity and abundance patterns recorded during the study indicate that the surrounding habitats continue to support healthy avian populations and maintain their ecological value.

The correlation between vegetation characteristics and avifaunal distribution further highlights the ecological integrity of the study area. Mangrove patches dominated by Avicennia marina, saline grasslands, coastal scrub vegetation, and mudflat ecosystems collectively provide a range of ecological niches that support birds with different feeding strategies and habitat requirements. This strong habitat–faunal linkage is indicative of a well-functioning coastal ecosystem with balanced ecological processes.

Overall Avifaunal Conclusion: The avifaunal assessment confirms that the Mithapur coastal ecosystem represents an ecologically valuable and biologically productive habitat supporting a rich assemblage of resident and migratory bird species. The diversity, abundance, and distribution of avifauna recorded across the study area reflect favourable habitat quality, adequate food availability, and healthy ecological conditions. The continued occurrence of migratory waterbirds and wetland-dependent species, including large congregations of Greater Flamingos, demonstrates the conservation significance of the area within the Central Asian Flyway. Importantly, no measurable adverse impact of long-term disposal activities on bird diversity, abundance, or habitat utilization was observed. Overall, the findings indicate that the study area maintains strong ecological resilience, supports important biodiversity values, and continues to function as a healthy coastal ecosystem of considerable conservation importance.

Ecological Assessment

SCOPE OF STUDY	METHODOLOGY	CONCLUSIONS
1. Comprehensive survey of the wildlife and vegetation in buffer areas (Study area map) including terrestrial and Marine Environment	A detailed survey has been carried out about distribution of flora and fauna in the coastal/intertidal area. The study includes presence of mangrove, coastal plants and animals. A detailed survey has been carried out about distribution of seagrass, corals, seaweeds and availability of other coastal water species	The comprehensive assessment of seawater quality across the study area demonstrates that the marine environment is in a healthy, stable, and ecologically favourable condition.
2. Monitoring of Marine and coastal biodiversity of Poshitra Bay as per Baseline study conducted in September 2023 (CSMCRI/TSP-1446) with	A detailed coastal survey has been carried out in the Positra bay and distribution of flora and fauna are identified. Distribution and abundance study of endemic species like Sakuraeolis	The ecological assessment confirms that the study area represents a biologically rich and environmentally stable coastal ecosystem with healthy vegetation communities,

specific focus on sea grass beds, and endemic species Sakuraeolis gujaratica and Anteaeolidiella poshitra.	gujaratica and Anteaeolidiella poshitra has been carried out.	ecologically important mangrove habitats, and diverse avifaunal populations.
3. Study of marine water and sediment quality parameters in sampling location as per previous study (CSMCRI/TSP-1446).	Identified sampling location as per previous study (CSMCRI/TSP-1446) and following parameters will be analysed:	All key physicochemical and nutrient parameters exhibited characteristics typical of a well-mixed coastal marine ecosystem and remained within ranges generally associated with good environmental quality.

PARAMETERS	COASTAL WATER	COASTAL SEDIMENTS
Physico chemical parameters:	Temperature, Salinity, Dissolved oxygen, Biochemical oxygen demand, Conductivity, Turbidity, pH, Total suspended solids, Nutrient parameters (Nitrite and nitrate, Ammonia, Inorganic phosphate), Heavy metals (As, Al, Cd, Co, Cu, Ni, Mn, Fe, Cr, Pb, Zn, Hg).	Heavy metals (As, Al, Cd, Co, Cu, Ni, Mn, Fe, Cr, Pb, Zn, Hg), PHC, organic carbon Sediment samples will be collected from coastal as well as inter-tidal area.
Biological parameters:	Phytoplankton: Only surface water samples Phytoplankton count, major genera and generic diversity and SWDI Zooplankton: Only surface water samples Zooplankton count; volume of zooplankton, major genera of zooplankton and group diversity and SWDI. Microbiology counts: Total viable count, Total Coliform, E. coli, Vibrio, Aeromonas, Pseudomonas spp.	Microbiology counts: Total viable count, Total Coliform, E. coli, Vibrio spp., Aeromonas, Pseudomonas spp. Benthic fauna: Identification of species and species diversity study

Environment Management Plan (EMP):

<table>
<tr><th>SCOPE OF STUDY</th><th>METHODOLOGY</th><th>CONCLUSIONS</th></tr>
<tr><td>1. Suggest EMP for Marine and coastal biodiversity of Poshitra Bay with specific focus on sea grass beds, and endemic species Sakuraeolis gujaratica and Anteaeolidiella poshitra.</td><td>Based on availability and abundance of marine and coastal species like seagrass beds, and endemic species like Sakuraeolis gujaratica and Anteaeolidiella poshitra, environmental management plan will be developed.</td><td rowspan="3">As part of compliance with the conditions stipulated in the approvals for laying treated waste water pipeline through Marine Sanctuary area, a Detailed Plan for Rehabilitation of the existing effluent discharge area through mangrove plantation was prepared and duly approved by the Chief Wildlife Warden, Government of Gujarat, Gandhinagar.
The mangrove plantation activities were proposed and implemented during FY 2019–20, 2020–21, 2021–22, 2022–23, 2023–24, and 2024–25, and have been successfully completed in consultation with the field staff of the Marine National Park, Dwarka Range.</td></tr>
<tr><td>2. Mudflat restoration plan with specific focus on waders and other water birds of the affected region be developed and implemented through concerned authority.</td><td>Mudflats will be identified. Survey will be made on distribution of waders and other water birds in the mud flat and other area. Mudflat restoration plan will be prepared.</td></tr>
<tr><td>3. Status of Rehabilitation plan for Mangrove Plantation approved by Chief Wildlife Warden vide letter dated 13.03.2020.</td><td>Health status assessment of mangrove plantation will be carried out by CSIR-CSMCRI and required measured will be suggested.</td></tr>
<tr><td>4. Status of Wildlife Conservation Plan approved by Chief Wildlife Warden vide letter dated 19.06.2018.</td><td>Status of approved Wildlife Conservation Plan will be assessed by CSIR CSMCRI and necessary recommendation will be suggested.</td><td>TCL has deposited an amount of ₹11.45 crore with the Gujarat Marine National Park and Marine Sanctuary Conservation Society towards habitat improvement and wildlife conservation activities.</td></tr>
<tr><td>5. Compliance status of Environmental approvals for Marine Outfall system (Treated wastewater and diffuser system)</td><td>Compliance monitoring of marine outfall is regularly monitored by some third party sponsored by TCL. CSIR-CSMCRI may study the compliance reports and make their recommendation.</td><td>TCL has fully commissioned and operationalised the closed pipeline and diffuser system for discharge of treated effluent into the marine outfall point, in line with the recommendations of the National Institute of Oceanography (NIO) and the revised effluent discharge standards prescribed for the soda ash industry (S. No. 75 - Solvay Process).</td></tr>
</table>

भारतीय गुणवत्ता परिषद्
QUALITY COUNCIL® OF INDIA
QCI
Creating an Ecosystem for Quality

NABET

National Accreditation Board for Education and Training

Certificate of Accreditation

CSIR-CSMCRI, Gujarat

GB Marg, Bhavnagar, Gujarat - 364002

CSIR-CSMCRI, Gujarat *is Re-Accredited (RA2)* ***as Category-A organization*** *under the QCI-NABET Scheme for Accreditation of EIA Consultant Organizations (Version 3), for the preparation of EIA/EMP reports in the sectors listed below, as per the specified categories-*

S.No	Sector Description	Sector (as per)		Cat.
		NABET	MoEFCC	
1.	All ship breaking yards including ship breaking units	30	7 (b)	A
2.	Ports, harbours, jetties, marine terminals, break waters and dredging	33	7(e)	A
3.	Common Effluent Treatment Plants (CETPs)	36	7(h)	B

Note: Names of approved experts and sectors are mentioned in RAAC minutes dated June 18, 2026, and posted on QCI-NABET website.

The Accreditation shall remain in force subject to continued compliance to the terms and conditions mentioned in QCI NABET's letter of accreditation bearing no QCI/NABET/ENV/ACO/26/4133 dated June 24,2026. The accreditation needs to be renewed before the expiry date by CSIR-CSMCRI, Gujarat following due process of assessment.

Valid up to
July 15, 2029

Issue Date
June 24, 2026

Certificate No.
NABET/EIA/26-29/RA 0499

Varinder Kanwar
Prof (Dr) Varinder S Kanwar
(CEO – NABET)

For the updated List of Accredited EIA Consultant Organizations with approved Sectors please refer to QCI-NABET website.

National Accreditation Board for Testing and Calibration Laboratories

NABL

CERTIFICATE OF ACCREDITATION

CSMCRI - ANALYTICAL TESTING AND EVALUATION LABORATORY

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2017

"General Requirements for the Competence of Testing & Calibration Laboratories"

for its facilities at

CSIR - CENTRAL SALT & MARINE CHEMICALS RESEARCH INSTITUTE, GUJUBHAI BADHEKA MARG, BHAVNAGAR, GUJARAT, INDIA

in the field of

TESTING

Certificate Number: TC-14732

Issue Date: 21/10/2024 **Valid Until:** 20/10/2028

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.
(To see the scope of accreditation of thislaboratory, you may also visit NABL website www.nabl-india.org)

Name of Legal Entity: CSIR - Central Salt & Marine Chemicals Research Institute

Signed for and on behalf of NABL

N. Venkateswaran
Chief Executive Officer