BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL,
PRINCIPAL BENCH AT NEW DELHI
IN
Appeal No. 49 of 2018
(Earlier Appeal No. 4 of 2017 (WZ))

IN THE MATTER OF: -

Conservation Action Trust &Ors. ....Appellant

VERSUS

Union of India &Ors. ....Respondents

ADDITIONAL AFFIDAVIT ON BEHALF OF RESPONDENT NO.1, MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

MOST RESPECTFULLY SHOWETH: -

I, Dr. Vinod Kumar Singh, working as Scientist "E" in the Ministry of Environment, Forest and Climate Change (MoEF&CC), Indira Paryavaran Bhavan, Aliganj, Jor Bagh Road, New Delhi - 3, the deponent herein, do hereby solemnly affirm and state on oath as under:-

1. That I am duly authorized and competent to swear the present counter affidavit on behalf of MoEF&CC based upon available records.

2. That the present additional affidavit is being filed by the Answering Respondent in pursuant to the order dated 19.08.2019 of this Hon'ble Tribunal wherein it was directed to have an environmental audit conducted through an agency i.e. CSIR-National Institute of Oceanography (NIO) or CSIR-NEERI. It was also directed that while conducting audit it may also be seen whether there is compliance of CRZ notification.

3. That the Answering Respondent has filed a detailed reply affidavit in June, 2017 and additional affidavit in January, 2020. The contents of the previous affidavits are being not repeated herein for the sake of brevity. However, the Hon'ble Tribunal may consider these affidavits as a part and parcel of this additional affidavit.

4. That in compliance of the order dated 19.08.2019 of this Hon'ble Tribunal, this Answering Respondent vide letter dated 23.0[illegible].2020

awarded the work of environmental audit to CSIR-NIO, Goa. The work order was issued stipulating terms of reference for conducting an environment audit based on the directions of this Hon'ble Tribunal. As per the aforesaid workorder, while conducting environment audit, NIO was required to "*ascertain environment impact due to Beaching method and Ship breaking method being used at Alang Ship Recycling Yard and also to verify the compliance of CRZ Notification in compliance to the order dated 19.08.2019 of Hon'ble National Green tribunal, Principal Bench, New Delhi*".

5. That, pursuant of aforesaid work order issued by this Answering Respondent, CSIR-NIO has submitted a Report on 'Marine Environmental Monitoring and Verification for Compliance of CRZ Notification at Alang Ship Recycling Yard". The Report is based on the study conducted during February-March, 2020 to meet the following objectives:

a) To evolve prevailing status of water quality, sediment quality and flora and fauna of project area,
b) To assess the impact of pollution due to ship breaking activities on the coastal ecology of Alang.
c) To assess the compliance of CRZ notification.

6. That report containseleven (11)sections/Chapters and the Executive Summary. The first three chapters pertain to background, project information and information on earlier studies conducted in surroundings of the region. The 'Chapter-4' details the investigations conducted by NIO to conduct of this environment audit. The 'Chapter-5' is on prevailing marine environments whereas 'Chapter-6' in on "Impact Assessment on Marine Environment". The details w.r.t "Assessment of Environmental and Socioeconomic Status of Ship Recycling Yards" and "Study of CRZ Compliances" have been given in 'Chapter-7' and 'Chapter-8' respectively.

7. The salient features of the aforesaid environment audit cum Report on "Marine Environmental Monitoring and Verification for Compliance of CRZ Notification at Alang Ship Recycling Yard" are reported to be as under:

(i) Water quality

The values of water temperature (°C) obtained during present study are compared with the values obtained in the surrounding areas and indicates that the temperature is comparable. The pH remains more or less same in the entire Gulf for the years and does not suggest any impact of ship breaking activities.

The present Suspended Solid (SS) values at Alang are higher than the earlier data of same region, such variation is expected in such dynamic area, which carries high load of suspended solid and high tidal current churns out the bottom sediment. The Alang contain higher average salinity compared to the surrounding region, which may be due to open mouth of Gulf connected with sea.

The average values of Dissolved Oxygen (DO) in the Alang area is above 5.5 mg/l and compares well with entire Gulf of Khambhat values, which explains healthy condition of the water quality off the Alang. Although the values of Biochemical Oxygen Demand (BOD) in Alang area are slightly higher as compared to the earlier data of surrounding areas, higher BOD also observed in Ghogha during present study indicates common phenomena in the Gulf and not because of Alang ship recycling work.

The concentration of PO_4^{3-} -P observed during present study is lower as compared earlier data. However, the impact of ship breaking activities on the concentration of PO_4^{3-} -P is not discernible.

The land run off and wastes brough through different sources by rivers has resulted enhanced concentration of nutrient in the gulf of Khambhat. Such enhancement is due to delayed flushing out to open shore region. Hence, elevated concentration of nutrients is the general characteristics of the Gulf and not because of ship breaking activities.

Significantly higher concentration of Petroleum Hydrocarbons (PHc) in the coastal water of Alang as compared to that of surrounding region clearly suggests PHc contamination in coastal water resulted due to ship breaking activities.

The concentration of phenol recorded during the present study is almost similar to the values of phenol generally found in the other region of Gulf. The adverse impact of ship-breaking activities on the concentration of phenol was not seen during the present study.

Concentration of dissolved metals is compared with the values available for other regions. The concentration of some of the metals recorded in present study are within the values recorded in some other regions, hence, impact of ship recycling on the concentration of dissolved metals is not observed.

(ii) Sediment quality

Concentration of metals such as Cr, Fe, Cu, Zn Pb and Hg were higher in the sediment of shore locations, which are under direct influence of ship cutting areas. The concentration of metals in intertidal region recorded during present study are lower than the earlier studies. Regular monitoring of the intertidal region can confirm the status of metals in the sediment of Alang.

The concentration of organic carbon is low in the sediment and does not show any adverse impact of ship breaking activities on its distribution at Alang. Thus, the ship breaking activities does not show any role on the concentration of organic carbon in intertidal sediment during the present study.

The overall scenario of total phosphorus in subtidal sediment indicates that there is no significant build-up of phosphorus in the sediment of Alang similar to that of surrounding region.

There was elevated concentration of PHc in the sediment of nearshore region of Alang. The level of PHc in the shore sediment is significantly higher than the values of offshore region. This may be due to the intertidal area which receives PHc during ship-breaking activities and spread towards the subtidal segment resulting in contamination to the nearshore sediments of Alang.

(iii) Biological characteristics

The concentration of chlorophyll a and phaeophytin are muchlower in the nearshore and offshore water of Alang as compared to earlier data. Such variations are expected in an area having highest suspended load in the water, which prevents penetration of light.

Phytoplankton population in the coastal water of Alang was noticeably high as compared to the data available for the same area during 2001. However, species diversity was comparable during present study. Overall variation of phytoplankton pigments and generic diversity indicates natural variability in the region and not affected by the ship breaking activities.

Zooplankton standing stock in terms of biomass, population was high as compared earlier results in Alang region, but lower in Ghogha region. Total zooplankton groups from the current study in the coastal waters of Alang are more or less similar to that of earlier results in the area. The community structure of zooplankton was also in the agreement of earlier data of surrounding region. Thus, zooplankton standing stock in the coastal water of Alang does not reveal any influence of ship breaking activities.

The overall average values of intertidal macrobenthic standing stock are comparable to that of Dahej and Bhavnagar and the earlier data of 2007-08. The faunal group was in the agreement of the values of earlier data except a few occasions. The impact of ship breaking activities on the intertidal macrobenthic standing stock was in general not significant except localized poor stock. There were some intertidal areas where the ship breaking activities were very active resulting in petroleum spills at the shore recorded during 2007-08 showing markedly poor macrobenthic standing stock confirming the impact of ship-breaking activities localized. Such spill was not observed during present study in the intertidal region. The biomass and population recorded during present study were better than Bhavnagar region and population was better than earlier record of Alang, indicating that there is no impact of ship breaking activities.

In Gulf of Khambhat, water current often exceeds > 3.0 m/s, thus it does not allow to settle the bottom sediment, which is reflected in the form of benthic xiv community and most of the time bottom sediment does not show any benthic population.

Uneven rocky bottom and high turbidity coupled with strong tidal currents make trawling or gill netting difficult and risky in the coastal water of Alang. Evidently, no active commercial fishing exists in this region excepting some gill netting or bag-netting or other traditional gears by local fishermen. Enquiries with the local fishermen also confirm that the trawlers generally do not operate in this area.

The intertidal area of Alang was devoid of mangroves vegetation. Thus, the question of adverse impact of ship breaking activities on mangroves does not arise.

The result of present study is compared with the marine water quality standards which indicates that values of pH, DO and BOD are almost in the agreement of water quality standards suggesting a healthy coastal environment. Floating matters oil, grease and scum (including petroleum products), as standard is 10 mg/l (10,000 µg/l) and PHc value (12.5-614.0 µg/l) is much lower than standard.

(iv) Ship recycling yards

Since India has accepted it, ship recyclers at Alang-Sosiya have willingly acquired a statement of compliance to Hong Kong Convention (HKC) by International Classification Societies as recognized by DG Shipping. During field collection random number of ship recycling yards were visited to evaluate the status of recycling yards. During visit it was found that as per the convention followed by recycler, some of yards come under green category and some have still to come to the level so as to receive green category status. Thus around 70% of recycling yards come under green category.

(v) Safety measures in the recycling yards at Alang

It was observed that the workers at ship recycling yards were well acquainted with safety and security method and all those working in the plots were found wearing helmets, safety jackets and boots. A training institute has been established by Gujarat Maritime Board (GMB) at Alang for the training of workers before their engagement for actual work of ship breaking and other activities. From the personal communication with shipbreaking workers, it was found that the quantum of accident is very less in recent years, due to the training and safety measures taken in the process.

(vi) Health facilities at Alang

Alang Red Cross Hospitals for Primary Medical Treatment. The hospital is financially assisted by GMB. GMB extended full support to create Multi Speciality Hospital at Alang itself which provides medical services to manpower at Ship Recycling yards and residents of nearby 45 villages around Alang. Another Private Hospital permitted by GMB also known as "Alang Hospital" for Secondary Medical Care. It has 33 beds. It is equipped with an X-ray facility and medical stores. Two doctors are available permanently. For any eventuality, expert doctors are also called to provide treatment to the affected workers.

(vii) Staying facility for ship recycling workers at Alang

GMB and Ship Recycling Industrial Association have provided housing facility to the workers in first phase for accommodating 1,008 persons. The facility is of the dormitory type comprising of 7 blocks (having a ground floor + 2 stories), canteen building, office building, shops, road, water supply and sanitary facilities with Sewerage Treatment Plant (STP), electrification etc. However, most of the migratory workers working in most recycling plots live poor life. These labours are migratory workers and directly not related to GMB and ship recycling operation.

(viii) Study of CRZ compliances

Activities in CRZ I (B)

During study it was observed that the major activities were carried in CRZ–I (B) area are beaching and cutting of the ships. The area around 300m in the CRZ-I (B) is mainly used for beaching and cutting of the ships in recycling yards. Although, around 70% plots have upgraded recycling yards/plot in green category as per Hong Kong convention and others are in process of upgradation. The ship breaking yards including ship breaking units are listed at 7(b) of schedule of EIA notification, 2006 covered under Category 'A', as it comes under the project requiring water front and fore shore 138 facilities. However, by grounding and cutting activities, temporarily disturbance benthic fauna takes place. Therefore, upgradation of ship recycling yard at Alang is highly required for the preservation of coastal environment.

Activities in CRZ–III region

All the developed plots and offices are within 120 m from high tide line, hence, in CRZ–III zone.

Activities in CRZ–IV region

As per information, anchoring of ships by buyers/recyclers is done CRZ–IV region before beaching. Hence, there are no other activities in the CRZ–IV region. Activities carried out in different CRZ classes at Alang–Sosiya ship–recycling yards are summarized in the table below:

Class of CRZ	**Activities**
CRZ–I (B)	I. Beaching of ships II. Cutting of ships in large pieces

	III. Transportation of large pieces to the respective yard
CRZ III	I. Construction of Offices of recycling yards II. Large pieces brought and cut to small pieces of transportable sizes III. Temporary storage of steels, electronic parts, wooden, hazardous wastes before hand over to authorized recyclers
CRZ IV	Anchorage of ships by buyers/recyclers before beaching.

8. That the conclusion of the report is being reproduce herein as under:

In general, the ecology of coastal water of Alang is seen similar to that of surrounding area of Bhavnagar and Dahej and it compares well with earlier studies of 2007-08 in Alang area. The adverse impact of ship breaking activities on water quality, sediment quality and biological characteristics was not significant except a certain intertidal region showing high concentration of PHc and some metals. The PHc values were significantly low during present study as compared to 2007-08 values. Phytoplankton and zooplankton values showed natural variability and not influenced by ship breaking activities. Influence of ship-breaking activities on intertidal macrobenthic fauna resulting poor standing stock, was localized at Alang. The results of bioaccumulation suggest that the concentration of all the metals are within the specified values for human consumption, except Fe. To confirm the impact of ship breaking activities on the ecology of Alang, the long-term monitoring is essential.

Present study reveals significant improvement in ship-recycling yards with respect to safety, security, health and environment. However, the living area of most of the shipbreaking workers is poor in regards to the infrastructure and sanitization, that can be prioritised in future. The residential accommodation developed by GMB jointly with shipbreakers association is either insufficient and/or there is no awareness among the workers. Although, around 70% recycling yards have adapted HKC to become to get green category certificate, many yards need to be upgraded to curtail pollution and enhance the security.

9. That the recommendations of the CSIR-NIO are as under:

a. To maintain a healthy environment of the coastal water of Alang, the ship-breakers are suggested to avoid the spillage of petroleum

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products andhazardous wastes and strictly follow the norms of GPCB.

b. Up gradation of the recycling yards needs immediate attention. Periodic monitoring for every year of the coastal ecology including marine biodiversityand bioaccumulation of metals in the marine organisms of Alang is needed. Any adverse impact on the coastal ecology including subtidal and intertidal should be brought in to the notice of concerned authority so as to take appropriate measures for future care of this region.

c. GMB should also oversee and ensure that the ship-recycling operation remains in safe & environmentally sound mode and therefore, entireoperations be supervised by Environmental Professionals of GMB.

A copy of the report is annexed herewith as **Annexure – I**.

10. That the Answering Respondent has highest regards for law and acts in a prudent manner with regard to the cases pending before this Hon'ble Tribunal.

11. That the present additional affidavit and report may kindly be taken on record and into consideration and this Hon'ble Tribunal may pass appropriate Order(s), direction(s) as deemed fit and proper under the facts and circumstances of the present case.

DEPONENT
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भारत सरकार, नई दिल्ली
Govt. of India, New Delhi

VERIFICATION

Verified at New Delhi on this the _______ day of July, 2020 that the contents of the above reply are true and correct, no part of it is false and nothing material has been concealed there from.

DEPONENT
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Fig. 3: CRZ Map (SHEET - 1)

Fig. 4: CRZ Map (SHEET - 2)

Fig. 5: CRZ Map (SHEET - 3)

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Marine Environmental Monitoring and Verification for Compliance of CRZ Notification at Alang Ship Recycling Yard

SPONSORED BY

Ministry of Environment, Forest and Climate Change

New Delhi

July 2020

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July 2020

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Mr. Atul Kotian	Biological Oceanography

EXECUTIVE SUMMARY

Alang is a census town in Bhavnagar district in the Indian state of Gujarat. The Alang and Sosiya ship - breaking yard (ASSBY) set up in 1982, is located in the Gulf of Khambat, 50 kilometers southeast of Bhavnagar. The Gulf of Khambhat is known for its high tidal range (Average 10 m) and makes it convenient to bring down the ships to shore based facilities. Intertidal zone exposes to around 3 km during ebb tide, which makes it convenient for ship breaking activities. The Gujarat Maritime Board (GMB) is the overall custodian for the world's largest Ship Recycling Yard located at Alang-Sosiya. The shipyards at Alang recycle approximately 30% of the volume of ships salvaged around the world. Stretching over ~10 km of the coastline, at present there are 167 ship recycling plots that are leased out to private entrepreneurs for ship recycling activity. GMB has a separate department for Alang which is responsible for execution of Ship Breaking Rules and Regulations for facilitating ship recycling activities at Ship Recycling Yards at Alang and Sosiya.

GMB has proposed for upgradation of existing ship recycling yard at Alang-Sosiya, Gujarat, which are: (i) Upgradation of existing ship recycling plots, (ii) Hazardous Material Removal Pre-Treatment Facility as Dry Dock, (iii) Additional Environmental Facility (Waste Oil Treatment and Incinerator Plant, (iv) Improvement of Labour Welfare Infrastructure (Housing, sanitation, water supply, hospital facilities, community center and community school) and (v) Additional Plots.

Accordingly, GMB obtained Environment and CRZ clearance from the Ministry of Environment, Forest and Climate Change through letter number F. No. 11-43/2014-IA III dated 2nd November 2016 with some specific and general conditions to GMB.

The Appeal No. 49 of 2018 (earlier Appeal No. 04 of 2017 (WZ) had been filed by Conservation Action Trust vs. Union of India & ORS under section 16 of the National Green Tribunal Act, 2010, challenging the Environment and CRZ Clearance granted on 02/11/2016 for the proposed project of upgradation of existing ship recycling yard at Alang-Sosiya, Gujarat for undertaking safe and environmentally sound ship recycling operations.

During the hearing of 19th August 2019, the Hon'ble NGT directed the Ministry of Environment, Forest and Climate Change to have an environmental audit conducted through an agency i.e. CSIR-National Institute of Oceanography or CSIR-NEERI. While conducting audit it may also be seen whether there is compliance of CRZ notification. Accordingly, the Ministry of Environment, Forest and Climate Change approached CSIR-National Institute of Oceanography (CSIR-NIO) for the same. The present study was conducted during February-March 2020 to meet the following objectives: a) To evolve prevailing status of water quality, sediment quality and flora and fauna of project area, b) To assess the impact of pollution due to ship breaking activities on the coastal ecology of Alang and c) To assess the compliance of CRZ notification.

To meet the above objectives, the coastal water of Alang-Sosiya was monitored in the pre-decided grid of an area of about 200 km^2 with 26 stations including 2 stations temporally (12 hours) (in grid size of 1km x 1km), and 1 additional stations towards offshore around 15 km away from the shore (as potential reference point) and 1 station towards Ghoga. The sampling network includes 6 locations at shore collection to find dissolution of pollutants, if any. The prevailing marine environmental quality assessed based on water quality, sediment quality and flora and fauna. Coastal waters of Alang are connected with Bhavnagar coast on one side and Dahej coast on the other side. CSIR-NIO, has large database, on coastal marine waters of Bhavnagar and Dahej coasts, which was used for comparison.

Water quality

The temperature around Alang varied in accordance with the air temperature. Although the air temperature varied in the range of 22.5 to 26.5°C, the water temperature was recorded from 22.0 to 25.5°C. There was no marked variation between surface and bottom temperature, which is expected from such a dynamic environment.

Levels of pH of the present study showed the normal range of the coastal water. Thus, the pH values of study area revealed a normal variation throughout this study (7.9-8.1).

The concentration of SS varied within a wide range (30- – 5219 mg/l) depending upon tide and current speed and time of collection. Although overall values of SS were high in the study area, some lower values found in the present study especially in surface water during slack period could be due to sluggish current resulting the settling down of SS load. The high SS values of the Alang region were in the agreement of the characteristic of Gulf of Khambhat. The source of high SS may be due to the load brought by several major rivers draining into Gulf and high turbulence generated by the tidal currents. Variation in turbidity was in line with SS and was in the range of 11.1-2441 NTU. The highest value of turbidity was recorded at the shore location, indicating result of wave action on the shore and churning out shore material in the water.

Salinity varied between 29.3 and 31.5 ppt. There was no particular trend of tidal variation in the salinity in the study region. Such values indicate that the flow of fresh water is minimized after withdrawal of monsoon, as there are many barrages constructed on the rivers to impound fresh water for different uses.

Dissolved oxygen measured during present study varied in the range of 5.2-6.6 mg/l. Significant wide variations in the concentration of DO were seen at shore segment (5.6-6.5 mg/l, av. 6.0mg/l), nearshore (5.2-6.6 mg/l, av. 5.7 mg/l), towards offshore (5.5-6.5 mg/l, av. 5.9 mg/l), offshore (5.7 mg/l) and towards Ghogha (6.5 mg/l), which together is indicative that the area sustains well oxygenated water.

The study revealed a variation of BOD ranged at 2.7-3.7 mg/l, which apparently suggest that the area does not sustain oxidizable organic matter, which can enhance the BOD value. The nutrients in terms of nitrogen and phosphorus occur in estuarine and coastal water in many forms which can be either in oxidation states, solid-liquid-gas phase or chemical structure. The forms of nitrogen are diverse ranging from nitrate (NO_3^- , +5) to ammonium (NH_4^+, -3) and compounds exist in all states in between. However, the dominant forms of nitrogen that exist in seawater are NO_3^--N, NO_2^--N and NH_4^+-N. NH_4^+-N which are produced during the oxidation of organic matter and get oxidized to NO_3^--N via NO_2^--N in the presence of sufficient quantity of DO in sea water.

The NO_3^--N concentration during the present study ranged at shore (26.0-32.2 µmol/l, av. 28.76 µmol/l), near shore showed (6.9-43.8 µmol/l, av 18.7µmol/l), towards offshore (9.3-32.7 µmol/l, av. 25.3 µmol/l), offshore (31.3-32.3, av 31.8 µmol/l) and towards Ghogha (30.6-31.0µmol/l, av. 30.8 µmol/l). Since the water was well mixed due to the high tidal currents, there was no significant variation in the concentration of NO_3^--N from surface to bottom.

The average concentration of NO_2^--N was always below 1 µmol/l in the coastal water of Alang. A wide variation in the concentration of NH_4^+-N (0.7-1.3 µmol/l, av. 0.95 µmol/l) at shore, 0.6-4.6 µmol/l (av. 2.3 µmol/l) nearshore, 0.3-2.2 µmol/l (av. 0.9 µmol/l) towards offshore, 0.5-0.7 µmol/l (av. 0.6 µmol/l) offshore and 1.4-1.6 µmol/l (av. 1.5 µmol/l) towards Ghogha was evident from the results. an enhanced concentration in nearshore (0.6-4.6 µmol/l) and towards Ghogha (1.4-1.6 µmol/l) during the present study, could be attributed to slightly increased level of organic load similar to the other area of Gulf of Khambhat. The PO_4^{3-}-P values ranged between 1.3-2.2 µmol/l at shore segment, 1.4-2.5 µmol/l at nearshore stations, 1.2-3.5 µmol/l towards offshore, 1.2-1.6 µmol/l at offshore and 0.1-0.2 µmol/l towards Ghogha. Some of the elevated concentration of PO_4^{3-}-P in the coastal water of Alang indicates the area is to be rich for nutrients similar to another region of Gulf of Khambhat. An increased concentration of PO_4^{3-}-P during October in the comparison of other months suggested the influence of land drainage on phosphate during postmonsoon.

The concentration of PHc ranged at shore segment (144.6-614.0 µg/l, av. 407.8 µg/l) followed by nearshore segment (34.2-143.0 µg/l, av. 82.6 µg/l) during February 2020. The values of PHc declined towards offshore (12.5-42.1 µg/l, av 22.1 µg/l), towards Ghogha (14.3µg/l) and in offshore (14.8 µg/l) were low. High concentration of PHc in shore and nearshore areas may be due to ship recycling activities. The variation of phenol ranged at shore segment (69.1-100.1μg/l, av 89.0 μg/l), nearshore segment (43.9-91.7 μg/l, av 69.1 μg/l) towards offshore (57.8-101.3 μg/l, av 76.0 μg/l), offshore (63.1 μg/l) and towards Ghogha (61.0μg/l) suggested the marginal high concentration of phenol. However, these values are in the agreement of other surrounding region of the Gulf of Khambhat and do not suggest the impact of ship breaking activities.

Dissolved metals

Concentration of metals Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Pb varied widely. However, offshore location showed lower concentration of metals except Mn. Concentration of As, Cd and Pb was low throughout the study area.

Sediment quality

The shore of Alang area was sandy whereas the nearshore and towards offshore region sustained silty-clay. However, offshore area was dominated by sandy-silt except. The upper region of intertidal was sandy, whereas middle and lower segment sustained silty-clay. This is expected since the swift currents do not favour the deposition of fine particles especially in the lower regions.

The variation of Al, Cr, Ti, Mn, Co, Pb, Cd, As, Fe, Ni, Cu, Zn and Hg varied in the Al of Cr of 86-413 μg/g (avg 150 μg/g), Mn of 730.6-2029 μg/g (avg 1005.7 μg/g), Fe of 5.76-23.4% (av 8.04%), Co of 30.43-82.18 μg/g (avg 39.12 μg/g), Pb of 12.04-80.32 μg/g (avg 19.26 μg/g), Cd of 0.13-0.52 μg/g (avg 0.21 μg/g), As of 3.96-26.07 μg/g (avg 8.94 μg/g), Ni of 37.11-67.13 μg/g (avg 47.1μg/g), Cu of 66.28-227.4 μg/g (av 93.81 μg/g), Zn of 67.75-1214.0 (av 151.6μg/g) and Hg of 0.02-0.28 μg/g (av. 0.09 μg/g) respectively were evident from the results.

The concentration of Al was minimum in the shore locations, but concentration of metals, especially Fe, Cr, Cu and Zn were high during all the sampling events, indicating their anthropogenic source i. e. potential ship breaking activities in the region. There was substantial decrease in the concentration of above metals towards offshore region. This may be due to the strong tidal current, in the region which do not allow settling of these metals.

Similar to the results of subtidal stations, the concentrations of selected metals such as Cr, Mn, Fe, Ni, Cu and Zn were enhanced in the upper most part of intertidal sediments of Alang. Thus Cr (112-326 μg/g, av 144.5 μg/g), Mn (73-1772 μg/g, av 1218 μg/g), Fe (7.6-17.2 %, av 10.0 %), Ni (37-.74 μg/g, av 57 μg/g), Cu (51-149μg/g,av 110 μg/g), Zn (69-608 μg/g, av 226 μg/g), As (7.4-18.8 μg/g, av 10.3 μg/g), Cd (0.19-0.81 μg/g, av 0.36 μg/g), Hg (0.03–0.55 μg/g, av. 0.19 μg/g) and Pb (9.8-66.8 μg/g, av 30.1 μg/g) showed wide variation and enhancement in the upper most segment of intertidal sediments.

The concentration of C_{org} varied in the range of 0.4-1.4% (av 0.9%), 0.4-1.1% (av 0.8%), 0.5-1.0% (av 0.8%), 0.5% and 1.0% in shore, nearshore, towards offshore, offshore and towards Ghogha segments respectively in the subtidal sediments.

Concentration of phosphorus in sediment varied between 637-812 μg/g (av 713 μg/g), 493-891 μg/g (av 689 μg/g), 659-966 μg/g (av 715 μg/g), 762 μg/g and 636 μg/g in shore, nearshore, towards offshore, offshore and towards Ghogha segments respectively in the subtidal region. The results indicated that there is no build-up of C_{org} and phosphorus in the subtidal sediment of Alang region and values recorded during present study compared well with earlier data in the same region.

As in the case of subtidal sediments, values recorded for C_{org} and phosphorus in the intertidal sediments of Alang were low and indicative of negligible accumulation of these elements. A wide variation in the concentration of PHc was observed. The PHc values varied in the range of 0.1-15.4 μg/g (av 2.8 μg/g), 0.1-1.2 μg/g (av 0.4 μg/g), 0.1-3.5 μg/g (av 1.0 μg/g), 1.1 μg/g and 1.0 μg/g at shore, nearshore, towards offshore, offshore and towards Ghogha segments respectively. These values clearly indicated the contamination of sediment in the shore stations. The PHc concentration at intertidal region recorded were: upper 0.1-4.0 µg/g (av 2.7 µg/g), middle 0.1-5.5 µg/g (av 3.5 µg/g) and lower 0.7-4.9 µg/g (av 3.9 µg/g). PHc values observed during present study reveals moderate contamination of intertidal sediment.

Biological characteristics

The total viable bacterial populations in the water samples ranged between 10 x 10^3 CFU/ml to as high as 2150 x 10^3CFU/ml. Other parameters like Total Coliform (TC), Faecal Coliform (FC) and *Escherichia coli* like organisms (ECLO) were not recorded from the study area except at stations 2 and 3.The total viable bacterial populations in the sediment samples ranged widely between 10 x 10^4CFU/g to as high as 1860 x 10^4CFU/g. Comparing the TVC counts of shore, nearshore and towards offshore segments, the shore segment recorded a higher TVC count in the sediments. TC was detected at stations 2, 14 and 22 with station 14 (72 x 10^3 CFU/g) having the highest count. FC was observed at station 14 and station 22. *Escherichia coli* like organisms (ECLO) and *Streptococcus faecalis* like Organism (SFLO) were not recorded from the sediments of the study area.

The chlorophyll a (0.01 – 4.72 mg/m^3; av 0.22 mg/m^3) and phaeophytin (0.0–1.21 mg/m^3; av 0.21 mg/m^3) concentrations indicated slight variations in the coastal ecosystem off Alang during February 2020. The highest concentrations of chlorophyll *a* were recorded at shore stations (0.10 – 4.72 mg/m^3; av 0.8 mg/m^3) and lowest at Ghogha (0.06 – 0.16 mg/m^3; av 0.10 mg/m^3). A decline in chlorophyll *a* was observed at towards offshore transect.

The concentration of phaeophytin were higher at near shore stations (0.01 – 0.99 mg/m^3; av 0.35 mg/m^3) and lower at offshore zone (0.01 – 0.07 mg/m^3; av 0.03 mg/m^3). Phaeophytin is a measure of dead cells and is an indirect indicator of stress conditions leading to deterioration of chlorophyll *a*.

The distribution of phytoplankton population (0.60 – 4.0 x 10^3 no/l; av 1.36 x 10^3 no/l) revealed variable phytoplankton cell count during February

2020 (Tables 5.3.5 and 5.3.6). Shore segment recorded comparatively higher phytoplankton cell count and ranged between 1.40 -4.0 x 10^3/l; av 2.1 x 10^3/l. *Navicula* (12.8%), *Thalassiosira* (12.3%), *Peridinium* (16.2%), and *Thalassiothrix* (10.8%), *Cyclotella* (10.7%) *and Coscinodiscus* (9.9%) were the most dominant genera present in the study area

A total of 21 genera of phytoplankton were recorded from the coastal waters off Alang during the present study. In general, the phytoplankton genera (2-10 no; av.6) did not exhibit any notable spatial variation. Shore segment (Av. 6 no) exhibited comparatively more numbers of phytoplankton genera than other segments of the study area.

A decreasing trend was observed in the distribution of zooplankton standing stock from nearshore segment to offshore region in the study area. Higher zooplankton standing stock in terms of biomass (0.6-13.7 ml/100 m^3; av 4.5 ml/100 m^3), and population (1.2 – 139.4x 10^3/100m^3; av 42.2x 10^3/100m^3) were present at the nearshore segment. The offshore segment recorded a low biomass ranged between (0.7 – 1.2 ml/100 m^3; av 1.0 ml/100 m^3), population (10.0 – 15.7x 10^3/100m^3; av 12.9x 10^3/100m^3). Copepods (83.8%) were the most dominant group followed by decapod larvae (9.5%) and chaetognaths (3.2%), suggesting a typical zooplankton community structure in the study area.

The intertidal results indicated a wide variation in biomass (0.0 – 20.3 g/m^2, wet wt.; av 2.5 g/m^2, wet wt.), population (0.0 – 5275 no/m^2; av 642 no/m^2) and faunal group (0-4, av 2) at the intertidal transects of Alang. Spatial variation was observed with higher intertidal macrobenthic standing stock at T-I as compared to other transects (T-II to T-IV). The high-water level transects were in general sandy in nature. Polychaetes (88.1%) was the most dominant group in the intertidal macrobenthic community, followed by brachyurans (7.2%) and pelecypods (3.1%).

During February 2020, the subtidal macrofaunal standing stock in terms of density and biomass ranged from 0.0-4200 no/m^2 (av 241 no/m^2) and from 0.0-13.6 g/m^2 wet wt (av 0.7 g/m^2; wet wt) respectively. Shore segment recorded comparatively higher macrobenthic biomass (0.0-13.6 g/m^2, wet wt.; av 2.1 g/m^2, wet wt.), and population (0.0 – 4200 no/m^2; av 730.5 no/m^2) at the study area. Polychaeta (90.2%) was the most dominant faunal group followed by isopods (4.8%), brachyurans (2.5%) and pelecypods (1.5%). The presence of a significantly poor macrobenthic standing stock at all segments of the coastal waters of Alang, which can be associated with the strong currents prevailing in the region and hard substratum present in some parts of the study area.

Uneven rocky bottom and high turbidity coupled with strong tidal currents make trawling or gill netting difficult and risky in the coastal water of Alang. Evidently, no active commercial fishing exists in this region excepting some gill netting or bag-netting or other traditional gears by local fishermen. Enquiries with the local fishermen also confirm that the trawlers generally do not operate in this area. There are about 17 species of finfishes, and 4 species of prawns were identified from the current sampling. The shoreline of the ship breaking yard at Alang is devoid of mangroves vegetation. Small patches of shunted mangroves were seen entirely out of the project area towards the eastern side of ship breaking yard.

Bioaccumulation

Concentration of all the metals in fishes analysed during present study was below the specified limit of USEPA and WHO, except Fe values which are higher site. Although the concentration of most of the elements were found to be below specified value, to understand the status of bioaccumulation in different organisms and the level of metal contents in their body tissues due to ship-breaking activities, continuous monitoring including the studies on bioaccumulation in the tissues of fishes and other marine organisms of the coastal water of Alang is essential.

IMPACT ASSESSMENT ON MARINE ENVIRONMENT

The assessment of marine ecology is based on the comparison of present study of Alang with earlier information available of the project site and the data of neighboring areas viz. Dahej and Bhavnagar. The results of water quality, sediment quality and biological characteristics are compared and discussed below:

Water quality

The values of water temperature (ºC) obtained during present study are compared with the values obtained in the surrounding areas and indicates that the temperature is comparable.

The pH remains more or less same in the entire Gulf for the years and does not suggest any impact of ship breaking activities.

The present SS values at Alang are higher than the earlier data of same region, such variation is expected in such dynamic area, which carries high load of suspended solid and high tidal current churns out the bottom sediment. The Alang contain higher average salinity compared to the surrounding region, which may be due to open mouth of Gulf connected with sea.

The average values of DO in the Alang area is above 5.5 mg/l and compares well with entire Gulf of Khambhat values, which explains healthy condition of the water quality off the Alang. Although the values of BOD in Alang area are slightly higher as compared to the earlier data of surrounding areas, higher BOD also observed in Ghogha during present study indicates common phenomena in the Gulf and not because of Alang ship recycling work.

The concentration of PO_4^{3-}-P observed during present study is lower as compared earlier data. However, the impact of ship breaking activities on the concentration of PO_4^{3-}-P is not discernible.

The land run off and wastes brough through different sources by rivers has resulted enhanced concentration of nutrient in the gulf of Khambhat. Such enhancement is due to delayed flushing out to openshore region. Hence, elevated concentration of nutrients is the general characteristics of the Gulf and not because of ship breaking activities.

Significantly higher concentration of PHc in the coastal water of Alang as compared to that of surrounding region clearly suggests PHc contamination in coastal water resulted due to shipbreaking activities.

The concentration of phenol recorded during the present study is almost similar to the values of phenol generally found in the other region of Gulf. The adverse impact of ship-breaking activities on the concentration of phenol was not seen during the present study.

Concentration of dissolved metals is compared with the values available for other regions. The concentration of some of the metals recorded in present study are within the values recorded in some other regions, hence, impact of ship recycling on the concentration of dissolved metals is not observed.

Sediment quality

Concentration of metals such as Cr, Fe, Cu, Zn Pb and Hg were higher in the sediment of shore locations, which are under direct influence of ship cutting areas.

The concentration of metals in intertidal region recorded during present study are lower than the earlier studies. Regular monitoring of the intertidal region can confirm the status of metals in the sediment of Alang.

The concentration of organic carbon is low in the sediment and does not show any adverse impact of ship breaking activities on its distribution at Alang. Thus, the ship breaking activities does not show any role on the concentration of organic carbon in intertidal sediment during the present study.

The overall scenario of total phosphorus in subtidal sediment indicates that there is no significant build-up of phosphorus in the sediment of Alang similar to that of surrounding region.

There was elevated concentration of PHc in the sediment of nearshore region of Alang. The level of PHc in the shore sediment is significantly higher than the values of offshore region. This may be due to the intertidal area which receives PHc during ship-breaking activities and spread towards the subtidal segment resulting in contamination to the nearshore sediments of Alang.

Biological characteristics

The concentration of chlorophyll *a* and phaeophytin are much lower in the nearshore and offshore water of Alang as compared to earlier data. Such variations are expected in an area having highest suspended load in the water, which prevents penetration of light.

Phytoplankton population in the coastal water of Alang was noticeably high as compared to the data available for the same area during 2001. However, species diversity was comparable during present study. Overall variation of phytoplankton pigments and generic diversity indicates natural variability in the region and not affected by the ship breaking activities.

Zooplankton standing stock in terms of biomass, population was high as compared earlier results in Alang region, but lower in Ghogha region. Total zooplankton groups from the current study in the coastal waters of Alang are more or less similar to that of earlier results in the area. The community structure of zooplankton was also in the agreement of earlier data of surrounding region. Thus, zooplankton standing stock in the coastal water of Alang does not reveal any influence of ship breaking activities.

The overall average values of intertidal macrobenthic standing stock are comparable to that of Dahej and Bhavnagar and the earlier data of 2007-08. The faunal group was in the agreement of the values of earlier data except a few occasions. The impact of ship breaking activities on the intertidal macrobenthic standing stock was in general not significant except localized poor stock. There were some intertidal areas where the ship breaking activities were very active resulting in petroleum spills at the shore recorded during 2007-08 showing markedly poor macrobenthic standing stock confirming the impact of ship-breaking activities localized. Such spill was not observed during present study in the intertidal region. The biomass and population recorded during present study were better than Bhavnagar region and population was better than earlier record of Alang, indicating that there is no impact of ship breaking activities.

In Gulf of Khambhat, water current often exceeds > 3.0 m/s, thus it does not allow to settle the bottom sediment, which is reflected in the form of benthic community and most of the time bottom sediment does not show any benthic population.

Uneven rocky bottom and high turbidity coupled with strong tidal currents make trawling or gill netting difficult and risky in the coastal water of Alang. Evidently, no active commercial fishing exists in this region excepting some gill netting or bag-netting or other traditional gears by local fishermen. Enquiries with the local fishermen also confirm that the trawlers generally do not operate in this area.

The intertidal area of Alang was devoid of mangroves vegetation. Thus, the question of adverse impact of ship breaking activities on mangroves does not arise.

The result of present study is compared with the marine water quality standards which indicates that values of pH, DO and BOD are almost in the agreement of water quality standards suggesting a healthy coastal environment. Floating matters oil, grease and scum (including petroleum products), as standard is 10 mg/l (10,000 µg/l) and PHc value (12.5-614.0 µg/l) is much lower than standard.

Ship recycling yards

Since India has accepted it, ship recyclers at Alang-Sosiya have willingly acquired a statement of compliance to HKC by International Classification Societies as recognized by DG Shipping. During field collection random number of ship recycling yards were visited to evaluate the status of recycling yards. During visit it was found that as per the convention followed by recycler, some of yards come under green category and some have still to come to the level so as to receive green category status. Thus around 70% of recycling yards come under green category.

Safety measures in the recycling yards at Alang

It was observed that the workers at ship recycling yards were well acquainted with safety and security method and all those working in the plots were found wearing helmets, safety jackets and boots. A training institute has been established by GMB at Alang for the training of workers before their engagement for actual work of ship breaking and other activities. From the personal communication with shipbreaking workers, it was found that the quantum of accident is very less in recent years, due to the training and safety measures taken in the process.

Health facilities at Alang

Alang Red Cross Hospitals for Primary Medical Treatment. The hospital is financially assisted by GMB. GMB extended full support to create Multi Speciality Hospital at Alang itself which provides medical services to manpower at Ship Recycling yards and residents of nearby 45 villages around Alang. Another Private Hospital permitted by GMB also known as “Alang Hospital” for Secondary Medical Care. It has 33 beds. It is equipped with an X-ray facility and medical stores. Two doctors are available permanently. For any eventuality, expert doctors are also called to provide treatment to the affected workers.

Staying facility for ship recycling workers at Alang

GMB and Ship Recycling Industrial Association have provided housing facility to the workers in first phase for accommodating 1,008 persons. The facility is of the dormitory type comprising of 7 blocks (having a ground floor + 2 stories), canteen building, office building, shops, road, water supply and sanitary facilities with Sewerage Treatment Plant (STP), electrification etc.

However, most of the migratory workers working in most recycling plots live poor life. These labours are migratory workers and directly not related to GMB and ship recycling operation.

CRZ COMPLIANCES

The entire ship recycling activities at Alang-Sosiya come under CRZ I(B), CRZ-III and CRZ-IV. The ship breaking yards including ship breaking units are listed at 7(b) of schedule of EIA notification, 2006 covered under Category 'A', as it comes under the project requiring water front. However, by grounding and cutting activities, temporarily disturbance of benthic fauna takes place. Therefore, upgradation of ship recycling yard at Alang is highly required for the preservation of coastal environment.

CONCLUSIONS

In general, the ecology of coastal water of Alang is seen similar to that of surrounding area of Bhavnagar and Dahej and it compares well with earlier studies of 2007-08 in Alang area. The adverse impact of ship breaking activities on water quality, sediment quality and biological characteristics was not significant except a certain intertidal region showing high concentration of PHc and some metals. The PHc values were significantly low during present study as compared to 2007-08 values. Phytoplankton and zooplankton values showed natural variability and not influenced by ship breaking activities. Influence of ship-breaking activities on intertidal macrobenthic fauna resulting poor standing stock, was localized at Alang. The results of bioaccumulation suggest that the concentration of all the metals are within the specified values for human consumption, except Fe. To confirm the impact of ship breaking activities on the ecology of Alang, the long-term monitoring is essential.

Present study reveals significant improvement in ship recycling yards with respect to safety, security, health and environment. However, the living area of most of the shipbreaking workers is poor in regards to the infrastructure and sanitization, that can be prioritised in future. The residential accommodation developed by GMB jointly in with shipbreakers association is either insufficient and/or there is no awareness among the workers. Although, around 70% recycling yards have adapted HKC to become to get green category certificate, many yards need to be upgraded to curtail pollution and enhance the security.

RECOMMENDATION

To maintain a healthy environment of the coastal water of Alang, the ship-breakers are suggested to avoid the spillage of petroleum products and hazardous wastes and strictly follow the norms of GPCB.

Upgradation of the recycling yards need immediate attention. Periodic monitoring for every year of the coastal ecology including marine biodiversity and bioaccumulation of metals in the marine organisms of Alang is needed. Any adverse impact on the coastal ecology including subtidal and intertidal should be brought in to the notice of concerned authority so as to take appropriate measures for future care of this region.

GMB should also oversee and ensure that the ship recycling operation remains in safe & environmentally sound mode and therefore, entire operations be supervised by Environmental Professionals of GMB.

List of Tables and Figures

1 INTRODUCTION

1 INTRODUCTION

1.1 Background

Alang is a census town in Bhavnagar district in the Indian state of Gujarat. The Alang and Sosiya ship – breaking yard (ASSBY) set up in 1982, is located in the Gulf of Khambhat, 50 kilometers southeast of Bhavnagar. The Gulf of Khambhat is known for its high tidal range (Average 10 m). Intertidal zone exposes to around 3 km during ebb tide, which makes it convenient for ship breaking activities. Large supertankers, car ferries, container ships and a dwindling number of ocean liners are beached during high tide. Alang is one of the largest ship–recycling yards in the world where thousands of workers are engaged to scrap ships. The Gujarat Maritime Board (GMB) is the overall custodian for the world's largest Ship Recycling Yard located at Alang–Sosiya. The shipyards at Alang recycle approximately 30% of the volume of ships salvaged around the world. Stretching over ~10 km of the coastline, at present there are 167 ship−recycling plots that are leased out to private entrepreneurs for ship−recycling activity. GMB has a separate department for Alang, which is responsible for execution of Ship Breaking Rules and Regulations for facilitating ship−recycling activities at Ship Recycling Yards at Alang and Sosiya. According to GMB 8062 ships scrapped till February 2020, with 63547493 MT light displacement (LDT).

Alang receives ships from across the world sometime containing left over dangerous pollutants, which may be toxic wastes, oil, polychlorinated biphenyls, petroleum hydrocarbons and heavy metals etc.

GMB has proposed for upgradation of existing ship−recycling yard at Alang–Sosiya, which are as follows;

1. Upgradation of existing ship−recycling plots
2. Hazardous Material Removal Pre–Treatment Facility as Dry Dock
3. Additional Environmental Facility (Waste Oil Treatment and Incinerator Plant

4. Improvement of Labour Welfare Infrastructure (Housing, sanitation, water supply, hospital facilities, community center and community school)
5. Additional Plots

Accordingly, GMB obtained Environment and Coastal Regulation Zone (CRZ) clearance from the Ministry of Environment, Forest and Climate Change through letter number F. No. 11–43/2014–IA III dated 2nd November 2016, with some specific and general conditions to GMB.

The Appeal No. 49 of 2018 (earlier Appeal No. 04 of 2017 (WZ).had been filed by Conservation Action Trust vs. Union of India & Ors under section 16 of the National Green Tribunal Act, 2010, challenging the Environmental Clearance granted on 02/11/2016 for the proposed project of upgradation of existing ship−recycling yard at Alang–Sosiya, Gujarat for undertaking safe and environmentally sound ship−recycling operations. The Applicant requested 0n 19/03/2018 to transfer the matter from NGT (WZ), Pune to NGT– Principal Bench as western zone bench of NGT has not been functional due to single member bench and the adjudication of the present matter had become uncertain. The matter got transferred to NGT– Principal Bench through order dated 21/03/2018 and appeal no: 49 of 2018. Thereafter in the matter the pleadings have been completed in the case and is waited for final hearing.

During the hearing of 19th August 2019, the Hon'ble NGT directed the Ministry of Environment, Forest and Climate Change to have an environmental audit conducted through an agency i.e. CSIR–National Institute of Oceanography or CSIR–NEERI. While conducting audit it may also be seen whether there is compliance of CRZ notification. Accordingly, the Ministry of Environment, Forest and Climate Change approached CSIR–National Institute of Oceanography (CSIR–NIO) for the same.

The Coastal waters of Alang are connected with Bhavnagar coast on one side and Dahej coast on the other side. The CSIR–NIO, has large database on the coastal marine waters of Bhavnagar and Dahej coasts, which will be used to evaluate the present status of Alang region. The present study was conducted during February–March 2020 to meet the following objectives:

1.2 Objectives

a) To evolve the prevailing status of water quality, sediment quality and flora and fauna of project area.
b) To assess the impact of pollution due to ship breaking activities on the coastal ecology of Alang.
c) To assess the compliance of CRZ notification

1.3 Scope of studies

The coastal water of Alang–Sosiya would be monitored in the pre–decided grid of an area of about 200 km^2 at 26 stations including 2 stations temporally (12 hours) (in grid size of 1km x 1km), and 1 additional stations towards offshore around 15 km away from the shore and 1 station towards Ghoga. Also, this includes 6 locations sampled for shore collection to find dissolution of pollutants, if any. The prevailing marine environmental quality would be assessed based on water quality, sediment quality and flora and fauna as detailed below:

1.3.1 Water quality

The samples obtained from the surface as well as at bottom (for depth exceeding 3 m) would be analysed for temperature, salinity, pH, SS, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), nitrate, nitrite, ammonia, phosphate, Petroleum Hydrocarbons (PHc), phenols and dissolved metals.

1.3.2 Sediment quality

Sediment collected from the subtidal water quality stations (26) as well as selected intertidal areas (4 intertidal transects T I – T IV with High Water Level (HWL), Mid Water Level (MWL) & Low Water Level (LWL), will be analysed for organic carbon (C_{org}), phosphorus, chromium (Cr), manganese (Mn), iron (Fe), aluminum (Al), cobalt (Co), nickel (Ni), copper (Cu), arsenic (As), zinc (Zn), cadmium (Cd), lead (Pb), mercury (Hg) and PHc to evolve prevailing sediment quality.

1.3.3 Flora and fauna

The biological status for the area will be assessed based on microbial characteristics including faecal Coliform and phytopigments, phytoplankton population and their species diversity; zooplankton biomass, population and group diversity; macrobenthic biomass, population and group diversity.

1.3.4 Bioaccumulation

Bioaccumulation of heavy metals in the tissues of fishes and prawns prevailing in the region will be studied.

1.4 Approach

The ship breaking activities at Alang extends around 10 km along the shore of coastal water of Alang–Sosiya. Some adverse impacts, due to ship breaking activities on marine ecology of the nearshore waters of Alang are expected. However, in planned schemes, these impacts are identified in advance in order to take suitable mitigation measures at the plan and design stages of activity. Hence, identification of impacts on marine ecology requires detailed and reliable information on water quality, sediment quality and flora and fauna of the project area against which perturbation due to activities can be compared.

It is inevitable that the ship breaking activities would cause environmental impacts, the intensity of which would vary depending on several factors such as the quality and quantity of wastes, the assimilative capacity of receiving nearshore seawater and degree of ecological sensitivity of marine area. As the enhancement of levels of pollutants in the receiving water over the natural background is the prime factor controlling the extent of influence on the ecology, it is crucial to define the baseline environmental quality against which the monitoring results could be compared. However, a natural marine environment is prone to spatial and temporal changes, associated with the tidal movements and seasonal fluctuations. Hence the impact of activities on ecology requires time series baseline data over a sufficient duration which is not available in the present case.

CSIR–NIO has got extensive data on water quality, sediment quality and flora and fauna of the surrounding area (Bhavnagar and Dahej). Apart from above CSIR–NIO conducted marine environmental monitoring during 2007–08 in the Alang–Sosiya region. These data from the CSIR–NIO data bank and the data collected from the coastal water of Alang–Sosiya region during present study will be used in this report to meet the above objectives.

CRZ demarcation maps prepared by National Centre for Sustainable Coastal Management (NCSCM) and provided by the GMB will be used to assess the compliance of the CRZ notifications.

2 PROJECT INFORMATION

2 PROJECT INFORMATION

This section is mostly based on the information provided by the GMB.

2.1 The Inception of the Alang–Sosiya Ship Recycling Yard

i) Alang is a census town in Bhavnagar District in the Indian state of Gujarat. Alang–Sosiya Ship Recycling Yard (ASSRY), one of the largest ship–recycling yards in the world, is located on the western coast of India in the Gulf of Cambay. In the past three decades, its beaches have become a major world–wide center for ship breaking. The shipyards at Alang recycle approximately 30% of the volume of ships salvaged around the world. It is considered the world's largest graveyard of ships. Large supertankers, car ferries, container ships and a dwindling number of ocean liners are beached during high tide.

ii) Operations in Alang recycling yard started in 1982 and today it is one of the choicest ship–recycling destinations for the ship owners around the world. The longest ship ever built, MV Seawise Giant, was beached there for demolition in December 2009. Alang accounts for nearly 90% of the ships broken in India, with other centers located in the states of West Bengal, Andhra Pradesh, Kerala, Tamil Nadu, and Maharashtra. Noting its level of compliance, its past development, in addition to proposed expansion, Alang represents the Indian image of ship–recycling.

iii) Recycling of ships on a large–scale requires extensive care on issues like physical, social and environmental infrastructure as well proper safety and environment management. Successful implementation of safe and environmentally sound ship−recycling requires not only financial resources, but also many other governing factors such as specialized knowledge of ship dismantling, chemistry between the ship recyclers and workers, availability of land and preparedness of ship recyclers and regulators to undertake skillful operations. The GMB is the State Government Agency working as the extended arm of Port State Control. DG Shipping, India, a designated regulator, has put in sincere efforts to develop these requirements to accelerate the growth of the ship–recycling industry, specifically at Alang.

iv) Though the largest one, in order to boost this recycling industry, Alang Ship Recycling has undergone continued efforts and has been adopting a 'best practice approach' to strengthen in the areas of infrastructure, regulations, health and safety, environmental aspects, economics and marketing, and thus to contribute to almost one third of the global ship−recycling volume.

2.2 Profile of Ship Recycling Plots

i) Alang–Sosiya Ship Recycling yards are aligned with the North–South Gujarat Coast in Bhavnagar District, as shown in the maps below. The yard has plots of various sizes, perpendicular to the coastline. The slope of the plots from shore to sea is 1:30 plus.

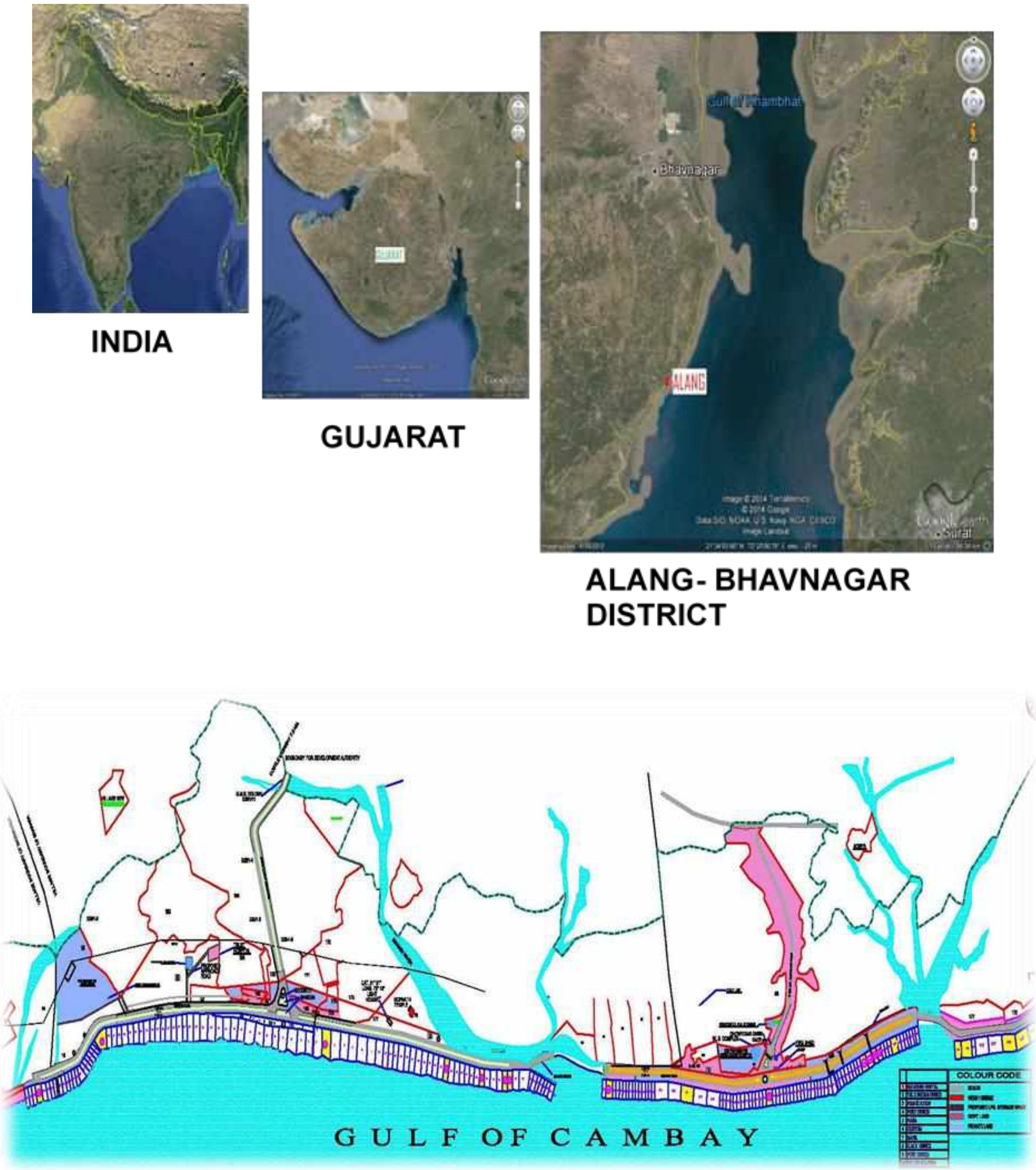


Figure 2.2.1:Location of Alang-Sosiya Ship Recycling yards

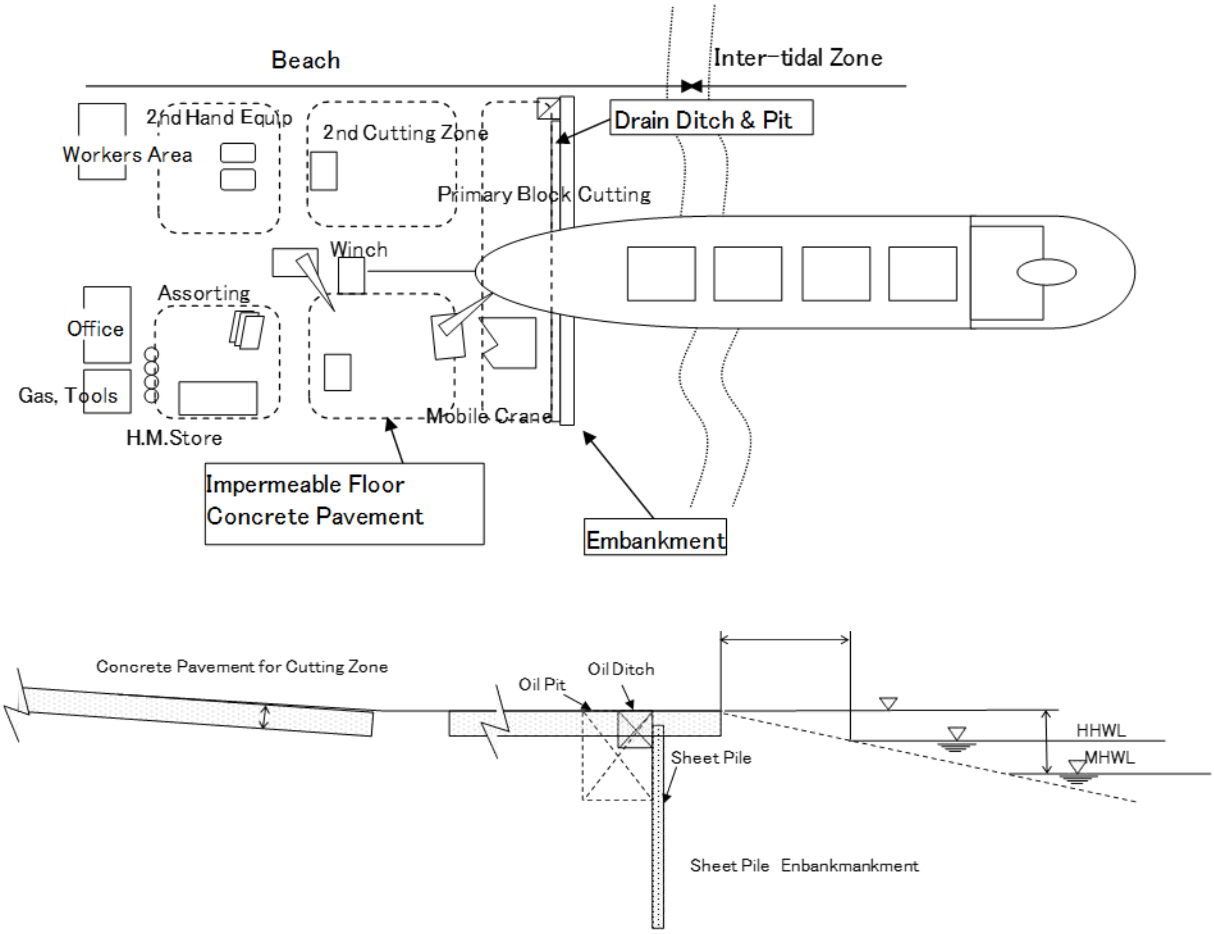
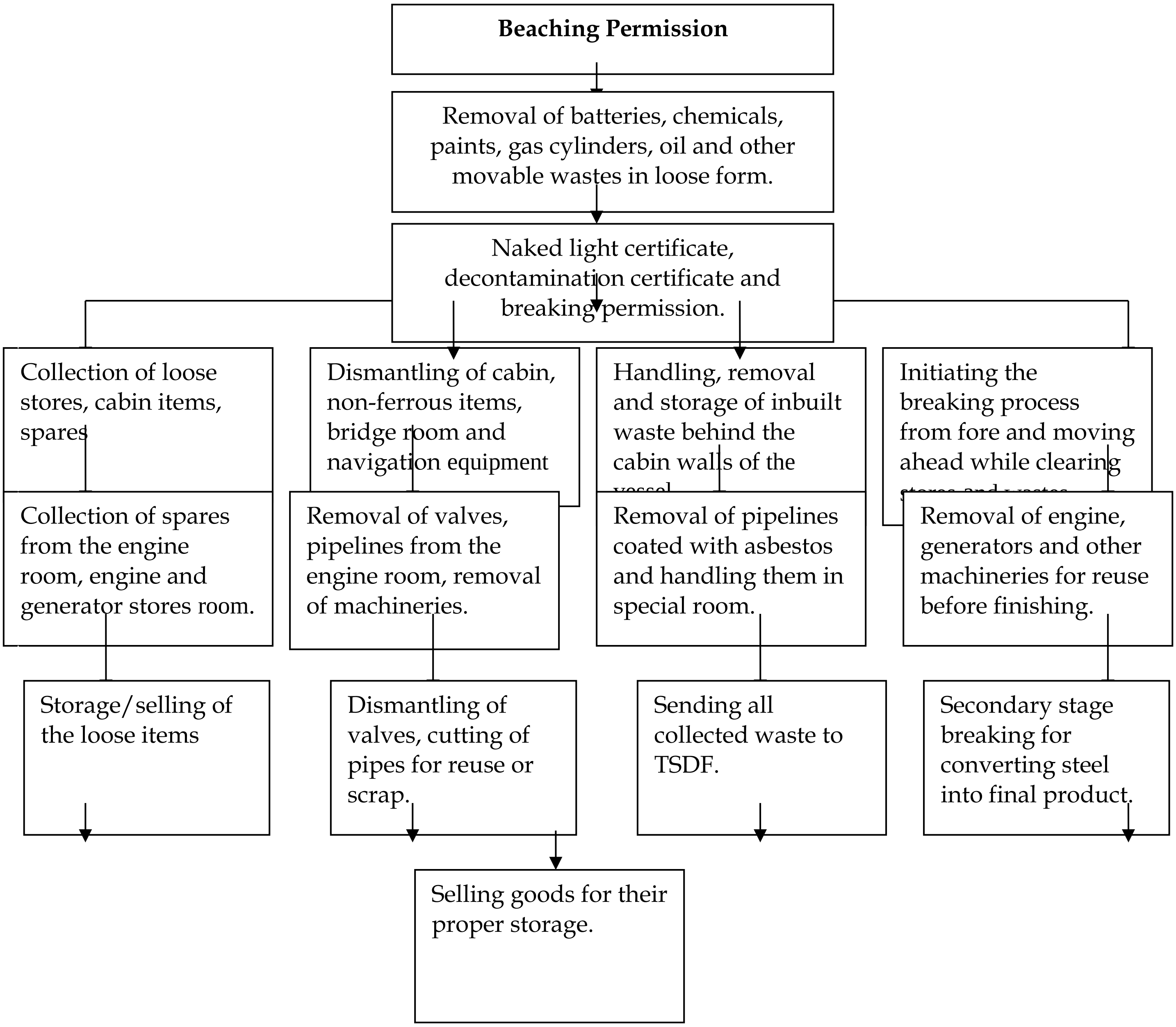


Figure 2.2.2: Schematic diagram of ship−recycling yards

2.3 Ship Scrapped and Recycling Process

The ship−recycling process is described in the chart as follows:



2.3.1 Number of ships scrapped down every year

The number of ships recycled at ASSRY since its inception at Alang and LDT value are given in the Table below:

YEAR	NOS. OF SHIPS	LDT IN MT
1982-83	5	24716
1983-84	51	259387
1984-85	42	228237
1985-86	84	516602
1986-87	61	395139
1986-88	38	244776
1988-89	48	253991
1989-90	82	451243
1990-91	86	577124
1991-92	104	563568
1992-93	137	942601
1993-94	175	1256077
1994-95	301	2173249
1995-96	183	1252809
1996-97	348	2635830
1997-98	347	2452019
1998-99	361	3037882
1999-00	296	2752414
2000-01	295	1934825
2001-02	333	2727735
2002-03	300	2420724
2003-04	294	1986123
2004-05	196	938976
2005-06	101	480361
2006-07	136	760800
2007-08	136	643437
2008-09	264	1945540
2009-10	348	2957225
2010-11	357	2816231
2011-12	415	3856072
2012-13	394	3575992
2013-14	299	3059890
2014-15	275	2490152
2015-16	249	2431752
2016-17	238	2535708
2017-18	253	2433347
2018-19	219	1773249
2019-20 (up to Feb 2020)	**195**	**1546158**
Total	**8062**	**63547492**

2.3.2 Comparison between conventional route and by ship−recycling route for producing 4 MT steel

Looking at the ship−recycling activities carried out at Alang since 1982 to till date, about 63.2 million ton of steel has been generated which directly reduced around 103 million-ton carbon emission as compared to steel production has generated through conventional route. Thereby, Alang ship−recycling yard has contributed largely towards environment by reducing generation of greenhouse gases for production of steel. The pollution potential of ship breaking activities as follows;

Resource consumption	Through Integrated Iron & Steel Route (from Iron ore)	Ship Recycling route (including re–rolling)
Iron Ore (t)	7 million	Nil
Refractory materials/additives (t)	2.8 million	Nil
Coal (t)	6.2 million	Nil
Process Chemicals (t)	0.16 million	Nil
Water (KL)	10000–24000	800
Oxygen (Nm^3)	$260x10^6$	$72x10^6$
Fuel Oil (t)	0.12 million	0.22 million
LPG (t)	Nil	0.016
Energy (as fuel & electricity)	80000×10^{12} J*	102640×10^{12} J
Green House Gas emission (CO_2) (t)#	7.32	0.8 (~ 90% reduction in carbon footprint as compared to traditional route for steel production)

*It does not include energy required for transport of raw materials to plant.

Source:

1. Report "Pollution Potential od Ship breaking activities" prepared by MECON Ltd. for CPCB in 2001.
2. Technical Report no.38 UNEP,1997.
3. # STEEL'S CONTRIBUTION TO A LOW CARBON FUTURE AND CLIMATE RESILIENT SOCIETIES world steel position paper published by World Steel Association.

2.3.3 Type of Ships

General Cargo, Bulk Carrier, LPG Tanker, Oil Tanker, Petroleum/Chemical Tanker, Passenger, Ro–Ro /Passenger, Container, Tug, Integrated Tug Barge, Cement Carrier, Reefer, Live Stock Carrier, Pure Car Carrier etc. are the ships, which get dismantled at ASSBY at Alang–Sosiya.

2.3.4 Name of Country from where the ships are brought

Ships are brought for demolition from various countries like Germany, Russia, China, United States of America, United Kingdom, Ukraine, Greece, Italy and Spain etc. from all around the world.

2.3.5 Quantity and Quality of left–over materials on the ships

Various types of wastes such as plastic, rubber, ceramic, Ferrous and Non–ferrous Metals, Oily waste, Lead Acid Batteries, Asbestos Containing Material (ACM) waste, Glass Wool, Thermocol, Paint Chips, TBD, PCB, Wood waste, Broken Glass, Food Waste, Expired Medicines and electronic equipment are generated during the course of ship breaking activity.

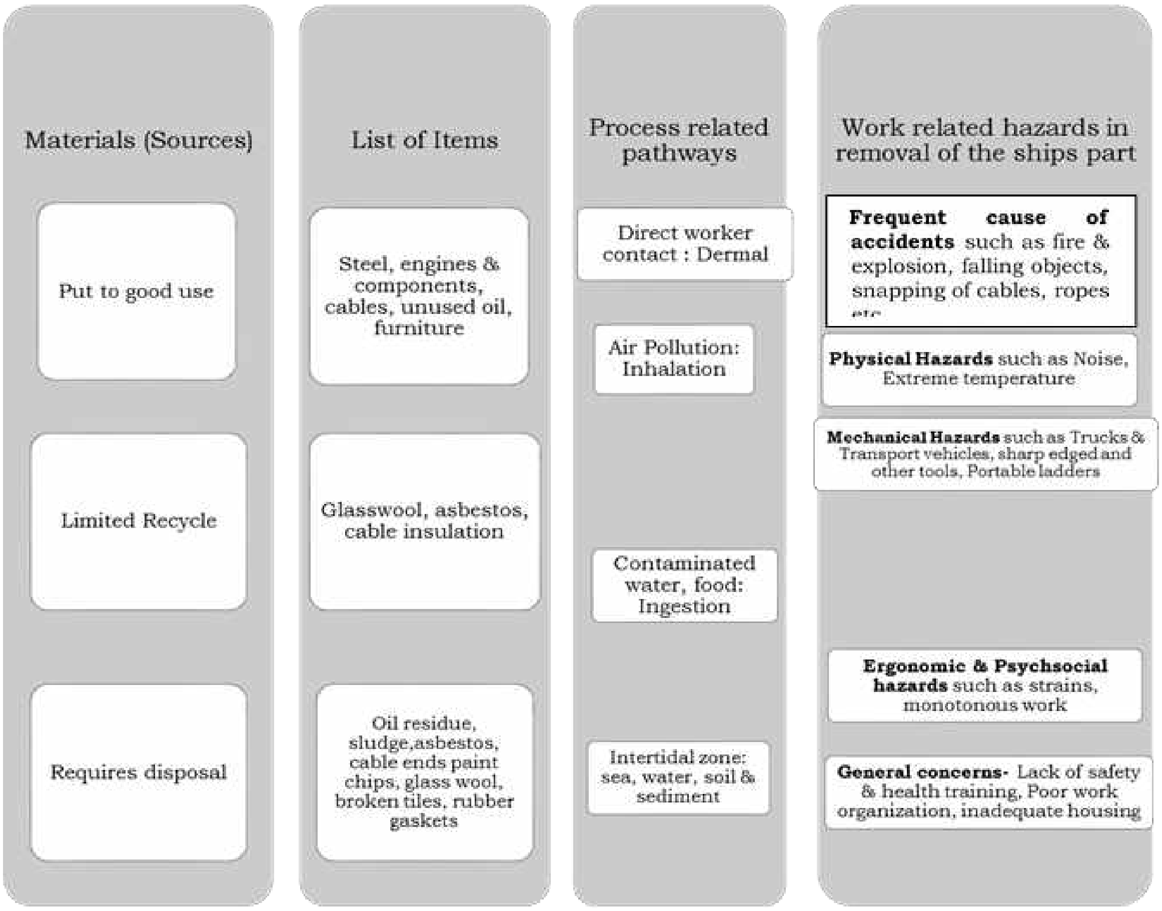
2.3.6 Hazardous Material

i) A ship consists mostly of steel. Consequently, at the end of its useful life, it becomes a source of ferrous scrap particularly suited for reprocessing into simple steel products such as steel rods used in civil construction, plates, angel sections, furniture, wood, sanitary ware, usable equipment such as pumps, motors, valves, generators, etc. The reprocessing of steel is an alternative to steel production from ore, and represents a significant saving in terms of energy consumption. Although scrap steel provides most of a ship's value, other lucrative returns come from non–ferrous items such as diesel engines, generators, deck cranes, compasses and other fixtures that can be resold. Ship scrapping is a sustainable activity from a resource utilization point of view. Ship recycling operations would become a hazard to workers and generate hazardous waste that could enter the natural environment if the following significant aspects were not addressed appropriately:

a) Occupational Safety & Health; and

b) Environments

ENVIRONMENTAL & SAFETY RELATED CONCERNS IN SHIP RECYCLING



ii) GMB has therefore provided the following hardware infrastructure to enhance and improve work conditions for labourers working in ship−recycling and also manage hazardous waste materials in such a way that it is disposed scientifically in a dedicated Treatment Storage and Disposal Facility (TSDF).

2.4 Safety Training and Labour Welfare Institute at Alang

The training institute of GMB in Alang has been in operation for the last 14 years and has trained more than 120,000 workers so far. Each year, more than 8,000 workers are trained in the Institute. GMB has hired an agency to train the new workers, as per the National Skill development Standards.

The various packages of training are as follows:

Sr. No.	Trainings
1	Introduction to Ship Recycling
2	Steel / Metal Cutting
3	Locational hazards
4	Hazards in Ship Recycling
5	Safety in Material Handling
6	Fire & Explosion Safety
7	First-Aid & Emergency Response
8	Basic awareness about environment and cleanliness

Only after receiving certification from the GMB, workers considered trained for the above hazards, and are permitted to work in the plots.

Workers at the training and welfare center, Alang

2.5 Treatment Storage Disposal Facility (TSDF)–Integrated Hazardous Waste Management Facility at Alang

i) Between 2001 and 2002, GMB engaged one of India's top consultants, M/s Engineers Indian Ltd (EIL), New Delhi for the preparation of Comprehensive Waste Management Plan. For the first time, GMB quantified and characterized hazardous and non–hazardous waste generated from ship−recycling. GMB has its in–house Environment Management Cell had assessed many ships beached at Alang and witnessed recycling of the ships had studied mass balance of the recycled ships including tanker, bulk carrier, container vessel, referred vessel and passenger liner. M/s EIL performed laboratory tests and studied Material Safety Data Sheets for those materials, which were neither categorized as hazardous waste or non–hazardous waste.

ii) The following table prepared during 2001–2002 study, shows the estimated quantities of waste of a hazardous and non–hazardous nature for 350 ships of average light displacement (LDT) of 10,000 MT.

Description of waste	Quantity in tons per 350 ships per year	Category Hazardous (H) or Non-Hazardous (NH) waste
Asbestos containing waste	175	H
Glass-wool and Thermocol	2000-3000	H
Sludge residues and contaminated materials	400	H
Plastics and cable pieces (with paint chips)	20	H
Rubber	49	NH
Fibre glass pieces	40	NH
Rexene pieces	50	NH
Iron Scale	900	H
Chicken mess	175	NH
Cardboard and packaging materials	35	NH
Glass pieces	175	NH
Municipal solid waste	5000	NH
Cement tile pieces	10000	NH
Bilge water	10,500 Kilo Litres	H

Accordingly, GMB has constructed landfill sites, as follows, in 2004– 2005:

a) Three cells i.e. disposal for asbestos and glass wool waste (43,000 m^3), disposal for industrial hazardous waste (10,200 m^3) and disposal for municipal solid waste (8,700 m^3) in 2005 – 2006.

b) Looking at completion of life of the landfill cells constructed in 2005 and need of other environment infrastructures at the site, it was decided to upgrade the existing TSDF site.

c) GMB has already upgraded the site during 2011–2013 with new landfill cells (100,000 m^3) other facilities i.e. incinerator (5 Metric Ton/day), bilge water treatment plant (30 Kiloliters per day) and firefighting system and thus it becomes a fully integrated waste management facility.

2.6 Existing environmental facilities at Treatment Storage Disposal Facility (TSDF) Site, Alang

	Item		Capacity
1	Landfill cell for Hazardous waste		70,000 m^3
2	Landfill cell for Municipal solid waste		35,000 m^3
3	Common hazardous waste incinerator		5 Mt/day
4	Fire hydrant system	Underground reservoir	200 m^3
		Over ground reservoir	5 m^3 × 2
5	Effluent treatment plant		30 KLPD

2.6.1 Asbestos Handling at Alang

a) Asbestos Containing Material (ACM) handling, scrapping and packing as per the US Occupational Safety and Health Administration (OSHA) guidelines.

b) Negative pressure chamber for removal, handling and packing of ACM onshore.

c) Negative pressure inflatable unit for removal, handling and packing of ACM onboard.

d) Bi–yearly medical tests for all involved in removal, scrapping, handling and packing of ACM.

e) Asbestos Personal Protective Equipment (PPE) Kit' usage.

f) Disposal for 'zero' exposure to ACM during removal and scrapping.

g) Handling and packing of ACM.

h) Training and awareness about ACM Health Hazards to all ACM handlers.

2.6.2 Waste Disposal at TSDF–Alang Site

Year	No. of ships	LDT	Hazardous Waste (HW)			Municipal Solid Wastes (MSW)		
			HW in MT	Kg of HW/ LDT of ship)	% of HW against LTD of ship	MSW in (MT)	Kg of MSW/LDT of ship)	% of MSW against LTD of ships
2006-07	136	760800	1032.86	1.358	0.136	46.205	0.061	0.006
2007-08	136	643437	2017.03	3.135	0.313	828.425	1.287	0.129
2008-09	264	1944162	5027.84	2.586	0.259	855.265	0.440	0.044
2009-10	348	2937802	5418.04	1.844	0.184	726.175	0.247	0.025
2010-11	357	2816236	8215.31	2.917	0.292	729.1	0.259	0.026
2011-12	415	3847000	8318.98	2.162	0.216	552.43	0.144	0.014
2012-13	394	3847566	10555.4	2.743	0.274	770.55	0.200	0.020
2013-14	298	3059891	7505.89	2.453	0.245	889.025	0.291	0.029
2014-15	275	2490152	7279.4	2.923	0.292	305.865	0.123	0.012
2015-16	249	2431752	4996.31	2.055	0.205	368.655	0.152	0.015
2016-17	259	2717933	6568.21	2.417	0.242	650.58	0.239	0.024
2017-18	253	2433347	7793.46	3.203	0.320	640.01	0.263	0.026
2018-19	219	1773249	6708.14	3.783	0.378	708.27	0.399	0.040
2019-20 upto Feb 2020	195	1546158	6937.790	4.487	0.449	420.730	0.272	0.027

GMB, Gujarat Pollution Control Board (GPCB) and State Government are constantly promoting the approach of maximizing recycling, reprocessing and reuse of the obsoleted materials leading to reduction of the above waste receipt at Alang's TSDF site from 1% of weight of the waste which was estimated during the time of designing the TSDF to less than 50% of that estimate.

GMB is constantly carrying out the drives for reuse, reduce and recycle of ship−recycling materials leading to minimization of waste receipt at TSDF at Alang.

2.7 Health facilities at Alang

Alang Red Cross Hospitals for Primary Medical Treatment. The hospital is financially assisted by GMB. GMB extended full support to create Multi Specialty Hospital at Alang itself, which provides medical services to manpower at Ship Recycling yards and residents of nearby 45 villages around Alang.

These services include Ortho, Physician, Skin, Dental, Paediatric, X–Ray, Patho–Lab, and ECG etc with indoor facility with NO CHARGE to workers.

1. This hospital has been opened with in March–2019 in Public Private Partnership Model (PPP) with 24 hours round the clock services. In last six month, total 27049 patients have been medically checked with 612 indoor patients, 1154 orthopaedic patients, 2710 skin patients, 3004 physician patients, 1074 X–rays, 12321 pathology lab testing cases, in emergency ECG 240 cases, burning 38 cases and common injuries 925 patients have been given medical treatments.

2. Another Private Hospital permitted by GMB also known as “Alang Hospital” for Secondary Medical Care. It has 33 beds. It is equipped with an X–ray facility and medical stores. Two doctors are available permanently. For any eventuality, expert doctors are also called to provide treatment to the affected workers.

3. In cases of emergency workers are given immediate treatment in the above hospitals, depending upon the types of accident and irrespective of

limit of ESIC cover. In addition to above, following further facilities are also available at Alang:

(i). Dedicated ambulances are made operational by GMB;

(ii) As per Rule 10 of the Factory Act, 1948, the medical examination of workers is carried out by SRIA, engaging Associate Fellow (Doctor) of Industrial Health (AFIH) Certified Doctors. Ship Recycling Industrial Association (SRIA) of India has engaged two such factory medical officers (qualified Doctors) for this purpose.

Red Cross Hospital (upper) and Mobile Medical Van (lower) at Alang.

2.8 Housing Facility for workers

GMB and Ship Recycling Industrial Association have provided housing facility to the workers in first phase for accommodating 1,008 persons. The facility is of the dormitory type comprising of 7 blocks (having a ground floor plus 2 stories), canteen building, office building, shops, road, water supply and sanitary facilities with Sewerage Treatment Plant (STP), electrification etc. So far Gujarat Maritime Board has incurred expenditure to the tune of INR 150 Cr (2.2 million USD) to cater for Safety Health Environment and Social Infrastructures since its inception.

2.9 Hong Kong Convention (HKC) for Ship Recycling –2009 and Compatibility with Indian Environmental Legislations

At present, ship−recycling at Alang and India comply with Ship Breaking Code, 2013 and also comply in general with HKC, 2009, which may be seen in following matrix:

Sr No	Major aspects as per IMO Convention	Status at Alang	Remarks	Fully Compliance to IMO Convention
1	Recycling Facility Management Plan	Ship Recyclers prepare Recycling Facility Management Plan. The plan is approved by State Maritime Board as per the Ship Breaking Code 2013	Complied	The Directions of Hon'ble SC issued in WP 657/95 on 6th September-2007 covers the scope of IMO Convention regarding ship recycling states hence, Alang complies with Hong Kong Convention for Ship Recycling in Advance before it is ratified. The aspects are also covered under Ship Breaking Code-2013 and is compiled by the Ship Recycling Yard at Alang complies with the same.
2	Ship Specific Dismantling Plan	Ship Recyclers prepare Ship Specific Dismantling Plan. The plan is approved by State Maritime Board as per the Ship Breaking Code 2013	Complied	
3	Oily Waste Reception Facility	Ship Recyclers send their oily waste to the Authorized Oil Refiners	Complied	
4	Paint Chips removal plan	Paint chips removed from the gas cutting lines are disposed to TSDF at Alang	Complied	
5	Asbestos Waste Handling	ACMs are safely removed by wet methods in negative pressure Chamber System	Complied	
6	Hazardous Waste Management	Fully operational (Landfill & Incinerator)	Complied	
7	Bilge Water Treatment Plan	Existing Facility is operated by providing ETP of 30 KLD capacity	Complied	

2.10 Current Transition Period

At Alang, there are 29 ship recyclers out of a total of 130 who are operational and have acquired statements of compliance to the Hong Kong Convention–2009.Total ship yards at Alang is 153. So far total 90 ship−recycling plots have earned statement of compliance. The compliance to HKC is checked by International Classification Societies and Indian Registrar of Shipping (IRS) recognized for it. The Classification Societies check each component prescribed under the Ship Recycling Facility Management Plan as per HKC and then certify for it. Those Classification Societies also check an Inventory of Hazardous Materials (IHM) for these ship−recycling facilities for any particular ship for the demonstration purpose. The ship−recycling yards would follow the same guidelines in the other ships to be allowed in their facilities. The very purpose of using an inventory of hazardous materials on board the vessel in ship−recycling operations is to prepare a proper disposal plan for hazardous waste generated from the ship's structures and stores, as well as waste generated during the operations on the ships. The IHM helps ship recyclers to spot the hazardous materials from identified locations in each ship and also with the deployment of proper resources to remove predicted quantity of wastes from the ships with due care. Thus ship recyclers and regulatory authorities in order to protect human health, safety and to prevent environmental pollution use an IHM provided in visiting ships.

Along with the above HKC compliant ship−recycling facilities, other ship−recycling facilities at Alang are examined by Gujarat Pollution Control Board, Petroleum& Explosive Safety Organization (PESO), Directorate of Factory Inspectorate, Atomic Energy Regulatory Board (AERB) and Gujarat Maritime Board to comply with Indian Regulations i.e. Hazardous waste management rules –2016, Petroleum rule, Factory rules, AERB Rules and GMB's safety regulations respectively.

3 SUMMARIES OF EARLIER STUDIES OF SURROUNDING REGION

3 SUMMARIES OF EARLIER STUDIES OF SURROUNDING REGION

The coastal water off Alang, Gujarat is well connected with nearby areas such as Dahej and Bhavnagar within Gulf of Khambat. Therefore, water and sediment quality data from these areas are considered for the comparison with present results in order to better assess the impact or modification (if any) due to the ship breaking activities on the ecology of Alang. The water and sediment quality along with biological characteristics of the coastal water of Dahej and Bhavnagar are discussed below:

3.1 Water quality

a) Temperature: The average water temperature of Dahej and Bhavnagar as recorded earlier were 26.0°C and 27.5°C respectively (Table 3.1.1–3.1.3). Similarly, the average water temperature recorded around Alang earlier was 27.0°C (Table 3.1.4). The variations of water temperature were in accordance with the air temperature depending upon the season and month of collection of water samples. The overall air temperature around Alang reported in the previous studies varied in the range of 25.4–31.0°C (Table 3.1.4).

b) pH: The average pH of 8.0 was recorded during both 1997 and 2007 in the coastal waters off Dahej. There was no marked variation between near shore and offshore locations. Bhavnagar showed average pH of 8.0 (Table 3.1.1 – 3.1.3). The range of pH between 7.8 and 8.2 recorded in these areas did not indicate any influence of anthropogenic input. Based on the monitoring results, pH around Alang during year 2007–08 was ranged at 8.0 – 8.3, averaged at 8.1 which is comparable with the pH in the surrounding regions of Gulf (Table 3.1.4).

c) SS: The marine water within Gulf of Khambhat generally characterized with high higher suspended solid (SS) content, mainly due to erosion of shore and bottom owing to high water current. The average SS contents of Dahej and Bhavnagar during earlier studies were 1791 mg/l and 1063 mg/l, respectively

(Table 3.1.1 – 3.1.3). These results represent the general characteristic of Interior Gulf. The average SS reported in the Alang region during 2007–08 ranged at 276–840 mg/l, was lower than SS values of Dahej and Bhavnagar regions (Table 3.1.4).

d) Salinity: The average salinity values around Dahej and Bhavnagar were mainly influenced with freshwater input therefore lower than the normal seawater salinity. The average values as recorded in the past were 27.4 ppt and 28.1 ppt around Dahej and Bhavnagar, respectively (Table 3.1.1 – 3.1.3). The range of salinity around Alang water was between 28.8 ppt and 34.7 ppt during 2007–08, averaged at 30.8 (Table 3.1.4).

e) DO and BOD: Dissolved oxygen in the surrounding areas of Alang during 1997 and 2007 is presented in (Table 3.1.1–3.1.3). From the Table it was evident that the average DO values of Dahej and Bhavnagar were 6.3 mg/l and 6.1 mg/l, respectively. This suggested that, both the area sustained more or less comparable values of DO, which indicated the healthy condition of the water. The range of DO at Alang was 4.1–7.6 mg/l during 2007–08, averaged at 6.1 mg/l (Table 3.1.4).

The average value of BOD was 1.5 mg/l at Dahej and 1.7 mg/l at Bhavnagar (Table 3.3.1 – 3.3.2), which is comparable with that of Alang (BOD= 1.3 mg/l – 5.9 mg/l) during 2007–08 (Table 3.1.4).

f) Phosphorus and nitrogen compounds: Coastal water off Dahej and Bhavnagar were found to be enriched with dissolved nutrients. The average concentration of PO_4^{3-}-P found at Dahej was 3.2 µmol/l. Similarly; Bhavnagar sustained enhanced concentration of PO_4^{3-}-P (av. 6.9 µmol/l) (Table 3.1.1 – 3.1.3). These high concentrations of PO_4^{3-}-P may be due to the load brought by the several rivers of contaminated water with the industrial effluents from the surrounding regions draining into the Gulf. The results of 2008 suggested that the concentration of PO_4^{3-}-P in Alang was in the range of 2.5 – 6.2 µmol/l (Table 3.1.4).

The average concentrations of NO_3^--N were 32.2 µmol/l in Dahej and 28.4 µmol/l in Bhavnagar (Table 3.1.1 – 3.1.3), which were higher as compare to other coastal regions. The earlier studies indicated that the Alang coastal water sustained with similar NO_3^--N ranged at 22.5 – 46.4 µmol/l during 2008 (Table 3.1.4).

It was evident from the earlier results that the average concentration of NO_2^--N was 0.5 µmol/l in Dahej and 0.6 µmol/l in Bhavnagar waters. However, the average concentration of NH_4^+–N was similar (1.1 µmol/l) in both Dahej and Bhavnagar coastal waters (Tables 3.1.1 – 3.1.3). As per the result of 2008, the NO_2^--N concentration in Alang was between 0.4 and 0.5 µmol/l, whereas NH_4^+–N was between 0.7 and 1.8 µmol/l. These values were comparable to the coastal waters off Alang (Table 3.1.4).

g) PHc and phenols: PHc concentration (avg. 8.0 µg/l) in the coastal water of Dahej was similar to that of near shore coastal water of Gujarat and does not suggest any contamination by petroleum compounds. The PHc concentration in the coastal water of Alang ranged between 12.1 – 524.3 µg/l in earlier studies and Phenol concentration between 15.4 – 102.0 µg/l during 2008 (Table 3.1.4).

3.2 Sediment quality

a) Metals: Sediment of coastal water of Dahej during earlier studies contained low concentration of Al (av. 5.4 µg/g). The concentration of Al is directly related to clay content and its concentration is generally not altered due to anthropogenic inputs. Hence, it indicated that the region contained sand in higher concentrations. The average concentrations of 98 µg/g, 1169 µg/g, 6.8 %, 42 µg/g, 58 µg/g, 77 µg/g, 105 µg/g and 0.07 µg/g for Cr, Mn, Fe, Co, Ni, Cu, Zn and Hg respectively were reported in the sediment of coastal water of Dahej (Table 3.2.1–3.2.2), which were similar to that found in the sediments of other coastal area of Gujarat.

The available published information of 2001 and 2004 on the metal concentration in sediment of Alang revealed high concentration especially in the nearshore sediments. The concentration of heavy metals viz Fe, Mn, Co, Ni, Cu, Zn, Cd, Hg and Pb were much higher at nearshore station of Alang as compared to control site at Piram according to the information available of 2001. The average concentrations of 9.2%, 134 µg/g, 1117 µg/g, 6%, 39 µg/g, 68 µg/g, 92 µg/g, 105 µg/g and 0.05 µg/g for Al, Cr, Mn, Fe, Co, Ni, Cu, Zn and Hg, respectively were reported in the sediment of coastal water of Alang during 2008 (Table 3.2.3).

b) Organic carbon (C_{org}): Low concentration of C_{org} (av. 0.3%) was reported in the coastal sediment of Dahej (Table 3.2.1–3.2.2). Same concentration was also found in the Bhavnagar coastal sediments. This showed that there was no buildup of organic load in both the regions. In the earlier study of 2007–08, the average concentration of C_{org} recorded in coastal sediment of Alang was 0.8% (Table 3.2.3).

c) PHc: PHc concentration observed in the sediment of Dahej was low (av 0.3 µg/g) whereas in the sediment of Bhavnagar the concentration of PHc was slightly higher (av. 0.5 µg/g) (Table 3.2.1–3.2.2). However, these values indicated that the sediments of both areas were free from any contamination from PHc. The average value of PHc in the earlier study of 2008 in the sediment of Alang was 1.4 µg/g (Table 3.2.3). This indicates no buildup of PHc in the Alang region.

3.3 Biological Characteristics

3.3.1 Phytoplankton

a) Pigments: The coastal water of Dahej was observed to have a poor phytoplankton production in terms of chlorophyll *a* (av. 0.6 mg/m^3) and phaeophytin (av. 1.3 mg/m^3) as evident in Table 3.3.1. The poor ratio of chlorophyll *a* / phaeophytin, as evident from the earlier studies indicated unhealthy condition for phytoplankton in the coastal waters of Dahej.

The coastal water of Bhavnagar also revealed the similar level of chlorophyll *a* (av 0.7 mg/m^3) and phaeophytin (av 1.3 mg/m^3). The higher concentration of phaeophytin as compared to chlorophyll *a* resulting poor ratio could be due to high suspended load prevailing at these locations. The available information of 2001 on phytoplankton pigments in the coastal water of Alang revealed significantly poor concentration of chlorophyll *a* (<0.2 – 2.0 mg/m^3) and phaeophytin (<0.1–0.8 mg/m^3). The coastal water of Alang region presented similar level of chlorophyll *a* (av. 0.9 mg/m^3) and phaeophytin (av. 1.01 mg/m^3) during October 2008.

b) Population: The distribution pattern of phytoplankton population was in agreement of pigments in the coastal water of Dahej and Bhavnagar (Table 3.3.1 – 3.3.3). The low values of cell counts (av 10.3 x10^3 /l) and total genera (4) at Dahej and at Bhavnagar (av 12.1x10^3 /l and 3) were indicative of poor phytoplankton production in the region.

The values of cell counts (av 17.4 x10^3 /l) and total genera (7) at Alang during 2008 were indicative of poor phytoplankton production in the region (Table 3.3.4).

The poor generic diversity of phytoplankton may be associated with high–suspended solids prevailing in the region. The major phytoplankton genera viz *Peridinium, Bacteriastrum, Navicula, Thalassiosira, , Nitzschia, and Amphiprora were* observed.

3.3.2 Zooplankton

The overall distribution of zooplankton standing stock in terms of biomass (av 3.6 ml/100m^3), population (av 24.3 x 10^3/100m^3) and total group (av. 10) in the coastal water of Dahej and biomass (av. 5.5 ml/100m^3), population (av. 20.9 x 10^3/100m^3) and total group (av. 12) of the coastal water of Bhavnagar were indicative of moderate secondary production in the regions (Table 3.3.5). Copepods and Decapod larvae were the major groups in the coastal water of Dahej. The distribution of zooplankton standing stock in terms of biomass (av 21.75 ml/100m^3), population (av 14.3 x 10^3/100m^3) and total group (av 12) was recorded in the coastal water of Alang during October 2008.The major groups reported in the region of Alang were Decapod Larvae, Copepods, Chaetognaths (Table 3.3.6).

3.3.3 Macrobenthos

a) Intertidal

The overall results of intertidal macrobenthic biomass (av. 3.4 g/m^2, wet wt.), population (av. 829 / m^2) and total groups (av. 4) in the coastal water of Dahej and biomass (av. 1.4 g/m^2, wet wt.), population (av. 458/m^2) and total group (av. 2) off Bhavnagar suggested poor macrobenthic standing stock from the intertidal region. Brachyurans, Polychaetes and Gastropods were the major groups during period of earlier studies (Table 3.3.7 – 3.3.8)

The overall results indicated lower average values of intertidal macrobenthic faunal biomass (av 0.3 g/m^2, wet wt.), population (av 171 / m^2) and total groups (av. 1). Polychaeta was the major group reported in the sediments of Alang during the earlier studies of 2007–08 (Table 3.3.9).

b) Subtidal

The results of subtidal macrobenthic standing stock of earlier studies are presented in Table 3.3.5. A poor macrobenthic standing stock in terms of biomass (0.4 g/m^2 wet wt), population (42/m^2) and faunal group (2) in the coastal water of Dahej and biomass (1.5 g/m^2 wet wt), population (91/m^2) and faunal group (2) of Bhavnagar were recorded during 1997–2007 (Table 3.3.7–3.3.8). Polychaetes, Brachyurans, Insects and Isopods were often recorded from this. A poor macrobenthic standing stock in terms of biomass (0.2 g/m^2 wet wt), population (53/m^2) and faunal group (1) in the coastal water of Alang in the earlier study of October 2008. Polychaetes, Decapod and Fish larvae were the major groups observed (Table 3.3.9).

4 INVESTIGATIONS CONDUCTED

4 INVESTIGATIONS CONDUCTED

4.1 Sampling location

The present study was conducted at 26 subtidal stations and 4 intertidal transects as evident in Figure 1.1.1. Station 1–6 were sampled from the shore, station 7–12 were around 1.5 km away from shore, station 13–18 were around 4 km away from the shore and station 19–23 were around 6 km away from the shore. Thus, the sampling was collected in 4 transects along the ship breaking yard in the grid size of approximately 1 km x1 km. In addition, station 24 was around 14 km away from the shore towards offshore and station 25 was around 23 km away towards Ghoga. The coordinates for all subtidal stations are as follows:

Station	Latitude	Longitude
1	21^{0}27’06.97”N	72^{0}13’53.39”E
2	21^{0}25’52.87”N	72^{0}13’03.64”E
3	21^{0}25’03.91”N	72^{0}12’19.59”E
4	21^{0}23’44.54”N	72^{0}10’48.62”E
5	21^{0}21’50.73”N	72^{0}09’20.55”E
6	21^{0}20’52.48”N	72^{0}08’25.13”E
7	21^{0}27’00.35”N	72^{0}14’16.13”E
8	21^{0}25’36.99”N	72^{0}13’51.96”E
9	21^{0}24’38.78”N	72^{0}13’09.32”E
10	21^{0}23’12.79”N	72^{0}11’29.84”E
11	21^{0}21’25.60”N	72^{0}10’08.84”E
12	21^{0}20’26.02”N	72^{0}09’13.41”E
13	21^{0}26’51.06”N	72^{0}15’48.53”E
14	21^{0}25’17.12”N	72^{0}15’12.96”E
15	21^{0}24’08.34”N	72^{0}14’04.73”E
16	21^{0}22’30.45”N	72^{0}12’13.89”E
17	21^{0}20’57.83”N	72^{0}11’12.79”E
18	21^{0}19’58.26”N	72^{0}10’10.27”E

19	21^{0}26’28.53”N	72^{0}17’29.45”E
20	21^{0}24’50.64”N	72^{0}16’25.42”E
21	21^{0}23’40.54”N	72^{0}15’17.19”E
22	21^{0}21’53.40”N	72^{0}13’51.92”E
23	21^{0}20’35.35”N	72^{0}12’18.15”E
24	21^{0}21’13.12”N	72^{0}18’55.96”E
25	21^{0}38’32.30”N	72^{0}19’37.17”E
26	21°17'35.84"N	72°14'27.17"E

Intertidal sampling was conducted at 4 transects (T I – T IV) to assess the status of intertidal macrobenthic fauna and sediment quality and the position of transects are as follows:

Transect	Latitude	Longitude
T I	21^{0}26’19.30”N	72^{0}13’32.80”E
T II	21^{0}24’49.40”N	72^{0}12’23.50”E
T III	21^{0}24’02.60”N	72^{0}11’37.60”E
TIV	21^{0}22’34.40”N	72^{0}10’03.60”E

4.2 Sampling frequency

Sampling was conducted during February–March 2020.

Temporal measurements over a tidal cycle (12 Hours) for selected parameters of water quality and biological characteristics were conducted at stations 8, and 11 and other stations were spot sampled.

Sediment sample, one each from all subtidal stations and multiple collections from intertidal transects depending on the exposed stretch were collected for analysis of metals, phosphorus, C_{org}, PHc, microbial counts and macrobenthos.

4.3 Sampling methodology

A Niskin water sampler with a mechanism of manual closing by messenger at desired depth was used for collecting sub–surface water samples. Sampling at the surface was done using a clean polyethylene bucket. Glass bottle sampler (1 L) was used for obtaining samples at 1 m below water surface, for the estimation of PHc. Water sample was collected mid depth at each sampling locations for the analysis of dissolved metals.

Oblique hauls for zooplankton were made using a Heron Tranter net (Mesh size 0.33 mm, mouth area 0.25 m^2) attached with a calibrated flow meter (General Oceanics). All collections were of 5 min duration (Plate 4.3.1). Samples were preserved in buffered formalin.

For the analyses of texture, metals, total phosphorous, total organic carbon (C_{org}), PHc, microbials and macrobenthos, the subtidal sediment samples were collected using a van–Veen grab of 0.04 m^2 area (Plate 4.3.2) and intertidal samples were obtained using quadrats sized 0.04 m^2 (Plate 4.3.3). intertidal samples were obtained with a hand–held shovel.

Plate 4.3.1: Collection of zooplankton sample

Plate 4.3.2: Photo showing sediment collection using van−veen grab

Plate 4.3.3: Sediment collection from intertidal area

For microbiological analysis, surface water was collected directly in a sterilised glass bottle. Sediment sample was obtained using van−Veen grab and transferred directly into sterilised polyethylene bag. Polyethylene bucket and Niskin sampler respectively, were used for sampling surface and near bottom waters for the estimation of phytoplankton pigments and population. Samples for enumeration of phytoplankton cell count were fixed in Lugol's iodine and a few drops of 3% buffered formaldehyde.

Zooplankton samples were collected by oblique hauls using Heron Tranter net (mesh size 200μ, mouth area 0.25 m^2) attached with a calibrated flow meter (2030R, General Oceanic, USA). Each collection was done by towing the net for 5 minutes. Samples were preserved in 5% buffered formaldehyde.

Sediment samples for subtidal macrobenthos were collected using a van Veen grab of 0.04 m^2 area. Intertidal collections between the HTL and the LTL were done using quadrates. Samples were preserved in 5% buffered formaldehyde rose bengal solution.

4.4 Method of analysis

4.4.1 Water Quality

Majority of the water quality parameters were analyzed within 24 h of collection in the temporary shore laboratory established at Bhavnagar. Colorimetric measurements were made on a Shimadzu (Model 1240) spectrophotometer. RF–5301 Shimadzu Spectrofluorometer was used for estimation of PHc. The analytical methods of estimations were as follows:

i) Temperature: Temperature was recorded using a mercury thermometer with an accuracy of 0.1° C.

ii) pH: pH was measured on a microprocessor–controlled pH analyzer. The instrument was calibrated with standard buffers before use.

iii) Suspended solids: A known volume of water was filtered through a pre–weighed 0.45 μm Millipore membrane filter paper, dried and weighed again.

iv) Turbidity: Turbidity was determined by nephalometric method using turbidity meter (Orion AQ4500 – Thermo Scientific).

v) Salinity: Salinity was measured using AUTOSAL Salinometer (GUILDLINE Instruments Ltd., Canada). The instrument was standardized with IAPSO Standard Seawater (OSIL, UK).

vi) DO and BOD: DO was determined by Winkler's method. For the determination of BOD, direct unseeded method was employed. The sample was filled in a BOD bottle in the field and incubated in the laboratory for 3 d at 27°C after which DO was again determined (Grasshoff 1983).

vii) Phosphate: Acidified molybdate reagent was added to the sample to yield a phosphomolybdate complex that was then reduced with ascorbic acid to a highly colored blue compound, which was measured at 882 nm.

viii) Nitrite: Nitrite in the sample was allowed to react with sulphanilamide in acid solution. The resulting diazo compound was reacted with N–1–Naphthyl–ethylenediamine dihydrochloride to form a highly colored azo–dye. The light absorbance was measured at 543 nm.

ix) Nitrate: Nitrate was determined as nitrite as above after its reduction by passing the sample through a column packed with amalgamated cadmium.

x) Ammonia: Ammonium compounds (NH_3+NH_4^+) in water were reacted with phenol in presence of hypochlorite to give a blue color of indophenol. The absorbance was measured at 630 nm.

xi) Petroleum Hydrocarbons: Water sample was extracted with hexane and the organic layer was separated, dried over anhydrous sodium sulphate and reduced under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310nm) with Saudi Arabian Crude residue (boiling point >100°C) as a standard (IOC–UNESCO 1984).

xii) Phenols: Phenols in water (500 ml) were converted to an orange colored antipyrine complex by adding 4–aminoantipyrine. The complex was extracted in chloroform (25 ml) and the absorbance was measured at 460 nm using phenol as a standard.

xiii) Dissolved metals: Samples collected by using Niskin sampler was filtered through 0.45μm membrane filter paper and stored in a precleaned plastic bottle. Appropriate quantity of nitric acid (suprapure) was added so as to bring down pH below 2. Selected trace metals were analysed by preconcentration method using APDC–MIBK (Bruland et al, 1979). The analysis was performed by using ICP–MS (Thermo Fisher Scientific). Mercury was analyzed by cold–vapor generation technique flow injection mercury system (FIMS–400, Perkin Elmer).

4.4.2 Sediment quality

a) Sampling procedure:

The sediment after retrieval was transferred to a polythene bag and preserved for further analysis at laboratory at CSIR–NIO, Mumbai.

b) Analytical procedures:

i) Texture: The sediment was dried at 60° C and analysed for particle size following the procedure of Holme and McIntyre (1984).

ii) Metals: The dried (<60°C) and powdered sediment was brought into solution by treatment with concentrated HF–$HClO_4$–HNO_3–HCl acids and the metals aluminium, chromium, manganese, iron, cobalt, nickel, copper and zinc were estimated by dual view inductively coupled plasma – optical emission spectrophotometer (ICP–OES, plasma 7300 DV, Perkin Elmer, Singapore) (Loring and Rantala 1992). Lead, cadmium and arsenic were analyzed by ICP–MS (Thermo Fisher Scientific) Mercury was estimated by flameless AAS (FIMS–400, Perkin Elmer) technique after digesting the sediment with aqua regia followed by oxidation with $KMnO_4$. Sodium borohydride was used as reductant (USEPA, 1979).

iii) Total organic carbon (C_{org}): Percentage of C_{org} in the dry sediment was determined by oxidizing the sample using chromic acid and estimating excess chromic acid by titrating against ferrous ammonium sulphate with ferroin as an indicator (Walkely and Black, 1934).

iv) Total Phosphorus: Digested sample was used for estimating phosphorus in the sediment. The method used was similar to that described under Section 4.4.1 (vii).

v) Petroleum Hydrocarbon (PHc): Sediment after refluxing with KOH−methanol mixture was extracted with hexane. After removal of excess hexane, the residue was subjected to clean−up procedure by aluminium oxide column chromatography. The hydrocarbon content was then estimated by measuring the fluorescence as described under Section 4.4.1 (xi).

vi) Bioaccumulation: Fishes collected from the help of the local fishermen were identified, dissected by using clean technique to avoid contamination. Different tissues were dried <55ºC, powdered, digested in microwave assisted digestion system and analysed for different element using ICP−MS.

4.4.3 Flora and Fauna

i) Microbiology

Bacteriological parameters of water and sediments were analyzed by plating techniques for Total Viable Counts (TVC), Total Coliforms (TC), Escherichia coli like organisms (ECLO), Faecal Coliform like organisms (FC), and Streptococcus faecalis like organisms (SFLO). Colonies of TC, ECLO, and SFLO were counted separately. The media employed for growth of colonies were as follows:

Nutrient agar (NA) for TVC, MacConkey agar (MC) for TC, MFC agar for ECLO, and faecal coliforms, and M. enterococcus agar for SFLO were used in spread plate technique, with serial dilution for enumeration of all groups.

ii) Phytoplankton

A known volume of water (500 ml) was filtered through a 0.45 µm Millipore Glass filter paper and the pigments retained on the filter paper were extracted in 90% acetone. For the estimation of Chlorophyll *a* and phaeophytin the fluorescence of the acetone extract was measured using Fluorometer (Turner Design, USA) before and after treatment with dilute acid (0.1N HCL).

Phytoplankton population: Water samples for phytoplankton cell counts were preserved in Lugol's solution with 2% formaldehyde. Enumeration and identification of phytoplankton were done under a compound microscope using a Sedgewick–Rafter slide.

iii) Zooplankton

Biomass was obtained by displacement volume method. Sub–sample (25–50%) was analysed under a Stereo Microscope (Leica, Germany) for faunal composition and population count.

iv) Benthos

The sediment samples were sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered formaldehyde. Total population was estimated as number of animals in 1 m^2 area and biomass on wet weight basis.

v) Fishery

Fishes caught by the local fishermen were collected and sorted out into different groups, weighted and species identification was determined. A part of the catch was preserved in 5% formaldehyde for identification upto species level.

4.4.4 CRZ compliance

CRZ map demarcation prepared by the NCSCM, Chennai was used to find out different establishments/activities in the different categories of CRZ. Global positioning system (GPS) and measure tape were used for the same. Since the CRZ map prepared by NCSCM is prior to CRZ notification of 2019, to assess the present situation, some information was also taken from CRZ notification 2019 published by the Ministry of Environment, Forest and Climate Change during January 2019.

5 PREVAILING MARINE ENVIRONMENTS

5 PREVAILING MARINE ENVIRONMENTS

The prevailing marine environment of the coastal water of Alang is discussed based on the results of parameters measured under water quality, sediment quality and flora and fauna, which are as follows:

5.1 Water quality

Changes in water quality can be vulnerable to the ecosystem and ultimately affect the aquatic lives. Therefore, knowledge on water quality is vital in order to assess the ecological condition of a designated aquatic regime. The combined results of water quality measured during different monitoring periods earlier around Alang (December, 2007, January, 2008, April, 2008, and October – November, 2008) are described along with present monitoring results (February 2020) and together displayed in Tables 5.1.1 – 5.1.4.

i) Temperature: The water temperature around Alang varied in accordance with the air temperature (Table 5.1.1 – 5.1.4). The range of air temperature was between 22.5 and 26.5°C, whereas the water temperature ranged at 22.0 – 25.5°C during present monitoring period (February, 2020). The surface and bottom average values of water temperature recorded during February, 2020 is summarized in the Table 5.1 (a) below:

Table 5.1 (a): Average water temperature off Alang during February 2020.

Water Temperature (ºC)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	23.0	–	**14**	24.0	23.5
2	23.5	–	**15**	22.5	22.0
3	23.0	–	**16**	24.5	24.0
4	23.0	–	**17**	25.5	24.5
5	23.0	–	**18**	25.0	25.0
6	23.0	–	**19**	24.5	24.0
7	24.5	24.0	**20**	24.5	24.0
8	24.3	24.2	**21**	23.5	24.0
9	23.5	22.0	**22**	22.5	22.5
10	23.5	23.5	**23**	24.5	24.5
11	23.7	23.7	**24**	23.5	23.0
12	23.5	–	**25**	24.0	23.5
13	23.5	23.5	**26**	24.8	–

Thus, there was no marked variation between surface and bottom water temperature due to dynamic nature of Gulf of Khambhat. The average values of water temperature in different segment recorded during different sampling events are presented in the Figure 5.1 (i) below:

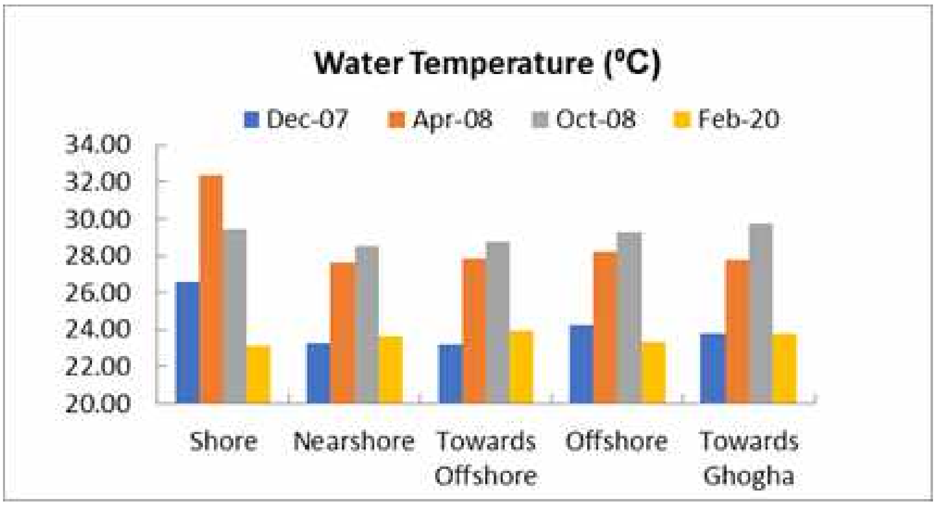


Figure 5.1 (i) Average variation in water temperature off Alang during different sampling events.

Water temperatures exceeded >32°C during April at shore stations. This could be due to the heated sand during low tide and the heat transferred to the water during high tide resulting in the temperature rise of the shore water.

Temporal variation: Study of temporal variation of water temperature is presented in the Figure 5.1 (ii) below:

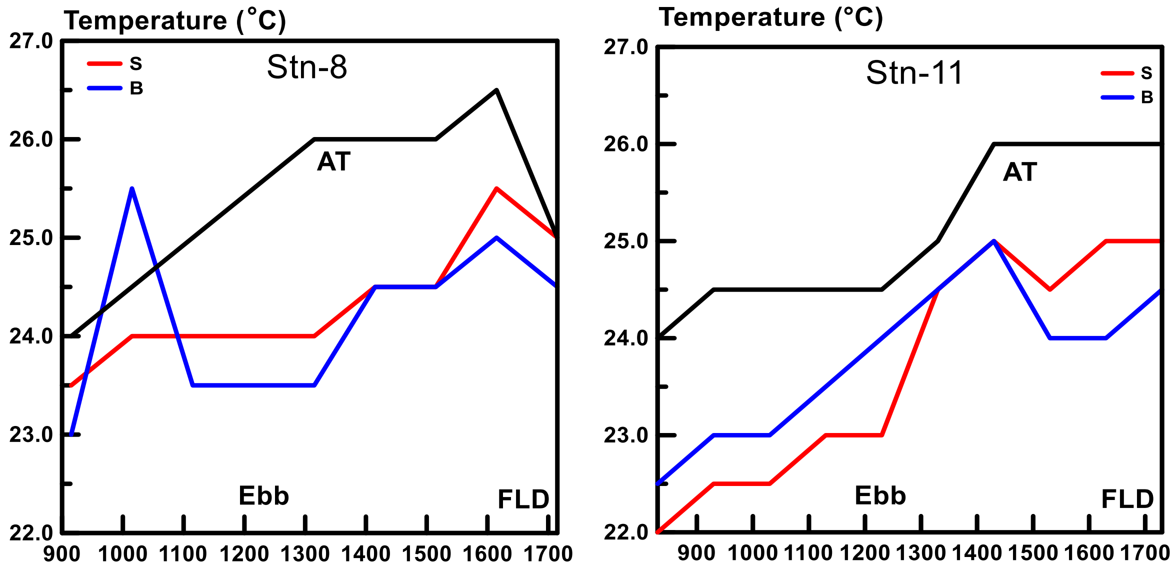


Figure 5.1 (ii) Temporal variation of water temperature off Alang during February 2020.

It is evident from above figures that the water temperature the water temperature varied in accordance of air temperature.

ii) pH: The pH of seawater normally varies in the narrow range of 7.8 to 8.3 due to the buffering influence of $CO_2/HCO_3^-/CO_3^{2-}$ system. Small deviations are however possible in inshore and coastal waters. The pH values of the present study showed the normal range of the coastal water (Tables 5.1.1–5.1.4). The overall average values of pH are presented in the Table 5.1 (b) below:

Table 5.1 (b): Average pH of water off Alang during February 2020.

pH					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	7.9	–	**14**	8.1	8.1
2	8.0	–	**15**	8.0	8.0
3	8.0	–	**16**	8.0	8.0
4	8.0	–	**17**	8.0	8.0
5	8.0	–	**18**	8.0	8.0
6	8.0	–	**19**	8.1	8.1
7	8.1	8.1	**20**	8.1	8.1
8	8.1	8.1	**21**	8.0	8.0
9	8.1	8.1	**22**	8.0	8.0
10	8.1	8.1	**23**	8.0	8.0
11	8.1	8.1	**24**	8.0	8.0
12	8.1	–	**25**	8.1	8.1
13	8.1	8.1	**26**	8.0	–

Thus, the average pH of study area revealed a normal variation in the range of seawater. The average pH recorded during different sampling events is presented in the Figure 5.1 (iii) below:

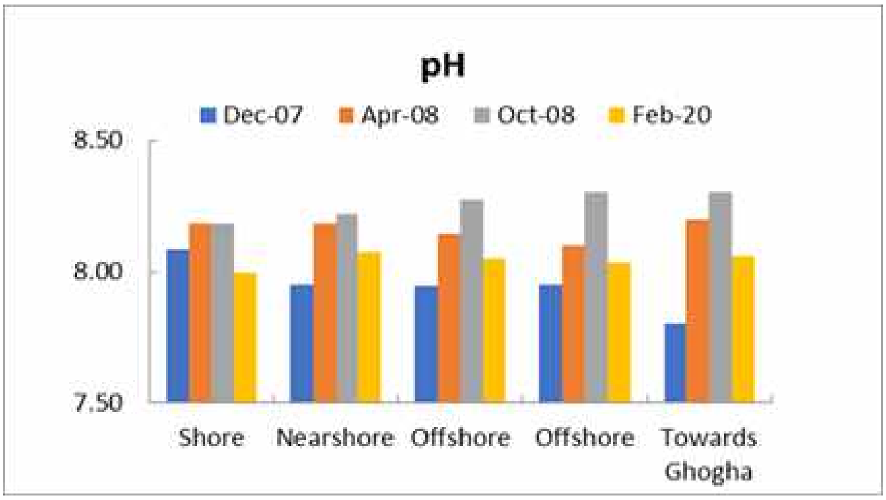


Figure 5.1 (iii) Average variation in water pH off Alang during different sampling events.

The overall pH values were indicative of the characteristic of coastal water of Gulf as displayed in Figure above. The average pH recorded during present study is in the same range as in the earlier studies.

Temporal variation: Tidal observation of pH recorded during February 2020 is presented in Figure 5.1 (iv) below:

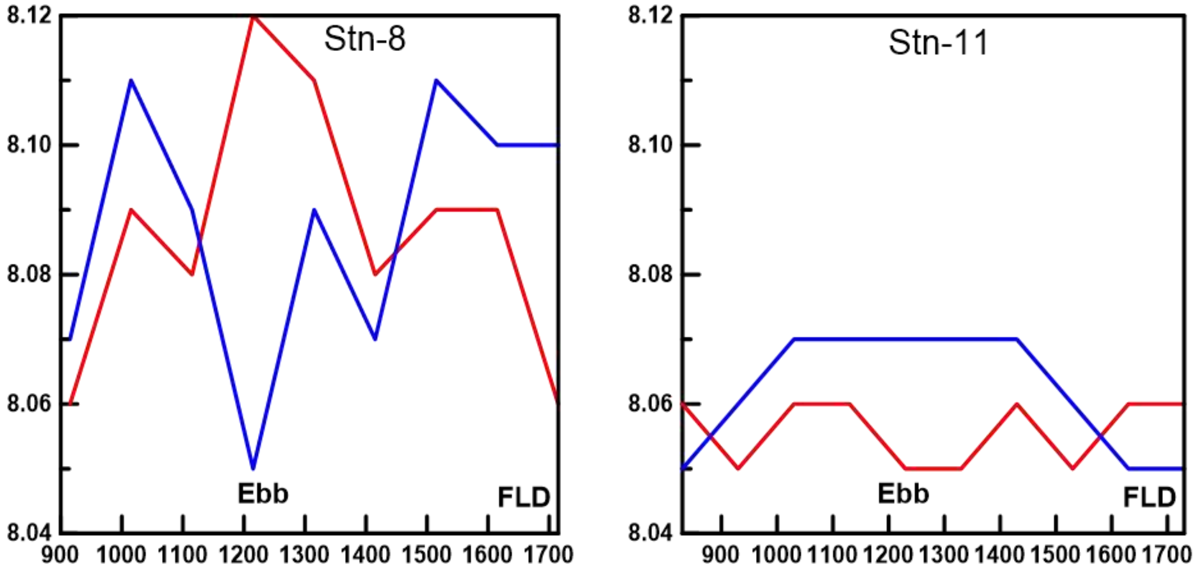


Figure 5.1 (iv) Temporal variation pH in the water off Alang during February 2020.

As it is evident from the above figure, pH of the area varied irrespective of tide and was in above 8.0, indicating that the natural variation of pH in the region.

iii) Suspended solids (SS): Suspended solid, which originates from the erosion of soil from forests and farmlands, is discharged in large quantities through rivers, particularly in the humid tropics, where heavy rainfalls occur during the wet season. Resuspension in the shallow parts of estuarine and coastal regions due to tidal currents may also contribute significantly to suspended matter in the water column, whereas import from the ocean plays minor role. The SS contains a variety of components including nutrients such as nitrogen and phosphorus. Since the major contribution comes from the disturbance of bed and shore sediments, energy of the region such as tidal currents is the vital influencing factor for SS and typically leads to high values in the bottom water. The major role played by SS is adsorption of constituents as well as contaminants from the water column. They get coagulated/flocculated/precipitated due to change of matrix. Pollutants such as metals, PHc, pesticides etc can be adsorbed onto SS and transferred to the bed sediment on settling.

Values of SS during present study are given in Tables 5.1.1 – 5.1.4. The concentration of SS varied within a wide range of 30 – 5219 mg/l depending upon tide and current speed, time of collection and location of station. The overall average values of SS (mg/l) are given in the Table 5.1 (c) below:

Table 5.1 (c): Average SS concentration in water off Alang during February 2020.

Suspended Solids (mg/l)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	1729	–	**14**	213	3739
2	1464	–	**15**	1747	3760
3	564	–	**16**	87	4995
4	392	–	**17**	295	2451
5	484	–	**18**	1300	2707
6	434	–	**19**	151	3980
7	1271	4951	**20**	2787	3896
8	1298	2801	**21**	326	209
9	269	1663	**22**	89	3856
10	69	80	**23**	609	861
11	561	452	**24**	46	2246
12	30	–	**25**	2529	4101
13	1906	5219	**26**	802	–

Thus average SS recorded during the present study varied differently at shore (392 – 1729 mg/l; av. 844 mg/l), near shore (30 – 4951 mg/l; av. 1222 mg/l), towards offshore (87 – 5219 mg/l, av. 2054 mg/l), offshore (46 – 2246 mg/l) and towards Ghogha (2529 – 4101 mg/l). Although overall values of SS were high in the study area, some lower values found in the present study especially in surface water during slack period could be due to sluggish current resulting the settling down of SS load. The high SS values of the Alang region were in the agreement of the characteristic of Gulf of Khambhat. The sources of high SS may be due to the load brought by several major rivers draining into Gulf and high turbulence generated by the tidal currents. The SS recorded during present study is compared in the Figure 5.1 (v) below:

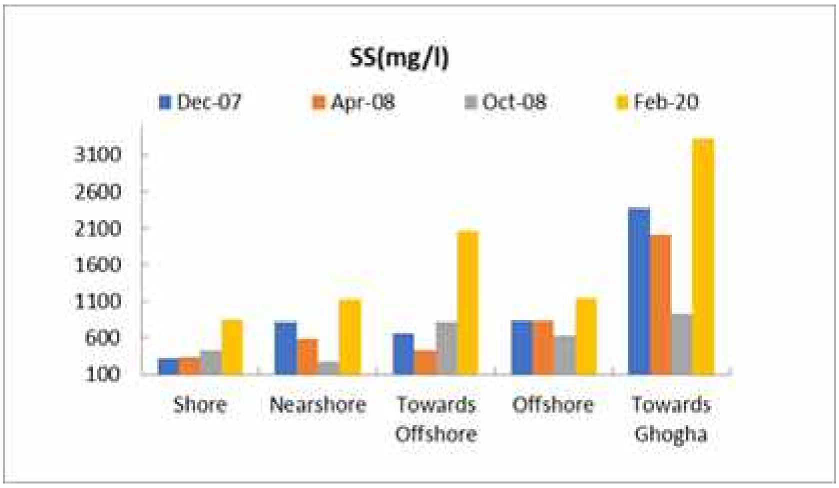


Figure 5.1 (v) Average concentration of SS in water off Alang during different sampling events.

The above figure indicates that SS recorded during February 2020 was higher compared to earlier values. Such uneven variation of SS in the Gulf of Khambhat is common due to swift current churning out the bottom sediment.

iv) Turbidity: Turbidity of water relates to optical clearness and is affected by contents of dissolved matter and SS present in it. In general, turbidity has direct relationship with SS in water. However, some deviations may occur as SS includes silt, sediment, non–settleable solids, bacteria, clay, algae and settleable solids, whereas turbidity may be the contribution of these plus dyes, coloured dissolved organic matter and humic acids excluding settleable solids. Measurement of turbidity is one of key parameter in deciding the quality of water as high turbidity can harm fish and other aquatic life by reducing food supplies, degrading spawning beds, and affecting gill function.

Values of Turbidity during present study are given in Tables 5.1.1 – 5.1.4. The Turbidity varied depending upon tide and current speed and time of collection. Thus Turbidity recorded during the present study varied differently at shore (62.7 – 2612.0 NTU, av. 1034.4 NTU), near shore (126.0 – 2028.0, av. 1110.5 NTU), towards offshore (10.9 – 2396 NTU, av. 885.2 NTU), offshore (28.0 – 1288.5 NTU, av. 658.25 NTU) and towards Ghogha

(1152.0 – 2295.0 NTU, av. 1723.5 NTU). The overall average values of Turbidity (NTU) are given in the Table 5.1 (d) below:

Table5.1 (d): Average turbidity value in water off Alang during February 2020.

Turbidity (NTU)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	2441	–	**14**	855.5	1043.5
2	2107	–	**15**	61.9	1621
3	352	–	**16**	60	2359.5
4	64.1	–	**17**	198	847.5
5	274.5	–	**18**	1264.5	1345.5
6	968	–	**19**	1114	1193
7	531.5	1527	**20**	176.5	2188
8	754.9	725.6	**21**	11.1	84.4
9	1232	1365.5	**22**	55.2	1793
10	1151.5	2007	**23**	103	2206
11	720.8	911.1	**24**	28.8	1288.5
12	859	–	**25**	1152	2295.5
13	416.5	478	**26**	847.6	–

As it can be seen in the table above, the highest value of turbidity was recorded at station 1, which represents the shore water quality, indicating result of wave action on the shore and churning out shore material in the water.

v) Salinity: Salinity is the indicator of freshwater incursion in the nearshore coastal water as well as excursion of tidal water in inland water bodies such as estuaries, creeks and bays. Normally seawater salinity is 35.5 ppt, which may vary depending on competition between evaporation and precipitation and freshwater addition. Thus, during premonsoon the evaporation leads to salinities higher than 35.5 ppt in certain regions while during monsoon and postmonsoon the salinities decreases markedly.

Salinity is known to influence several processes like dissolution and dispersion. Most of the constituents brought by the river runoffs are generally removed at the confluence of riverine and saline water due to salt content. A few highly mobile and tolerant species with broad diets seem relatively unresponsive to salinity, whereas most estuarine animals show distribution pattern or behaviors that are related to salinity patterns.

Salinity of Alang area recorded during the present study is presented in Tables 5.1.1–5.1.4. The range of Salinity varied from 29.3 ppt to 31.6 ppt during the present study. There was no significant variation from surface to bottom in the concentration of salinity indicating the well–mixed water of Alang due to high turbulence generated by high current in the area. The average values of salinity recorded during present study are given in the Table 5.1. (e) below;

Table5.1 (e): Average salinity values in water off Alang during February 2020.

Salinity (ppt)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	30.5	–	**14**	30.7	31
2	30.7	–	**15**	31.3	31.1
3	30.7	–	**16**	30.6	30.6
4	30.7	–	**17**	30.5	30.7
5	30.7	–	**18**	30.8	30.7
6	30.7	–	**19**	29.4	30.4
7	30.2	30.1	**20**	30.4	30.8
8	30.3	30.1	**21**	31.3	31.2
9	30.3	30.3	**22**	31.5	31.2
10	30.6	30.6	**23**	30.8	31.1
11	30.8	30.7	**24**	31	30.9
12	30.7	–	**25**	29.3	29.3
13	29.8	30.3	**26**	31.1	–

Thus, there was no significant variation from surface to bottom in the concentration of salinity indicating the well–mixed water of Alang due to high turbulence generated by high current in the area. The average values of salinity recorded during different season are presented in the Figure 5.1 (vi) below:

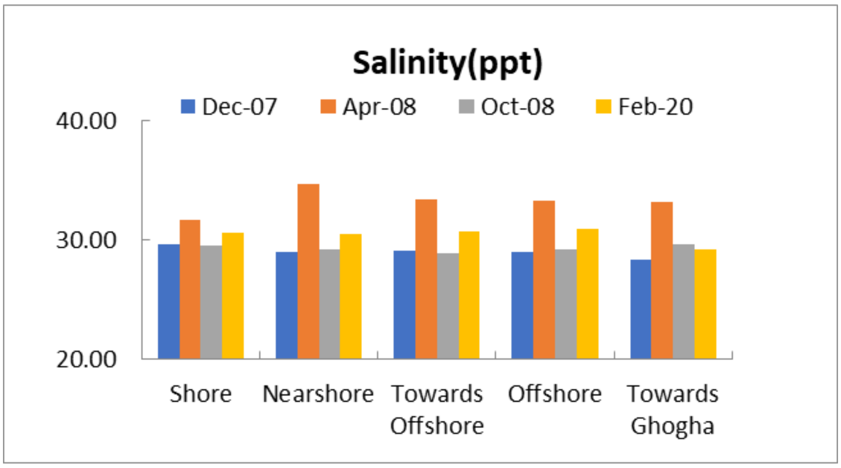


Figure 5.1 (vi) Average concentration of salinity off Alang during different sampling events.

Salinity during December (27.2 – 30.3 ppt, av. 29.2 ppt), October– (27.2 – 30.2 ppt, av. 29.1 ppt) was low. It increased to 28.2 – 37.0 ppt (av. 33.5 ppt) during April suggesting clear seasonal variation. During rainy season, huge amount of freshwater is poured to the Gulf of Khambhat by, Mahi, Narmada and Tapi rivers, which alters the salinity of the Gulf during monsoon. Though the spatial variation was not very clear, the values of salinity recorded during the present study for shore (30.5 – 30.7ppt, av. 30.6 ppt), nearshore (29.3 – 31.0 ppt, av. 30.4 ppt), towards offshore (29.4 – 31.6 ppt, av. 30.7 ppt), offshore (30.9 – 31.0 ppt, av. 30.9 ppt) and towards Ghogha (29.3 ppt) revealed variations generally seen for the Gulf region.

Temporal variation: To find out the tidal variation, if any in the salinity value, temporal studies were performed at stations 8 and 11 and given in the Figure 5.1 (vii) below;

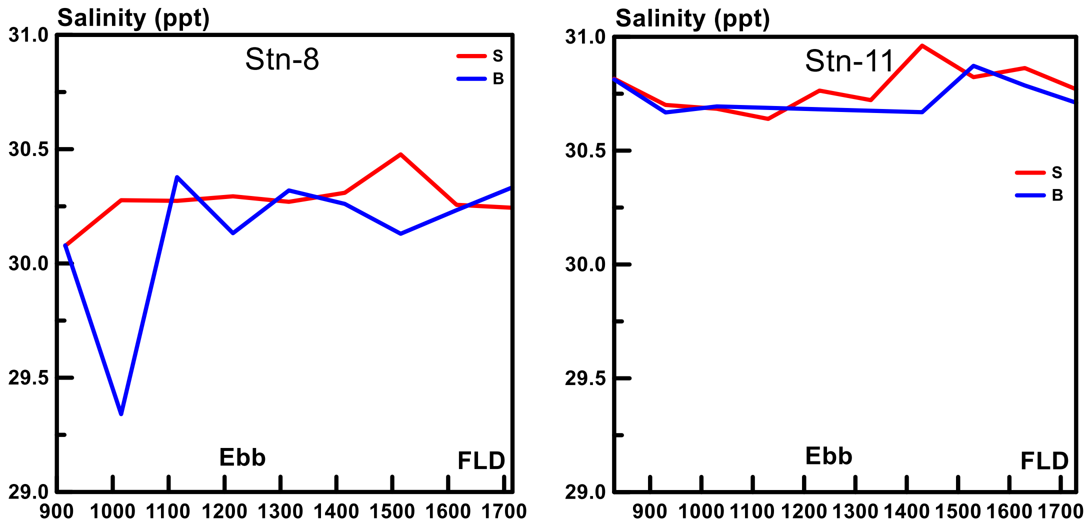


Figure 5.1 (vii) Temporal variation of salinity in the water off Alang during February 2020.

As it is evident from above figures, there was no particular trend of tidal variation in the salinity of the study region. Such values indicate that the flow of fresh water is minimized after withdrawal of monsoon, as there are many barrages constructed on the rivers to impound fresh water for different uses.

vi) Dissolved oxygen (DO): DO content of water is a vital water quality parameter since the health of the aquatic life is ultimately linked with its availability. The source of DO in water is the photosynthesis by aquatic plants and dissolution from the atmosphere. However, DO is consumed during respiration and decaying of organic matter. Hence, the high content of organic matter can deplete DO levels as can be detrimental to marine life. Although there is no unanimity on the level of DO, that should be maintained in coastal marine waters conducive to biota. It is considered that the level should not fall below 3 mg/l for prolonged periods in creeks, estuaries and coastal waters for healthy ecosystem.

Dissolved oxygen measured during present study varied in the range of 5.2–6.6 mg/l (Tables 5.1.1–5.1.4). Significant wide variations in the concentration of DO were seen at shore segment (5.6–6.3 mg/l, av. 6.0mg/l), nearshore (5.2–6.6 mg/l, av. 5.7 mg/l), towards offshore (5.5–6.5 mg/l, av. 5.9 mg/l), offshore (5.7 mg/l) and towards Ghogha (6.5 mg/l).

The overall average concentration of DO (mg/l) in surface and bottom is shown in the Table 5.1 (f).

Table5.1 (f): Average DO values in water off Alang during February 2020.

Dissolved Oxygen (mg/l)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	6.3	–	**14**	5.6	5.6
2	6.3	–	**15**	5.9	5.7
3	5.7	–	**16**	5.7	5.6
4	6.0	–	**17**	5.7	5.9
5	5.9	–	**18**	5.7	5.8
6	6.0	–	**19**	5.6	5.5
7	5.8	5.8	**20**	6.4	6.4
8	5.8	5.7	**21**	6.4	6.5
9	5.9	6.3	**22**	5.7	5.7
10	5.5	5.5	**23**	5.5	5.9
11	5.5	5.5	**24**	5.7	5.7
12	5.8	–	**25**	6.5	6.5
13	6.0	5.9	**26**	5.7	–

In spite of high concentration of SS hampering photosynthesis, overall average DO concentration often recorded higher than 5.0 mg/l during present study, indicating healthy environment off Alang. The present values of DO are compared in the Figure 5.1 (viii) below:

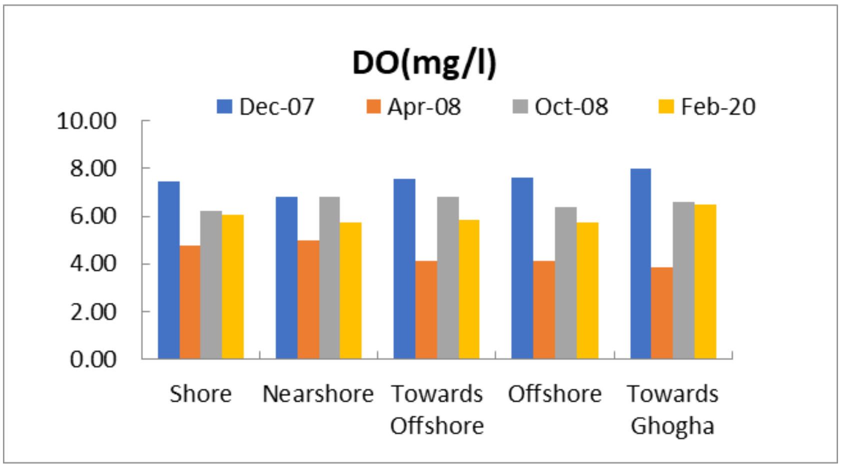


Figure 5.1 (viii) Average concentration of DO off Alang during different sampling events.

The above figure indicates that DO values recorded during December 2007 were higher than other months values in all the segments followed by October 2008 and February 2020. The lowest values were recorded during April 2008. The average value of DO is exactly reverse to that of salinity (Figure 5.1 (vi)). Such variation is expected, as dissolution of oxygen is inversely proportion to that of salinity.

Temporal variation: Results of temporal study to understand tidal variation is presented in the Figure 5.1 (ix) below:

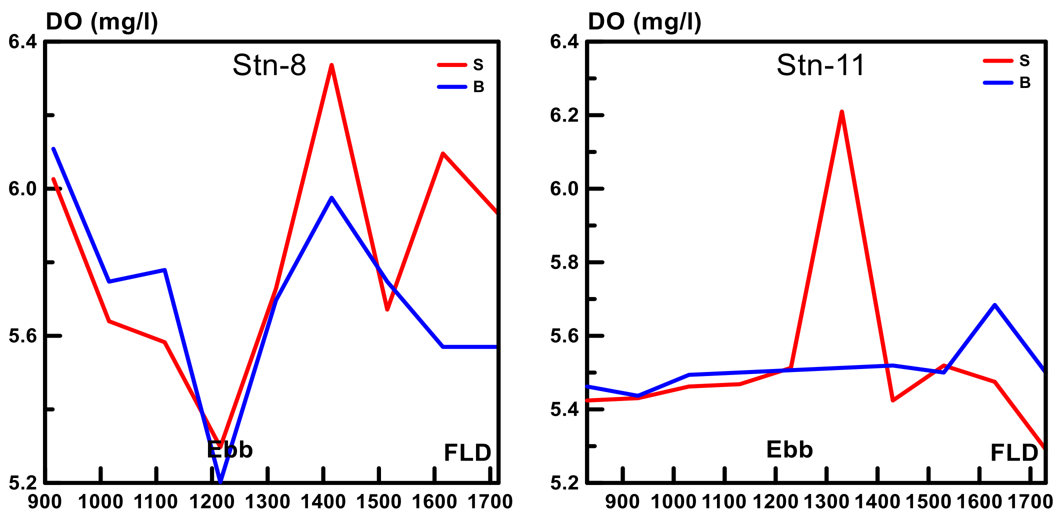


Figure 5.1 (ix) Temporal variation of DO in the water off Alang during February 2020.

Minimum concentration of DO recorded during ebb at station 8 may be due to the variation in SS values. However, there was no particular tidal trend at station 11.

vii) Biochemical Oxygen Demand (BOD): The average values of BOD generally below 2 mg/l in tropical coastal waters. This is because all–natural waters contain oxidizable organic matter of natural origin which include a variety of organic compounds in minute quantities and much of this is derived from land drainage. Tables 5.1.1–5.1.4 reveal a variation of BOD ranged at 2.7–3.7 mg/l, which apparently suggest the that the area does not sustain oxidizable organic matter, which can enhance the BOD value. However, a wide variation of BOD was observed and found in the range of 3.0–3.7mg/l (av. 3.4 mg/l) at shore, 2.7–3.5 mg/l (av. 3.2 μmol/l) nearshore, 3.0 –3.6 mg/l (av. 3.2mg/l) towards offshore, 3.1 mg/l in offshore and 3.6 mg/l towards Ghogha was evident from the results. The overall average BOD values in surface and bottom water during this study are given Table 5.1 (g) below:

Table5.1 (g): Average BOD values in water off Alang during February 2020.

Biochemical Oxygen Demand (mg/l)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	3.4	–	**14**	3.2	3.1
2	3.7	–	**15**	3.1	3.1
3	3.0	–	**16**	3.1	3.0
4	3.7	–	**17**	3.0	3.5
5	3.3	–	**18**	3.2	3.3
6	3.5	–	**19**	3.2	3.0
7	3.1	2.7	**20**	3.5	3.5
8	3.2	3.0	**21**	3.5	3.6
9	3.4	3.4	**22**	3.0	3.2
10	3.1	3.2	**23**	3.1	3.3
11	3.1	3.3	**24**	3.1	3.1
12	3.5	–	**25**	3.6	3.6
13	3.1	3.2	**26**	3.3	–

Thus, the above table indicates that average BOD values were < 4.0 mg/l during present study, indicating no substantial organic load, which can enhance BOD values substantially. The average BOD values recorded during present study are compared in the Figure 5.1 (x) below:

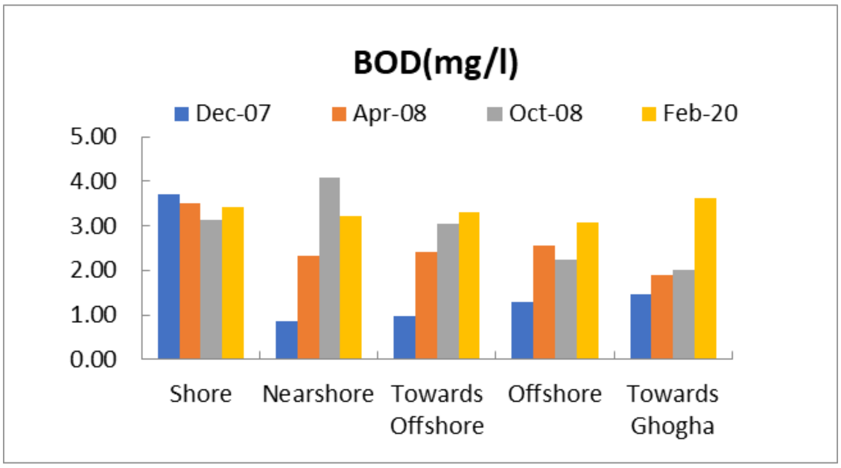


Figure 5.1 (x): Average concentration of BOD off Alang during different sampling events.

The above Table indicates that though the average value of BOD was comparable in shore and nearshore regions, it was high in towards offshore, offshore and towards Ghogha region. However, values were < 4.0 mg/l.

vii) Nitrogen and Phosphorus compounds: The nutrients in terms of nitrogen and phosphorus occur in estuarine and coastal water in many forms which can be either in oxidation states, solid–liquid–gas phase or chemical structure. The forms of nitrogen are diverse, ranging from nitrate (NO_3^- , +5) to ammonium (NH_4^+, –3) and compounds exist in all states in between. However, the dominant forms of nitrogen that exist in seawater are NO_3^-–N, NO_2^-–N and NH_4^+–N. NH_4^+–N which are produced during the oxidation of organic matter and get oxidized to NO_3^-–N via NO_2^-–N in the presence of sufficient quantity of DO in sea water. The NO_2^-–N is an intermediate product of oxidation of NH_4^+–N and reduction of NO_3^-–N and is thermodynamically unstable. Inorganic phosphorus occurs most often as the phosphate (PO_4^{3-}–P). Though these nutrients are essential for marine lives, their enrichment can lead to an excessive algal growth, increased metabolism, and changes in community structure, a condition known as eutrophication.

a) Nitrate: Values of NO_3^-–N observed during present study varied in the range of 6.9–43.8 µmol/l (Tables 5.1.1–5.1.4).

The average concentration of NO_3^-–N remained high at all the locations as evident in Tables 5.1.1–5.1.4, suggesting characteristics of Gulf. The NO_3^-–N concentration during the present study at shore (26.0–32.2 µmol/l, av. 28.76 µmol/l), near shore showed (6.9–43.8 µmol/l, av 18.7µmol/l), towards offshore (9.3–32.7 µmol/l, av. 25.3 µmol/l), offshore (31.3–32.3, av 31.8 µmol/l) and towards Ghogha (30.6–31.0µmol/l, av. 30.8 µmol/l). Since the water was well mixed due to the high tidal currents, there was no significant variation in the concentration of NO_3^-–N from surface to bottom.

The overall average values of nitrate (µmol/l) are given in the Table 5.1 (h) below:

Table5.1 (h): Average NO_3^-–N values in water off Alang during February 2020.

NO_3^-–N (µmol/l)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	29.7	–	**14**	10.5	11.6
2	31.6	–	**15**	27.0	26.9
3	28.2	–	**16**	30.9	32.6
4	29.1	–	**17**	28.5	29.9
5	26.1	–	**18**	30.3	29.4
6	27.8	–	**19**	19.0	23.6
7	15.8	23.3	**20**	30.3	31.1
8	25.9	28.7	**21**	21.7	29.6
9	11.9	17.2	**22**	27.6	29.2
10	11.6	8.3	**23**	29.8	26.4
11	17.7	18.0	**24**	32.3	31.3
12	14.9	–	**25**	30.6	31.0
13	12.4	18.6	**26**	29.7	–

Thus, the average values of NO_3^-–N were between 10.5–32.6 µmol/l during February 2020. To compare the segment wise variation of NO_3^-–N , the average values are plotted in the Figure 5.1 (xi) below:

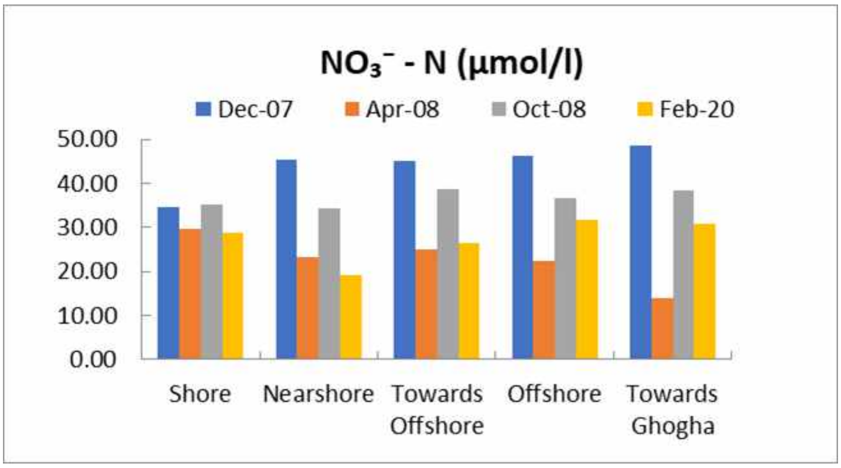


Figure 5.1 (xi): Average concentration of NO_3^-–N off Alang during different sampling events.

Thus, the values of NO_3^-–N recorded for nearshore (34.0–56.5 µmol/l, av. 45.3 µmol/l), towards offshore (26.4–60.7 µmol/l, av. 45.0 µmol/l), offshore (42.7–53.7, 46.4 µmol/) and towards Ghogha (44.7–51.7 µmol/l, av. 48.5 µmol/l) during December 2007 were nearly similar. The NO_3^-–N concentrations during October 2008 at nearshore (14.4–45.8 µmol/l, av. 23.3 µmol/l), towards offshore (16.7–39.2 µmol/l, av. 24.9 µmol/l), offshore (15.9–29.8, av. 22.5) and towards Ghogha (12.7–15.6 µmol/l, av. 14.0 µmol/l) were lower than that of December 2007. The values of NO_3^-–N were higher during December 2007 compared to the all other observations.

The overall higher values of nitrate during October and December (post monsoon) in the comparison of February and April (pre monsoon) indicated that the during monsoon season flux of nitrogenous compound takes place through land washings and the buildup of nitrate takes place thereafter during post monsoon. Thus, comparatively lower concentration of nutrients during February and April indicates the seasonal cycles with algal uptake dominating during spring and summer.

Temporal variation: Temporal study conducted to find tidal variation of NO_3^-–N at stations 8 and 11 are given in the Figure 5.1 (xii).

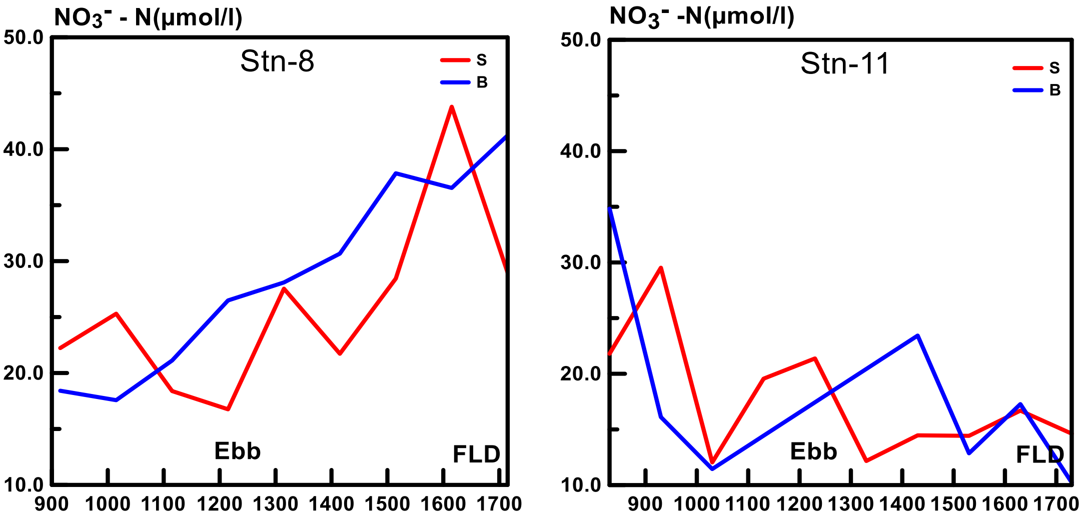


Figure 5.1 (xii) Temporal variation of NO_3^-–N in the water off Alang during February 2020.

Although the values of NO_3^-–N at station 8 showed increase from morning to evening, no clear tidal variation was observed at both stations.

b) Nitrite: The concentration of NO_2^-–N is the range of 0.09–1.6 µmol/l for the present study as evident in Tables 5.1.1–5.1.4. Though there was no distinguished variation in the concentration of NO_2^-–N from surface to bottom that could be due to well–mixed water by high currents. The average values of nitrite recorded during the present studies are presented in the Table 5.1 (i) below:

Table 5.1 (i): Average NO_2^-–N values in water off Alang during February 2020.

NO_2^-–N (µmol/l)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	0.4	–	**14**	0.4	0.4
2	0.3	–	**15**	0.1	0.1
3	0.2	–	**16**	0.2	0.1
4	0.2	–	**17**	0.1	0.1
5	0.2	–	**18**	0.1	0.1
6	0.3	–	**19**	0.3	0.3
7	0.3	0.3	**20**	0.1	0.2
8	0.3	0.3	**21**	0.1	0.1
9	0.3	0.3	**22**	0.1	0.2
10	0.2	0.1	**23**	0.1	0.1
11	0.2	0.1	**24**	0.2	0.1
12	0.2	–	**25**	0.2	0.2
13	0.4	0.5	**26**	0.9	–

It is evident from the above Table that the average concentration of nitrite was always below 1 µmol/l in the coastal water of Alang. Comparison of data collected during different sampling events are given in the Figure 5.1 (xiii).

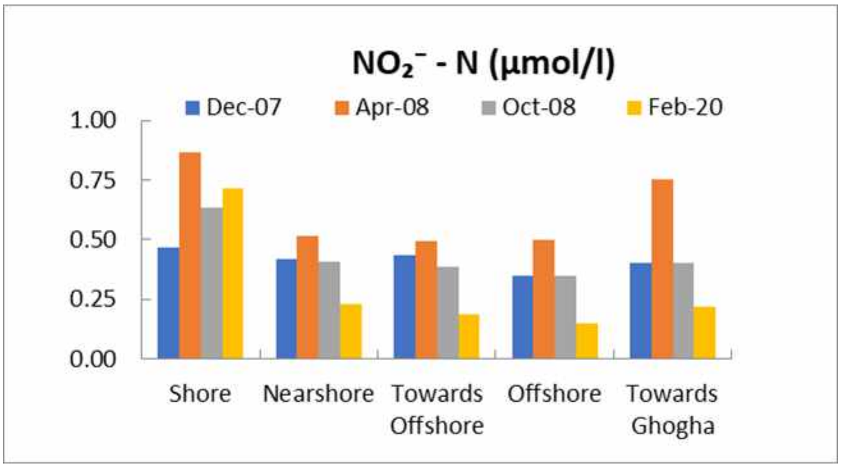


Figure 5.1 (xii): Average concentration of NO_2^-–N off Alang during different sampling events.

It is evident from above figure that the average values NO_2^-–N remains low irrespective of season of collection, indicating oxidizing condition in the region.

Temporal variation: Temporal variation of NO_2^-–N studied at stations 8 and 11 are given in the Figure 5.1 (xiii) below:

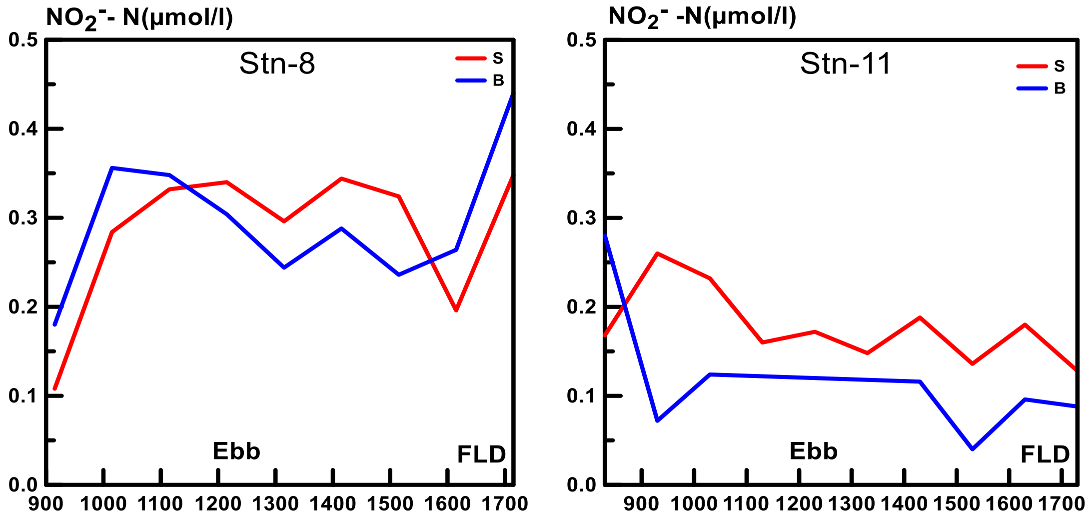


Figure 5.1 (xiii) Temporal variation of NO_2^-–N in the water off Alang during February 2020.

There was no particular tidal trend observed in the concentration of NO_2^-–N at both the stations.

c) Ammonia: The results of ammonia are presented in Tables 5.1.1–5.1.4. Although there was uneven distribution of NH_4^+–N, lower concentration recorded at offshore station, indicates the impact of shore–based activities in the region. However, a wide variation in the concentration of ammonia (0.7–1.3 µmol/l, av. 0.95 µmol/l) at shore, 0.6–4.6 µmol/l (av. 2.3 µmol/l) nearshore, 0.3–2.2 µmol/l (av. 0.9 µmol/l) towards offshore, 0.5–0.7 µmol/l (av. 0.6 µmol/l) offshore and 1.4–1.6 µmol/l (av. 1.5 µmol/l) towards Ghogha was evident from the results. The overall average concentration of ammonia (µmol/l) is presented in the Table 5.1 (j):

Table5.1 (j): Average NH_4^+–N values in water off Alang during February 2020.

NH_4^+–N (µmol/l)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	1.2	–	**14**	2.0	2.2
2	1.0	–	**15**	0.4	0.7
3	1.0	–	**16**	0.6	0.8
4	0.9	–	**17**	0.4	0.5
5	0.7	–	**18**	0.6	0.8
6	0.9	–	**19**	1.9	2.0
7	1.2	1.2	**20**	0.6	0.5
8	2.0	1.5	**21**	0.4	0.4
9	1.8	2.1	**22**	0.5	0.6
10	3.7	2.9	**23**	1.0	1.1
11	2.8	2.3	**24**	0.5	0.7
12	3.5	–	**25**	1.6	1.4
13	1.2	1.4	**26**	0.9	–

The average values of NH_4^+–N, revealed an enhanced concentration in nearshore (0.6–4.6 µmol/l) and towards Ghogha (1.4–1.6 µmol/l) during the present study, which could be attributed to slightly increased level of organic load similar to the other area of Gulf of Khambhat. Comparison of present average data of different segments is presented in the Figure 5.1 (xiv).

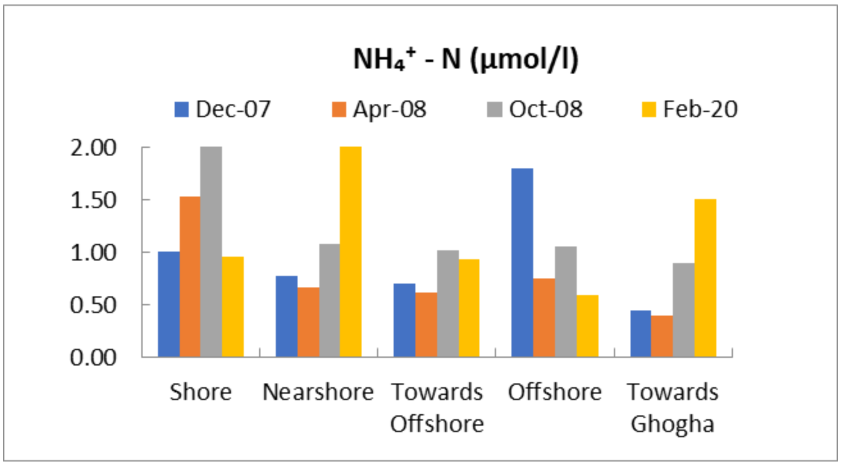


Figure 5.1 (xiv): Average concentration of NH_4^+–N off Alang during different sampling events.

Thus, above figure indicates increase of NH_4^+–N in nearshore and towards Ghogha during February 2020, compared to the earlier data.

However, it was lower in shore and offshore regions. Such variations may be attributed to the tidal movement of water, which is uneven in the gulf.

Temporal variation: like other parameters, tidal variation NH_4^+–N was also studied during the sampling period and presented in the Figure 5.1 (xv).

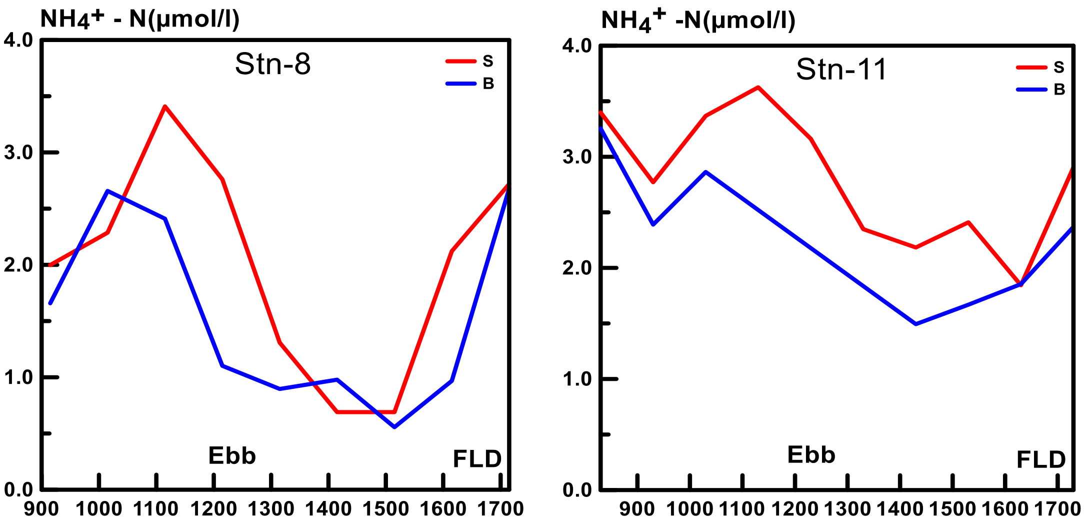


Figure 5.1 (xv) Temporal variation of NH_4^+–N in the water off Alang during February 2020

The above figure indicates that the particular tidal variation of NH_4^+–N was not taking place and random variation was observed.

d) Phosphate: The results of PO_4^{3-}–P are presented in the Tables 5.1.1–5.1.4. Phosphate values ranged between 1.3–2.2 µmol/l at shore segment, 1.4–2.5 µmol/l at nearshore stations, 1.2–3.5 µmol/l towards offshore, 1.2–1.6 µmol/l at offshore and 0.1–0.2 µmol/l towards Ghogha. Some of the elevated concentration of PO_4^{3-}–P that the coastal water of Alang to be rich for nutrients similar to another region of Gulf of Khambhat. The overall average values of phosphate (µmol/l) are presented in Table 5.1 (k) below:

Table5.1 (k): Average PO_4^{3-}–P values in water off Alang during February 2020.

PO_4^{3-}–P (µmol/l)					
Station	**Surface**	**Bottom**	**Station**	**Surface**	**Bottom**
1	1.9	–	**14**	1.3	1.4
2	2.1	–	**15**	1.4	1.6
3	1.7	–	**16**	1.2	1.6
4	1.5	–	**17**	2.0	2.5
5	1.6	–	**18**	2.9	1.6
6	1.4	–	**19**	1.3	1.4
7	2.0	2.2	**20**	1.6	2.5
8	1.7	1.8	**21**	1.4	1.4
9	1.9	2.0	**22**	1.4	1.6
10	2.1	2.1	**23**	1.8	1.9
11	1.7	1.8	**24**	1.2	1.6
12	2.0	–	**25**	0.2	0.1
13	1.3	1.3	**26**	1.7	–

The above table indicates random distribution of PO_4^{3-}–P and there was no much difference in average concentration from shore to offshore region. As in the case of other parameter, there is no substantial variation from surface to bottom, which are characteristics of Gulf of Khambhat as a result of turbulence generated by swift current in the region. Present data of PO_4^{3-}–P is compared with earlier data off Alang in the Figure 5.1 (xvi) below:

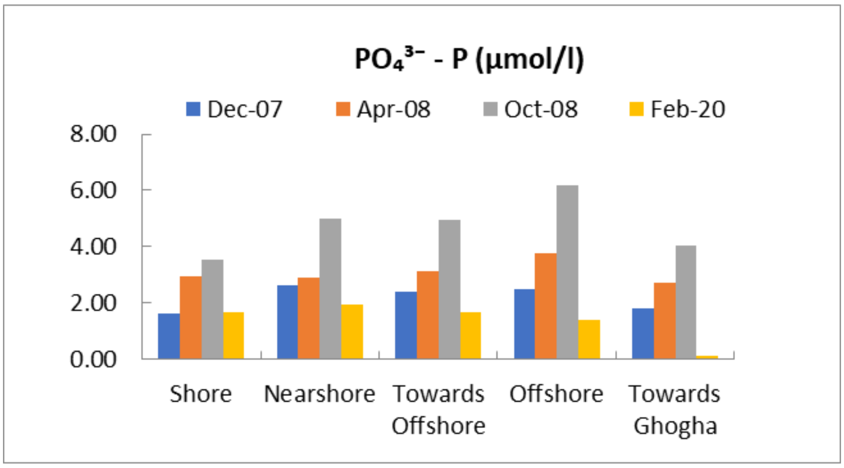


Figure 5.1 (xvi): Average concentration of PO_4^{3-}–P off Alang during different sampling events.

The above graph indicates an increased concentration of PO_4^{3-}–P during October in the comparison of other months suggesting the influence of land drainage on phosphate during postmonsoon.

Temporal variation: Tidal variation of PO_4^{3-}–P is presented in the Figure 5.1 (xvii) below:

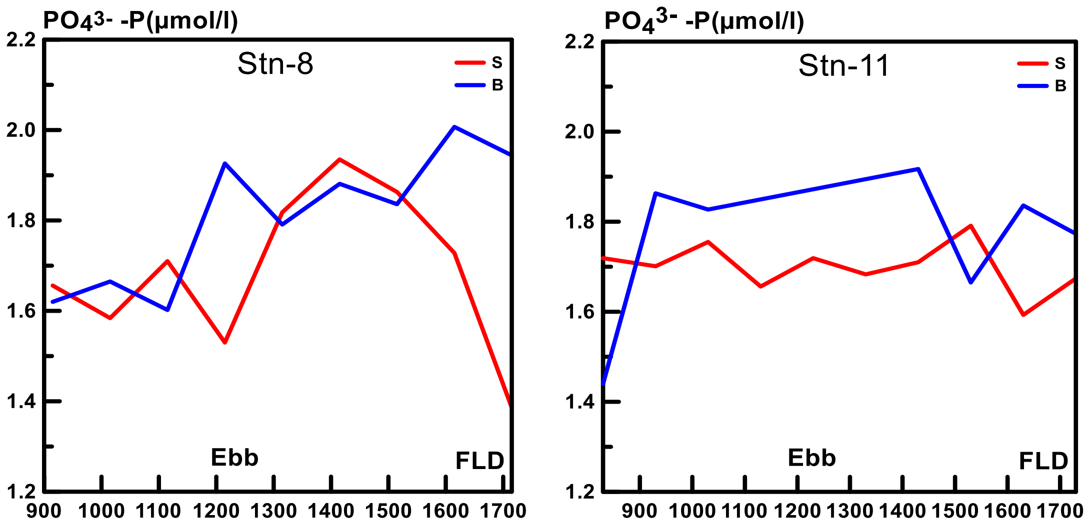


Figure 5.1 (xvii) Temporal variation of PO_4^{3-}–P in the water off Alang during February 2020.

Like other nutrients there was no tidal variation of PO_4^{3-}–P at both the stations, the variation in the area indicates presence of the nutrients in the area since long time and not from particular source.

viii) PHc and Phenols: PHc in the aquatic environment originates from residual fuels, accidental petroleum spills and effluents from industries such as refineries and petrochemical. The elevated levels of PHc are expected from ship breaking activities if the breaking is not done with proper precautions. Generally unpolluted aquatic system sustains trace levels (few micrograms per litre) of PHc. Phenols are generally present in the concentration of few microgram per litre as microbiologically produced polyphenols in natural waters.

The concentration of PHc at shore segment (144.6–614.0 µg/l, av. 407.8 µg/l) followed by nearshore segment (34.2–143.0 µg/l, av. 82.6 µg/l) during February 2020. The values of PHc declined towards offshore (12.5–42.1 µg/l, av. 22.1 µg/l),towards Ghogha (14.3µg/l) and in offshore (14.8 µg/l) were low. A small patch of oil spill was observed during survey, such oil spills may be the source of high concentration of PHc in shore and nearshore station.

The variation of phenol at shore segment (69.1–100.1µg/l, av. 89.0 µg/l), nearshore segment (43.9–91.7 µg/l, av. 69.1 µg/l) towards offshore (57.8–101.3 µg/l, av. 76.0 µg/l), offshore (63.1 µg/l) and towards Ghogha (61.0µg/l) suggested the marginal high concentration of phenol. However, these values are in the agreement of other surrounding region of the Gulf of Khambhat and do not suggest the impact of ship breaking activities.

The average concentrations of PHc (µg/l) and phenols (µg/l) are presented in the following Table 5.1 (l) below:

Table5.1 (l): Average PHc (µg/l) and phenols (µg/l) values in water off Alang during February 2020.

Station	PHc (µg/l)	Phenol (µg/l)	Station	PHc (µg/l)	Phenol (µg/l)
1	144.6	69.1	**14**	22.9	57.8
2	315.1	97.7	**15**	42.1	88.8
3	614.0	100.1	**16**	22.5	72.2
4	584.3	90.0	**17**	18.5	101.3
5	446.9	96.2	**18**	26.1	88.3
6	342.1	80.9	**19**	18.0	63.8
7	116.0	79.0	**20**	14.6	69.6
8	97.1	67.4	**21**	17.3	94.6
9	143.0	67.7	**22**	13.3	63.4
10	42.7	43.9	**23**	12.5	66.7
11	62.8	79.4	**24**	14.8	63.1
12	34.2	77.3	**25**	14.3	61.0
13	35.2	69.4	**26**	–	54.7

From the above table, it is evident that the shore stations contain high concentration of PHc. The PHc and phenol values recorded during present study are are compared with the data recorded during earlier studies in the Figure 5.1 (xviii) below:

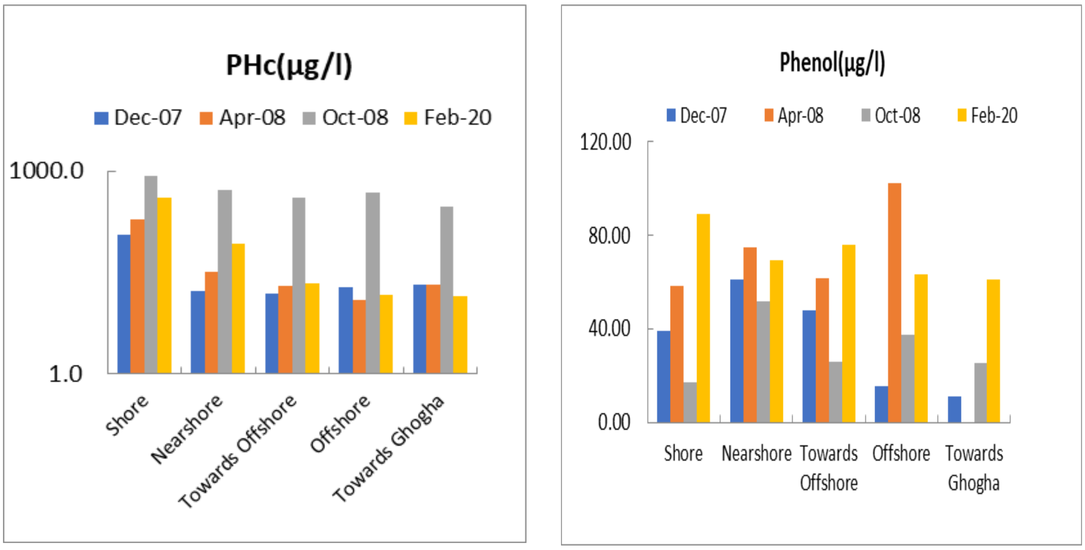


Figure 5.1 (xviii): Average concentration of PHc and phenol off Alang during different sampling events.

From the above graph, it is evident that the shore stations contain high concentration of PHc during all seasons. The concentration of PHc during the present study has declined remarkably as compared to the October 2008 values. Such result may be attributed to the enforcement of ship−recycling conventions to curtail the pollution due to ship−recycling activities. The average concentration of phenols was either comparable with earlier data or marginally higher during February 2020. However, these values represent general characteristics of the Gulf.

ix) Dissolved metals: The distribution of dissolved metals in seawater collected from different locations in this study is presented in Table 5.1.5 Concentration of metals Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd and Pb varied widely. However, offshore location showed lower concentration of metals except Mn. Concentration of As, Cd and Pb was low throughout the study area.

5.2 Sediment quality

Many important elements and chemical compounds which are present in the marine environment are known to be attached to inorganic particles. These chemical species include many of the most important elements and compounds including mercury, lead, cadmium, PCBs, and plutonium. When these compounds are introduced into the nearshore marine environment, even if they are initially in the dissolved form. These compounds rapidly become removed onto particles and get sedimented. Hence, sediments play a critical and beneficial role in reducing the availability of metals to water or biota, by acting as sinks. However, when primary sources of pollutants such as metals are eliminated, the sediments may act as secondary sources posing potential long–term threat to the aquatic ecosystem. Hence, analysis of sediment for metal content plays an important role to assess the pollution load. Similarly the texture of sediment becomes important to understand the quality of sediment which facilitates the accumulation of metals in it. The results of texture and metals are discussed below.

(i) Texture: Texture of subtidal and intertidal sediments is presented in Tables 5.2.1–5.2.2. The shore stations contained high percentage of sand with negligible concentrations of silt and clay except during December 2007 and February 2020. Nearshore and towards offshore sediments were dominated by silty–clay. However, offshore and towards Ghogha sediments were high in sand and silt percentage.

In intertidal sediment percentage of sand was high at upper segment. The middle and lower segment contained silty–clay sediments. The overall average percentage of sand, silt and clay is shown in the following Table 5.2 (a) below:

Table 5.2 (a): Variation of sediment texture in the subtidal region off Alang during different sampling events.

Segment	Dec–07			Apr–08			Oct–08			Feb–20		
	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)
Shore	54.8	41.7	3.5	98.8	0.2	1.0	98.3	0.1	1.6	37.5	55.1	7.5
Nearshore	10.3	80.1	9.6	8.7	84.0	7.3	27.5	64.9	7.5	2.3	85.7	12.0
Towards offshore	11.0	80.8	8.7	18.0	72.4	9.5	42.0	51.6	6.5	13.1	78.4	8.5
Offshore	61.4	34.8	3.8	16.1	78.7	5.2	88.0	10.4	1.6	70.5	23.8	5.7
Towards Ghogha	97.6	0.0	2.4	89.4	8.6	2.0	–	–	–	0.2	88.4	11.4

It is evident in the above Table that the shore of Alang area was sandy whereas the nearshore and towards offshore region sustained silty–clay. However, offshore area was dominated by sandy–silt except during April, when the sediment was silty–clay.

The results of texture recorded in intertidal sediment are as Table 5.2 (b) as follows;

Table 5.2 (b): Variation of sediment texture in the intertidal region off Alang during different sampling events.

Segment	Dec–07			Apr–08			Oct–08			Feb–20		
	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)	Sand (%)	Silt (%)	Clay (%)
Upper	82	15.9	1.7	76	20.6	3.3	97	1.1	2.1	79	16.1	5.2
Middle	2.8	93.3	3.9	6.9	88.4	4.8	30	63.9	6.4	61	35.1	4.2
Lower	3.1	89	7.9	8.9	84.5	6.6	25	67.8	6.9	69	21.5	9.5

The upper region of intertidal area was sandy, whereas middle and lower segment sustained silty–clay. This is expected since the swift currents do not favour the deposition of fine particles especially in the lower regions.

(ii) Heavy metals: Sediment in the estuary and coastal region is largely derived from weathering rocks of the surrounding coast and that transported from the catchments. These sediments contain heavy metals to a varying degree depending on the source rock from which they are derived. Strong tidal currents sweeping the Gulf disperse the settled sediment in the water column. Fine particles of SS thus can scavenge trace metals in water, which are present in extremely low concentrations and transfer them to the bed sediment on settling. They are enriched in the sink as detrital minerals and chemically sorbed and complexed, coprecipitated, flocculated and precipitated forms. The content largely depends upon the grain size and composition of bed sediment. For example, smaller grain size and higher clay matter may result in higher concentration of metals in sediments.

The results of concentration of heavy metals analysed in the subtidal and intertidal sediments are summarized below:

The results of metals indicated some impact of ship breaking activities on the distribution at the shore segments. Thus, the variation of Al, Cr, Ti, Mn, Co, Pb, Cd, As, Fe, Ni, Cu, Zn and Hg varied in the Al of 3.68–6.95% (av. 5.84%), Cr of 86–413 µg/g (av. 150 µg/g), Mn of 730.6–2029 µg/g (av. 1005.7 µg/g), Fe of 5.76–23.4% (av 8.04%), Co of 30.43–82.18 µg/g (av. 39.12 µg/g), Pb of 12.04–80.32 µg/g (av. 19.26 µg/g), Cd of 0.13–0.52 µg/g (av. 0.21 µg/g), As of 3.96–26.07 µg/g (av. 8.94 µg/g), Ni of 37.11–67.13 µg/g (av. 47.1µg/g), Cu of 66.28–227.4 µg/g (av. 93.81 µg/g), Zn of 67.75–1214.0 (av. 151.6µg/g) and Hg of 0.02–0.28 µg/g (av. 0.09 µg/g), respectively were evident from the results (Table 5.2.1).

The average values of metals recorded in subtidal sediments during different study periods are furnished in the Table 5.2 (c) shown below:

Table 5.2 (c): Average concentration of metals in the subtidal region off Alang during different sampling events.

Metal	Dec–07	Apr–08	Oct–08	Feb–20
Shore				
Al (%)	5.8	4.6	6.3	5.34
Cr (µg/g)	206	146	220	223
Mn (µg/g)	1474	1570	1797	1339
Fe (%)	11	13.9	17.5	12.1
Co (µg/g)	47	43	27	44
Ni (µg/g)	100	106	52	58
Cu (µg/g)	128	151	200	126
Zn (µg/g)	337	497	494	374
Hg (µg/g)	0.31	0.2	0.12	0.19
As (µg/g)	–	–	–	12.85
Cd (µg/g)	–	–	–	0.29
Pb (µg/g)	–	–	–	36.62
Nearshore				
Al (%)	8	9.8	11.7	6.32
Cr (µg/g)	121	132	126	135
Mn (µg/g)	1054	965	1011	886
Fe (%)	5.9	6.5	7.5	6.9
Co (µg/g)	44	43	31	38
Ni (µg/g)	82	75	51	45
Cu (µg/g)	94	92	96	88
Zn (µg/g)	89	82	99	90
Hg (µg/g)	0.04	0.05	0.01	0.07
As (µg/g)	–	–	–	7.84
Cd (µg/g)	–	–	–	0.23
Pb (µg/g)	–	–	–	16.1
Towards offshore				
Al (%)	8.1	8.4	10.7	5.92
Cr (µg/g)	126	130	121	130
Mn (µg/g)	1139	860	1059	912
Fe (%)	6.8	4.9	6.7	6.7
Co (µg/g)	43	41	32	37
Ni (µg/g)	84	70	51	43
Cu (µg/g)	94	84	91	80
Zn (µg/g)	89	113	87	82
Hg (µg/g)	0.04	0.03	0.01	0.04
As (µg/g)	–	–	–	7.65
Cd (µg/g)	–	–	–	1.66
Pb (µg/g)	–	–	–	13.2
Offshore				
Al (%)	7.1	8.4	9.9	3.8
Cr (µg/g)	134	150	141	136
Mn (µg/g)	1217	1056	1397	1302

Fe (%)	–	6.3	6.1	8
Co (µg/g)	42	43	32	46
Ni (µg/g)	83	79	40	43
Cu (µg/g)	94	102	73	99
Zn (µg/g)	105	189	67	103
Hg (µg/g)	0.07	0.09	ND	0.09
As (µg/g)	–	–	–	11.02
Cd (µg/g)	–	–	–	0.21
Pb (µg/g)	–	–	–	13.67
Towards Ghogha				
Al (%)	3.7	5.6	–	6.41
Cr (µg/g)	86	168	–	97
Mn (µg/g)	1005	987	–	893
Fe (%)	2.5	6.7	–	6.7
Co (µg/g)	21	43	–	32
Ni (µg/g)	41	92	–	43
Cu (µg/g)	37	98	–	88
Zn (µg/g)	41	78	–	80
Hg (µg/g)	0.07	0.14	–	0.1
As (µg/g)	–	–	–	6.65
Cd (µg/g)	–	–	–	0.13
Pb (µg/g)	–	–	–	12.63

As it is evident from the above table, the concentration of Al was minimum in the shore locations, but concentration of metals, especially Fe, Cr, Cu and Zn was high in all the sampling events, indicating their anthropogenic source and no doubt ship cutting activities in the region. There was substantial decrease in the concentration of above metals towards offshore region. This may be due to the strong tidal current, in the region, which do not allow settling of these metals.

Intertidal

The values of metals recorded in the intertidal region of Alang are presented in the Tables 5.2.2. Similar to the results of subtidal, the concentrations of selected metals such as Cr, Mn, Fe, Ni, Cu and Zn were enhanced in the upper most part of intertidal sediments of Alang. Thus Cr (112–326 µg/g, av. 144.5 µg/g), Mn (73–1772 µg/g, av. 1218 µg/g), Fe (7.6–17.2 %, av. 10.0 %), Ni (37–74 µg/g, av. 57 µg/g), Cu (51–149µg/g, av. 110 µg/g), Zn (69–608 µg/g, av. 226 µg/g), As (7.4–18.8 µg/g, av. 10.3 µg/g), Cd (0.19–0.81 µg/g, av. 0.36 µg/g), Hg (0.03–0.55 µg/g, av 0.19 µg/g) and Pb (9.8–66.8 µg/g, av. 30.1 µg/g) showed wide variation and enhancement in the upper most segment of intertidal sediments. It is evident from Table 5.2.2 that the sediment of T–I sustained high percentage of sand and lower percentage of Al, higher concentration of Cr, Mn, Fe, Cu, Zn, As, Hg and Pb. It indicates that these metals do not represent sediment bound concentration, but have anthropogenic source.

The average values of the metals recorded at the intertidal region during different seasons are shown in the Table 5.2 (d) below:

Table 5.2 (d): Average concentration of metals in the intertidal region off Alang during different sampling events.

Upper region				
Metal	**Dec–07**	**Apr–08**	**Oct–08**	**Feb–20**
Al (%)	2.1	4.1	7.3	5.6
Cr (µg/g)	282	169	268	151
Mn (µg/g)	2569	2078	1588	1229
Fe (%)	24.6	21.4	15.8	10.5
Co (µg/g)	49	56	39	41.5
Ni (µg/g)	151	130	47	60
Cu (µg/g)	235	246	95	118
Zn (µg/g)	574	746	175	261
Hg (µg/g)	–	–	–	11.3
As (µg/g)	–	–	–	0.44
Cd (µg/g)	0.14	0.27	0.2	0.43
Pb (µg/g)	–	–	–	30.7
Middle region				
Al (%)	7.1	8.4	8.6	4.95
Cr (µg/g)	133	146	216	158
Mn (µg/g)	1098	1055	2090	1199
Fe (%)	5.1	5	20.5	10.06
Co (µg/g)	46	44	43	36
Ni (µg/g)	84	76	87	53
Cu (µg/g)	101	97	190	109
Zn (µg/g)	107	145	471	237
As (µg/g)	–	–	–	11
Cd (µg/g)	–	–	–	0.31
Hg (µg/g)	0.04	0.02	0.04	0.04
Pb (µg/g)	–	–	–	37.5
Lower region				
Al (%)	7.5	8.4	10.3	5.8

Cr (µg/g)	128	137	200	179
Mn (µg/g)	1115	962	1227	1224
Fe (%)	7	4.9	8.7	9.5
Co (µg/g)	44	43	42	46
Ni (µg/g)	83	73	56	58
Cu (µg/g)	99	91	109	103
Zn (µg/g)	102	82	109	180
As (µg/g)	–	–	–	8.6
Cd (µg/g)	–	–	–	0.31
Hg (µg/g)	0.34	0.24	0.04	0.06
Pb (µg/g)	–	–	–	22

(iii) Organic carbon and phosphorus:

Generally, organic matter in natural coastal sediment originates from terrestrial run–off and remains with organisms inhabiting the region. Their decay is one of the important sources of nutrients in the water column. Anthropogenic organic inputs however, can increase the content to abnormal levels disturbing the equilibrium of the ecosystem. Organic matter settling on the bed is scavenged by benthic organisms to a large extent. Heterotrophic microorganisms that require DO decompose organic matter and maintain the balance. Hence, DO in the sediment–interstitial water is continuously consumed and anoxic conditions develop if the organic matter is more than that can be oxidized through oxygen as an oxidant. Such conditions are harmful to benthic fauna.

Lithogenic phosphorus in marine sediments is derived from the geological sources through river flows, while; the anthropogenic phosphorus is the result of sewage and industrial discharges, agricultural runoff etc. Solubilisation of $FePO_4$, $Ca_3(PO_4)_2$, $CaHPO_4$ and $Mg_3(PO_4)_2$ during heterotrophic decomposition of organic matter is attributed to the formation of organic acids which function as chelating agents releasing free phosphate ions. In anaerobic conditions, however, the reduction of iron from ferric to ferrous state takes place to release inorganic phosphorous bound in sediment.

Subtidal: The results of organic carbon (C_{org}) and phosphorus studied in the sediment are presented in Table 5.2.1. The concentration of C_{org} varied in the range of 0.4–1.4% (av 0.9%), 0.4–1.1% (av 0.8%), 0.5–1.0% (av 0.8%), 0.5% and 1.0% in shore, nearshore, towards offshore, offshore and towards Ghogha segments respectively in the subtidal sediments. No marked seasonal variation in the concentration of C_{org} was observed.

Concentration of phosphorus varied between 637–812 µg/g (av. 713 µg/g), 493–891 µg/g (av. 689 µg/g), 659–966 µg/g (av. 715 µg/g), 762 µg/g and 636 µg/g in shore, nearshore, towards offshore, offshore and towards Ghogha segments respectively in the subtidal region. The overall average concentration of C_{org} and phosphorus (µg/g) are presented in the following Table:

Table 5.2 (e): Average concentration of C_{org} (%) and P (µg/g) in the subtidal region off Alang during different sampling events.

Segment	December 2007		April 2008		October 2008		February 2020	
	C_{org}	P	C_{org}	P	C_{org}	P	C_{org}	P
Shore	0.7	734	0.5	693	0.8	759	0.9	713
Nearshore	0.8	637	0.7	854	0.9	850	0.8	689
Towards offshore	1.0	689	0.6	619	1.0	795	0.8	715
Offshore	0.8	717	0.3	667	1.1	869	0.5	762
Towards Ghogha	0.5	484	0.2	1028	–	–	1.0	636

From the above results, it is evident that there is no buildup of C_{org} and phosphorus in the sediment of Alang region and values recorded during present study compared well with earlier data.

Table 5.2 (f): Average concentration of C_{org} (%) and P (µg/g) in the intertidal region off Alang during different sampling events.

Segment	December 2007		April 2008		October 2008		February 2020	
	C_{org}	P	C_{org}	P	C_{org}	P	C_{org}	P
Upper region	1.0	454	0.7	705	0.9	743	1.7	948
Middle region	0.9	698	0.7	689	0.9	920	0.8	851
Lower region	1.1	692	0.7	686	0.9	761	1.0	925

As in the case of subtidal sediments, values recorded for C_{org} and phosphorus in the intertidal sediments of Alang were low and indicative of negligible accumulation of these elements.

(iv) PHc: Naturally contents of PHc are low, and associated with vegetation decay, erosion etc. PHc entering through the spillage on water partly evaporates and the leftover residue eventually sinks to the bottom due to increase in density or its incorporation with particulate matter. Thus bed sediment may serve as a sink to PHc and its high levels may indicate gross sediment contamination in the region, over a period of time.

Subtidal: The concentrations of PHc recorded at the subtidal stations during three seasons of present monitoring are presented in Tables 5.2.1. A wide variation in the concentration of PHc is evident from the Table. The PHc values varied in the range of 0.1–15.4 µg/g (av 2.8 µg/g), 0.1–1.2 µg/g (av 0.4 µg/g), 0.1–3.5 µg/g (av 1.0 µg/g), 1.1 µg/g and 1.0 µg/g at shore, nearshore, towards offshore, offshore and towards Ghogha segments respectively. These values clearly indicated the contamination of sediment in the shore stations. The average values of PHc (µg/g) in the subtidal segments recorded during present and earlier studies are presented in the following Table 5.2 (g):

Table 5.2 (g): Average concentration of PHc (µg/g) in the subtidal region off Alang during different sampling events.

Segment	December 2007	April 2008	October 2008	February 2020
Shore	5.6	3.2	2.6	2.8
Nearshore	1.6	1.5	2.1	0.4
Towards offshore	2.8	0.3	0.5	1.0
Offshore	2.7	0.3	0.4	1.1
Towards Ghogha	–	0.2	–	1.0

It is evident from above Table that the shore stations are contaminated by PHc. as in the case of Such elevated values may be indicative of impact of shipbreaking activities is confined to the shore segment.

Intertidal: The values of PHc in the intertidal sediments are presented in the Table 5.2.2. Results clearly indicated that the intertidal sediments of transect T–I to T–III were contaminated with respect to PHc. This was expected as huge number of ships was being scrapped down on the beach of Alang and spillage of used as well as unused oil could not be avoided even taking utmost precautions. The PHc concentration at upper 0.1–4.0 µg/g (av 2.7 µg/g), middle 0.1–5.5 µg/g (av 3.5 µg/g) and lower 0.7–4.9 µg/g (av 3.9 µg/g) segments were recorded. The average concentrations of PHc (µg/g) in the intertidal region of Alang recorded during present study is compared with the values of earlier studies in the Table 5.2 (h) below:

Table 5.2 (h): Average concentration of PHc (µg/g) in the intertidal region off Alang during different sampling events.

Segment	December 2007	April 2008	October 2008	February 2020
Upper region	16.6	0.7	0.6	2.7
Middle region	3.7	1.6	3.0	3.5
Lower region	20.2	1.1	2.9	3.9

The overall results revealed the highest concentration of PHc during December 2007. PHc values observed during present study reveals moderate contamination of intertidal sediment.

5.3 Flora and fauna

Study of the biological status of a marine ecosystem is an essential prerequisite to assess the existing status of developments in the coastal zone. Despite many changes in the physico−chemical properties of water body and sea bed sediment, the ultimate consequences of pollutants may reflect on the biological system.

Hence, the investigations of an ecosystem and particularly of its communities constitute an important part of any ecological assessment. This can be achieved by selecting a few reliable parameters from a complex community structure. In view of wide variations in biological production in an ecosystem, the biological parameters considered for the present study are microbial parameters, phytoplankton production in terms of pigments, cell count and generic diversity, zooplankton standing stock in terms of biomass, population and total groups, macrobenthos standing stock in terms of biomass, population and faunal groups. The phytoplankton pigment, cell count and zooplankton standing stock reflect the primary productivity of water column at the primary and secondary levels. Benthic organisms being sedentary animals associated with the seabed, provide information regarding the combined effects of stress, if any, and hence are good indicators of early warning of potential damage. A collective evaluation of all the above components is a reliable approach to predict the state of equilibrium of marine life in coastal waters.

With this view, the status of flora and fauna in the nearshore water of Alang is evaluated in terms of microbial population, phytoplankton pigments, population and total genera, zooplankton biomass, population and total groups and intertidal and subtidal macrobenthic biomass, population and total groups. The results of these studies are presented below:

5.3.1 Microbiological Aspects

Microbial ecology is at the forefront of developing and applying a new generation of indicators of environmental stress and ecological change. The roles played by marine microorganisms are profound in the overall normal functioning, stability and continuance of the marine ecological processes. Despite their small size marine microorganisms are far more critical as they are linked to water column and sediment (benthic) processes. Marine microorganisms occupy the base of the food web, and form food for protozoa, invertebrate larvae and many large zooplankton and regenerate dissolved nutrients for marine photosynthesis and formation of newer organic biomass. Bacteria are significant links to many biological and non−biological events in the oceans. As we learn about the diversity of microorganisms and their associated processes, our view of the marine ecosystem is being transformed, and the relevance of microbes to marine resiliency and marine resource management is becoming undeniable. The sheer number of microorganisms acts as sentinels for health status within the marine ecosystem as well as their vast diversity, and different functions have led to the realization of threats from emerging pathogens. To bring into focus the importance of marine bacteria at the base of the food web, an assessment of their abundance and distribution are essential. The microbial diversity of coastal waters can be influenced by anthropogenic activities also besides oceanic processes.

The principal source of waterborne diseases such as cholera, typhoid and hepatitis are due to contamination of water by sewage and animal wastes. Apart from potable water, bacterial contamination occurs in surface waters such as those used for shellfishing areas, beaches, fisheries and recreational facilities. Though 90% of the intestinal bacterial population dies off within 2 days in natural waters, the remaining 10% decline much more slowly. Coliform bacteria such as *Escherichia coli* and *faecal streptococci* (Genus: Streptococcus) are the two most important groups of non−pathogenic bacteria found in sewage. Because of the number of problems associated with the determination of populations of individual pathogens, non−pathogenic bacteria (such as coliforms) are used as indicators of water pollution. Untreated domestic wastewater has about 3−million coliforms/100 ml. Because pathogens originate from the same source, the presence of high numbers of coliforms indicates potential danger. Bacteriological analyses for the present study included the enumeration of total viable bacterial counts (TVC) and coliforms at 25 stations in coastal waters off Alang, Bhavnagar. Total Viable Counts (TVC), Total Coliform (TC), *Escherichia coli* like organisms (ECLO) and *Streptococcus faecalis* like Organism (SFLO) were studied. The microbiological results for water and sediments are given in Tables 5.3.1 and 5.3.2.

a. Water

The total viable bacterial populations in the water samples ranged between 10 x 10^3 CFU/ml to as 2150 x 10^3 CFU/ml (Table 5.3.1) in the study area. The lowest counts were recorded at stations 3 and 6 and the highest counts were recorded at station 18 (Table 5.3.1). Other parameters like Total Coliform (TC), Faecal Coliform (FC) and *Escherichia coli* like organisms (ECLO) were not recorded from the study area except at stations 2 and 3.

b. Sediment

The total viable bacterial populations in the sediment samples ranged widely between 10 x 10^4 CFU/g to 1860 x 10^4 CFU/g (Table 5.2) in the study area. The lowest counts were recorded at stations 11, 13 and 22 and the highest counts were at station 2 (Table 5.3.2). Comparing the TVC counts of shore, nearshore and towards offshore segments, the shore segment recorded a higher TVC count in the sediments. Though the offshore station indicated higher TVC count, this was a single value and therefore was not considered for comparison. TC was detected at stations 2, 14 and 22 with station 14 (72 x 10^3 CFU/g) having the highest count. FC was observed at station 14 and station 22. *Escherichia coli* like organisms (ECLO) and *Streptococcus faecalis* like Organism (SFLO) were not recorded from the sediments of the study area. Segment wise average record of TVC count in water and sediment off Alang is presented in the Figure 5.3.1 below:

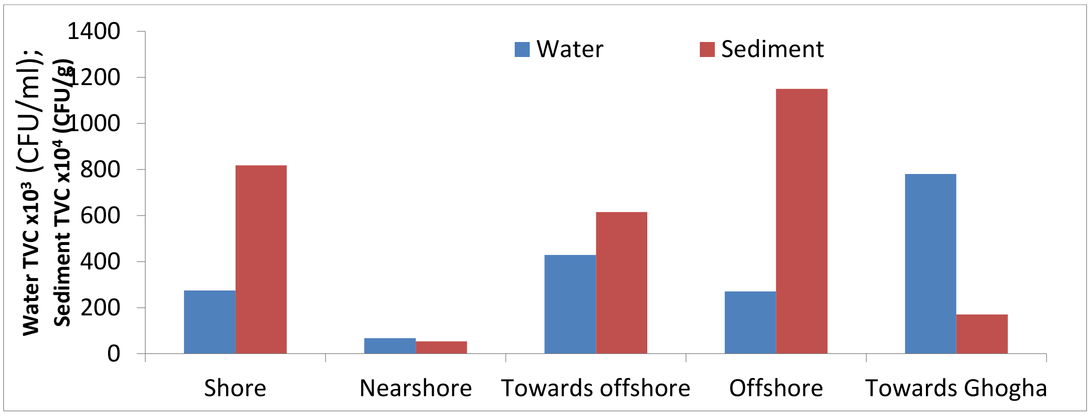


Figure 5.3.1: TVC count in water and sediments from various segments at Alang during February 2020.

From the graph, it is evident that TVC count in sediments was higher when compared with water.

5.3.2 Phytoplankton

Phytoplankton forms the vast array of minute and microscopic plants passively drifting in natural waters and mostly confined to the illuminated zone. In an ecosystem these organisms constitute primary producers forming the first link in the food chain. Phytoplankton long has been used as indicators of water quality. Some species flourish in highly eutrophic waters while others are very sensitive to organic and/or chemical wastes. Some species develop noxious blooms, sometimes creating offensive tastes and odours or anoxic or toxic conditions resulting in animal death or human illness. Because of their short life cycles, phytoplankton responds quickly to environmental changes. Hence their standing crop in terms of biomass, cell counts and species composition are more likely to indicate the quality of the water mass in which they are found.

Generally, phytoplankton standing crop is studied in terms of biomass by estimating chlorophyll *a* and primary productivity and in terms of population by counting total number of cells and their generic composition. When under stress or at the end of their life cycle, chlorophyll *a* in phytoplankton decomposes with phaeophytin as one of the major products.

a) Phytoplankton pigments: The results of phytoplankton pigments in terms of chlorophyll *a* and phaeophytin recorded during present study are given in Tables 5.3.3 and 5.3.4. The chlorophyll a (0.01 – 4.72 mg/m^3; av 0.22 mg/m^3) and phaeophytin (0.0–1.21 mg/m^3; av 0.21 mg/m^3) concentrations indicated slight variations in the coastal ecosystem off Alang during February 2020. The highest concentrations of chlorophyll *a* were recorded at shore stations (0.10 – 4.72 mg/m^3; av 0.8 mg/m^3) and lowest at Ghogha (0.06 – 0.16 mg/m^3; av 0.10 mg/m^3).

A decline in chlorophyll *a* was observed at towards offshore transect (Figure 5.3.2). The concentrations of phaeophytin were higher at near shore stations (0.01 – 0.99 mg/m^3; av 0.35 mg/m^3) and lower at offshore zone (0.01 – 0.07 mg/m^3; av 0.03 mg/m^3) (Figure 5.3.3). Phaeophytin is a measure of dead cells and is an indirect indicator of stress conditions leading to deterioration of chlorophyll *a*.

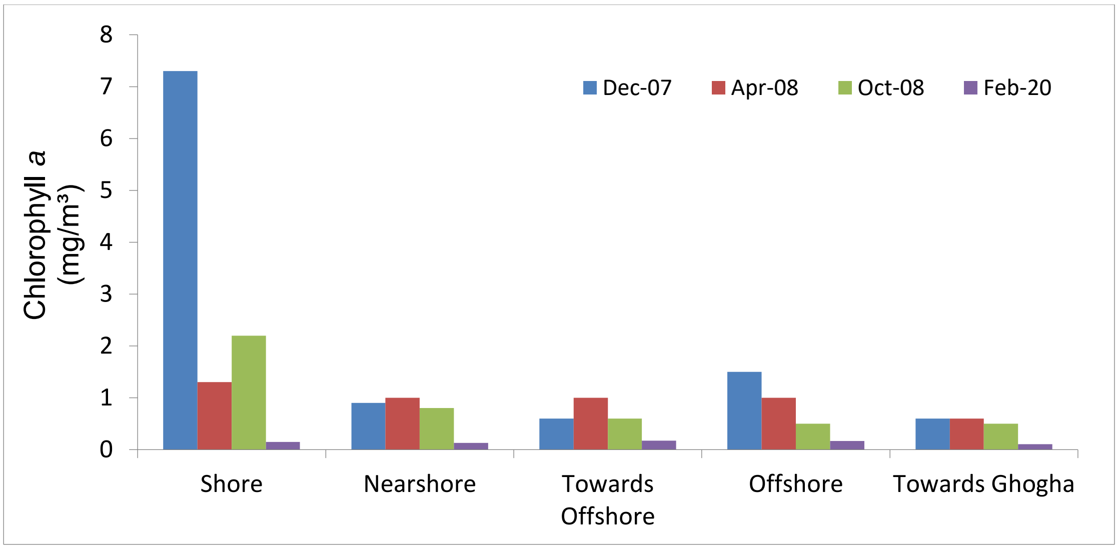


Figure: 5.3.2: Distribution of Chlorophyll *a* at various segments in the study area.

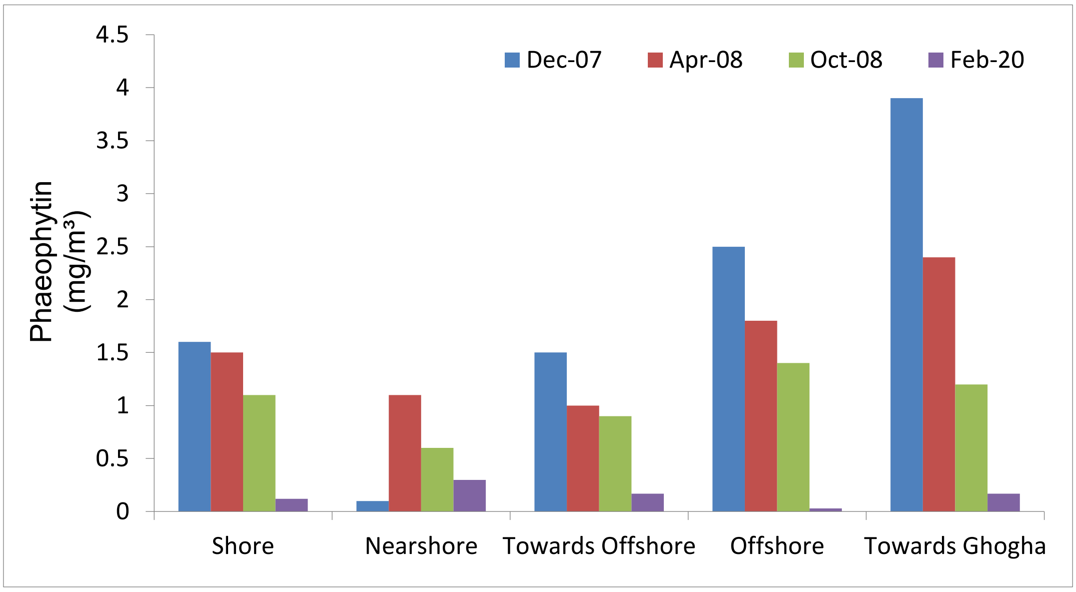


Figure: 5.3.3: Distribution of Phaeophytin at various segments in the study area.

It is evident from the above figure (Figure 5.3.2) that average concentrations of chlorophyll *a* in the study area varied in a small range over the years till October 2008, with a sporadic high value observed during December 2007. Chlorophyll a and phaeophytin distribution in the different segments of the study area during February 2020 was lower in comparison with previous observations.

b) Phytoplankton population: The distribution of phytoplankton population (0.60 – 4.0 x 10^3 no/l; av 1.36 x 10^3 no/l) revealed variable phytoplankton cell count during February 2020 (Tables 5.3.5 and 5.3.6). Shore segment recorded comparatively higher phytoplankton cell count and ranged between 1.40 –4.0 x 10^3/l; av 2.1 x 10^3/l. Stations towards offshore recorded the least cell count, in the range of 0.60 – 1.40 x 10^3/l; av. 1.06 x 10^3/l; Figure 5.3.4).

Navicula (12.8%), *Thalassiosira* (12.3%), *Peridinium* (16.2%), and *Thalassiothrix* (10.8%), *Cyclotella* (10.7%) *and Coscinodiscus* (9.9%) were the most dominant genera present in the study area (Table 5.3.7). A total of 21 genera of phytoplankton were recorded from the coastal waters off Alang during the present study. In general, the phytoplankton genera (2–10 no; av. 6 no) did not exhibit any notable spatial variation. Shore segment (av. 6 no) exhibited comparatively more numbers of phytoplankton genera than other segments of the study area.

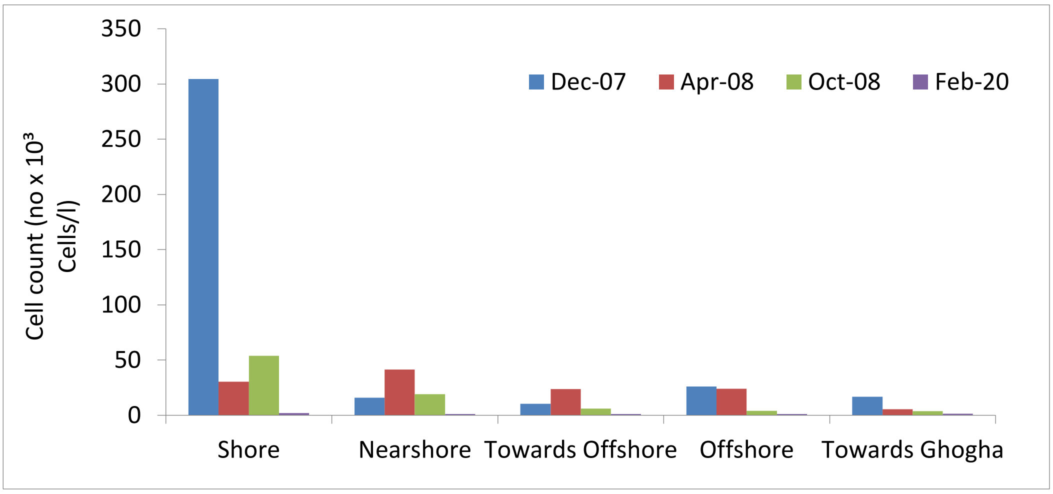


Figure 5.3.4: Phytoplankton cell count at various segments in the study area during different sampling events.

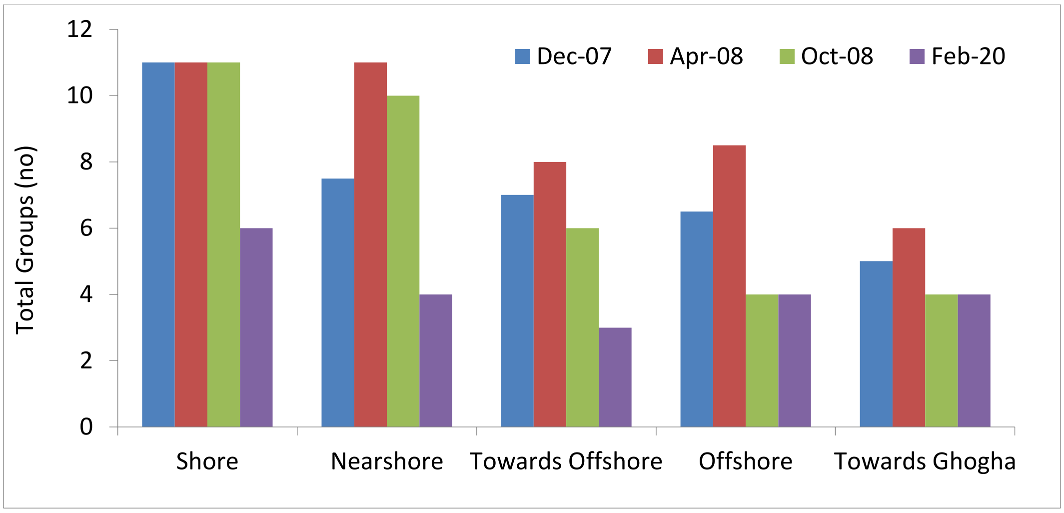


Figure 5.3.5: Phytoplankton total groups at various segments in the study area during different sampling events.

It was observed from the Figures 5.3.4 and 5.3.5 that phytoplankton cell counts and genera present in the study area were lower in the present study (February 2020) than previous observations. Such low values may be attributed to the high-suspended sediments during the present study (Section 5.1).

5.3.3 Zooplankton

Zooplankton includes arrays of organisms, varying in size from microscopic protozoans of a few microns to some jelly organisms with tentacles of several meters long. They play an intermediate role between phytoplankton and fish and are considered as the chief index of utilization of aquatic biotope at the secondary trophic level.

Zooplankton standing stock in terms of biomass (0.1–13.7 ml/100m^3; av 2.4 ml/100m^3) and abundance (1.1–139.3x 10^3/100m^3; av 22.6x 10^3/100m^3) indicated considerable spatial and tidal fluctuations in the coastal waters off Alang (Table 5.3.8 and 5.3.9). A decreasing trend was observed in the distribution of zooplankton standing stock from nearshore segment to offshore region in the study area. Higher zooplankton standing stock in terms of biomass (0.6–13.7 ml/100 m^3; av. 4.5 ml/100 m^3), and population (1.2 – 139.4 x 10^3/100m^3; av. 42.2 x 10^3/100m^3) were present at the nearshore segment. The offshore segment recorded a low biomass ranged between (0.7

– 1.2 ml/100 m^3; av. 1.0 ml/100 m^3), population (10.0 – 15.7 x 10^3/100m^3; av. 12.9 x 10^3/100m^3) (Figures 5.3.5 and 5.3.6).

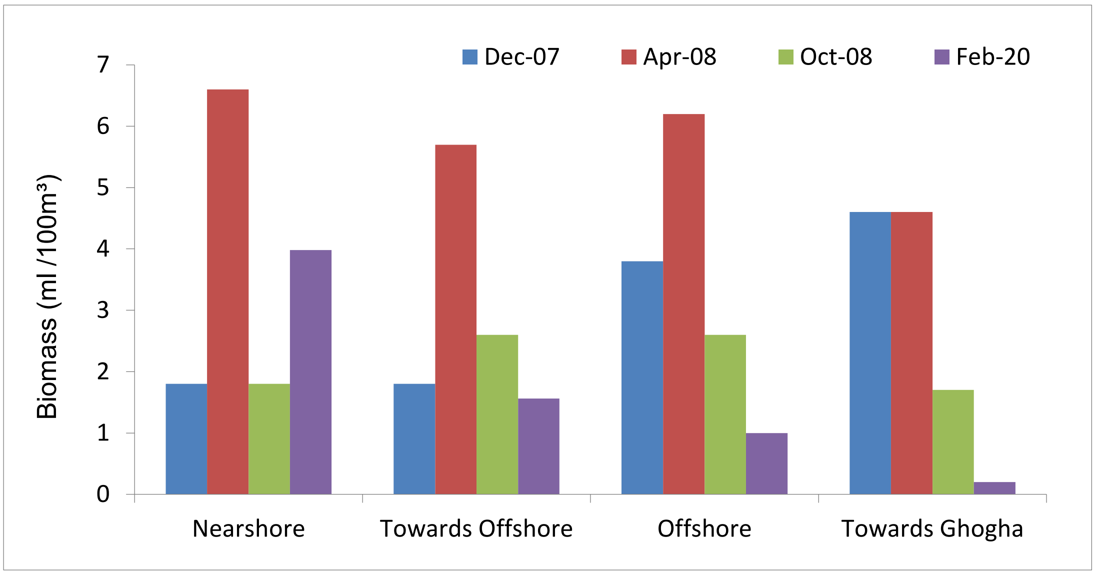


Figure 5.3.5: Distribution of zooplankton biomass at various segments in the study area during different sampling events.

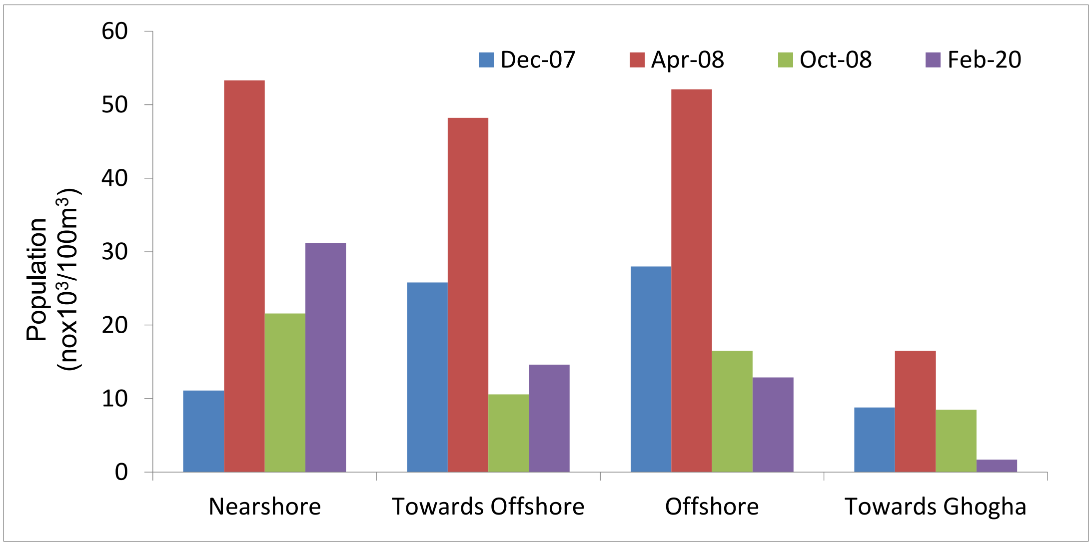


Figure 5.3.6: Distribution of zooplankton population at various segments in the study area during different sampling events.

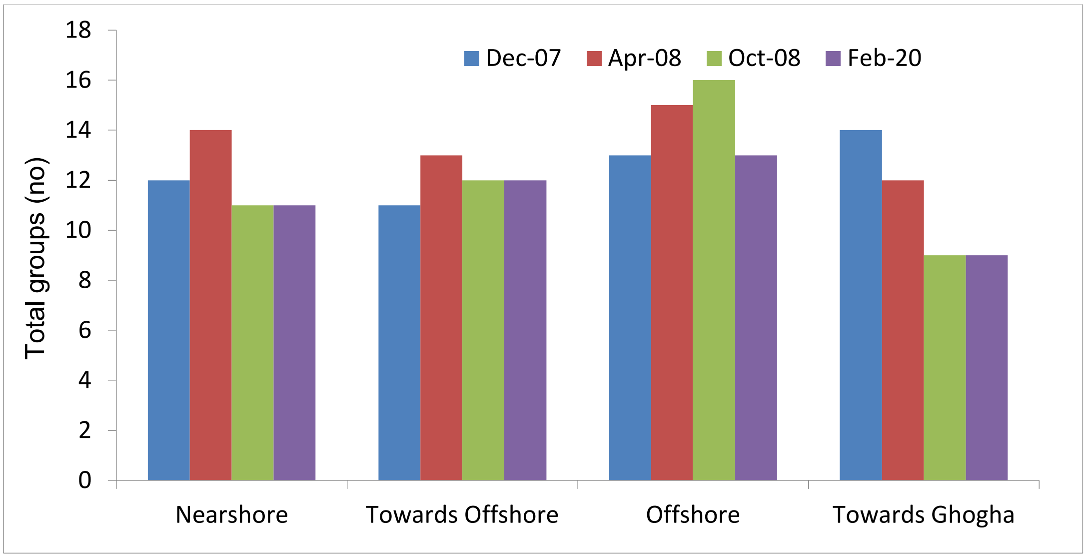


Figure 5.3.7: Distribution of zooplankton groups at various segments in the study area during different sampling events.

Copepods (83.8%) were the most dominant group followed by Decapod larvae (9.5%) and Chaetognaths (3.2%), suggesting a typical zooplankton community structure in the study area (Tables 5.3.10 and 5.3.11).

Wide spatial variations in zooplankton biomass and population off Alang were not evident from the above results. The zooplankton standing stock of the present study with the earlier data (December 2007 to February 2020) showed a random distribution of these organisms in the different segments. These variations in zooplankton standing stock were invariably associated with factors like tide, patchiness in their distribution, seasonal changes and grazing pressure within the food chain. Such variations are common to dynamic coastal waters. The figures (5.3.5 and 5.3.6) revealed that in general the zooplankton standing stock in terms of biomass, abundance displayed lower values in the recent observations as compared to previous years with some exceptions.

5.3.4 Macrobenthos

Depending upon their size, benthic animals are divided into three categories, microfauna, meiofauna and macrofauna. Benthic community responses to environmental perturbations are useful in assessing the impact of anthropogenic perturbations on environmental quality. Macrobenthic organisms which are considered for the present study are animal species with body size larger than 0.5 mm. Samples for macrobenthos were collected from intertidal segments as well as subtidal stations for the estimation of macrobenthic density, biomass and composition.

(a) Intertidal

The intertidal macrobenthic standing stock in terms of biomass, population and faunal group are presented in Tables 5.3.12 to 5.3.14. The results indicated a wide variation in biomass (0.0 – 20.3 g/m^2, wet wt.; av. 2.5 g/m^2, wet wt.), population (0.0 – 5275 no/m^2; av. 642 no/m^2) and faunal group (0–4, av. 2) at the intertidal transects of Alang. Spatial variation was observed with higher intertidal macrobenthic standing stock at T–I as compared to other transects (T–II to T–IV) as evident in Figures 5.3.8 to 5.3.10. The high–water level transects were in general sandy in nature. Polychaetes (88.1%) was the most dominant group in the intertidal macrobenthic community, followed by Brachyurans (7.2%) and Pelecypods (3.1%).

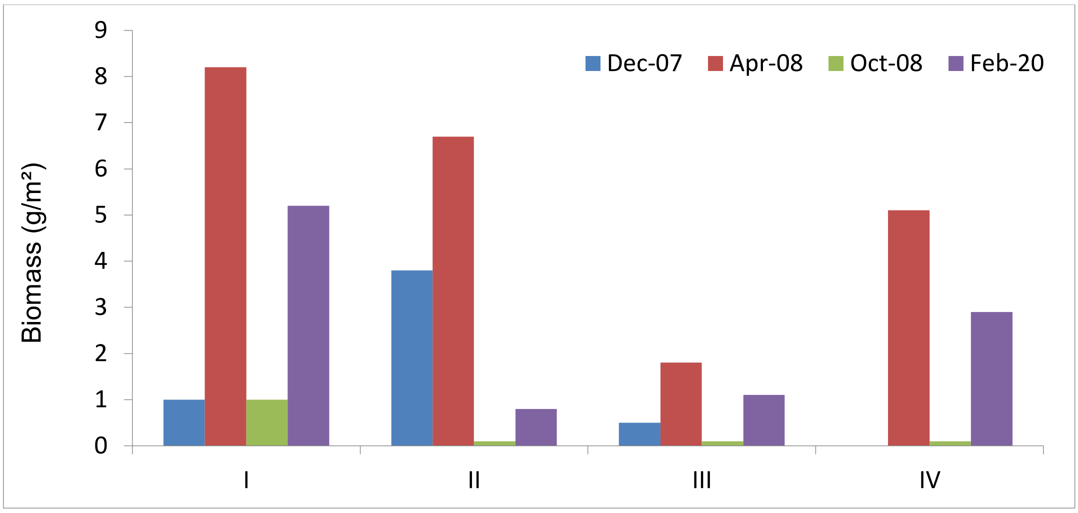


Figure 5.3.8: Distribution of macrobenthic biomass at various intertidal transects in the study area.

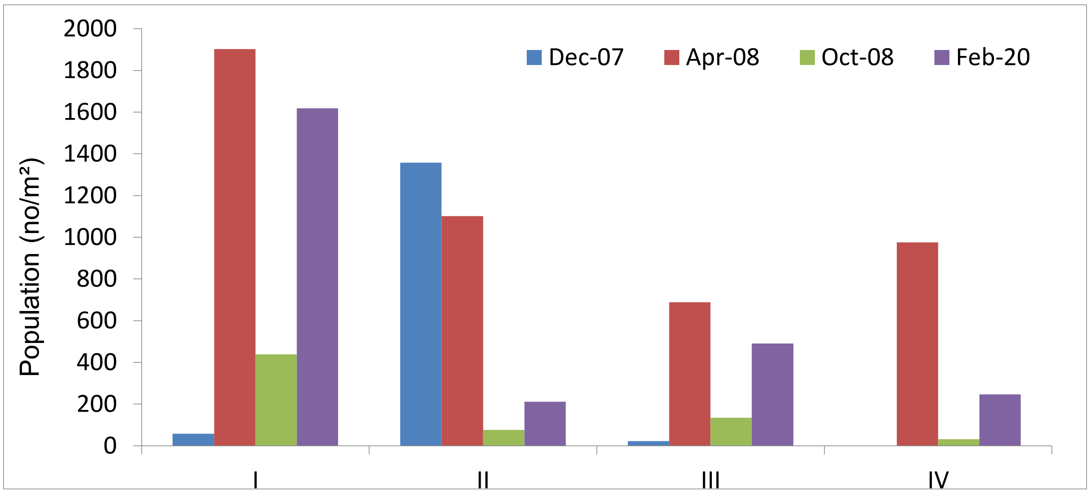


Figure 5.3.9: Distribution of macrobenthic population at various intertidal transects in the study area.

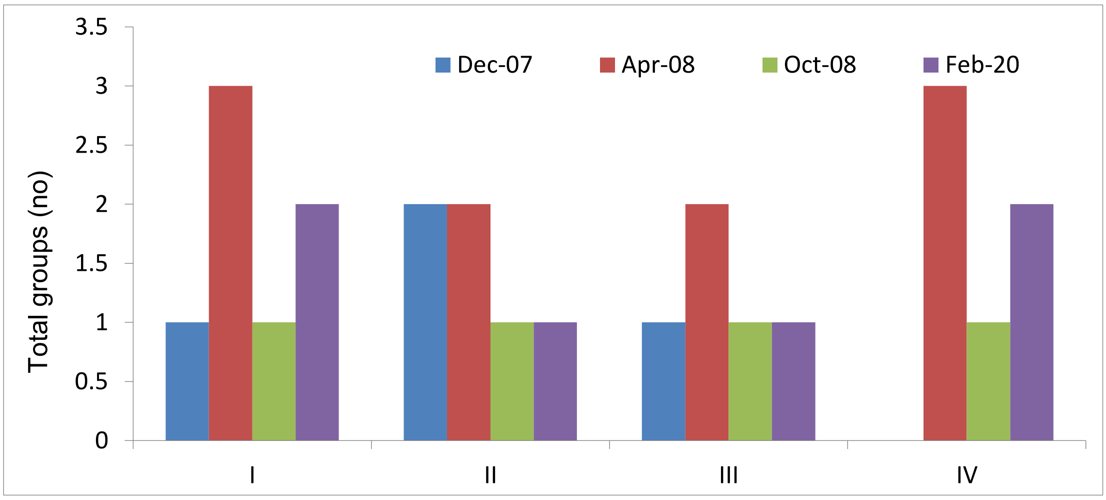


Figure 5.3.910: Distribution of macrobenthic faunal groups at various intertidal transects in the study area.

From the figure, it is evident that transect T–I sustained better biomass and abundance in general as compared to previous observations, except during April 2008. Transect T–II and T–III, the most significantly affected regions had a low intertidal macrobenthic standing stock in terms of biomass, population and faunal group diversity (Figure 5.3.8 and 5.3.9).

The transect T–IV, which was at the end of ship−recycling yard towards west, was rocky in nature and sustained better biomass and population in comparison with transects –TII and T–III. Community structure at the intertidal area of Alang revealed poor group diversity in the region. Polychaeta was the dominant group throughout the study area.

a) Subtidal

During February 2020, the subtidal macrofaunal standing stock in terms of density and biomass ranged from 0–4200 no/m^2 (av. 241 no/m^2) and from 0–13.6 g/m^2 wet wt. (av. 0.7 g/m^2; wet wt) respectively (Table 5.3.15–5.3.16). Shore segment recorded comparatively higher macrobenthic biomass (0–13.6 g/m^2, wet wt.; av. 2.1 g/m^2, wet wt.), and population (0 – 4200 no/m^2; av. 730.5 no/m^2) at the study area. Polychaeta (90.2%) was the most dominant faunal group followed by isopods (4.8%), Brachyurans (2.5%) and Pelecypods (1.5%). The overall scenario of macrobenthic standing stock is presented as follows:

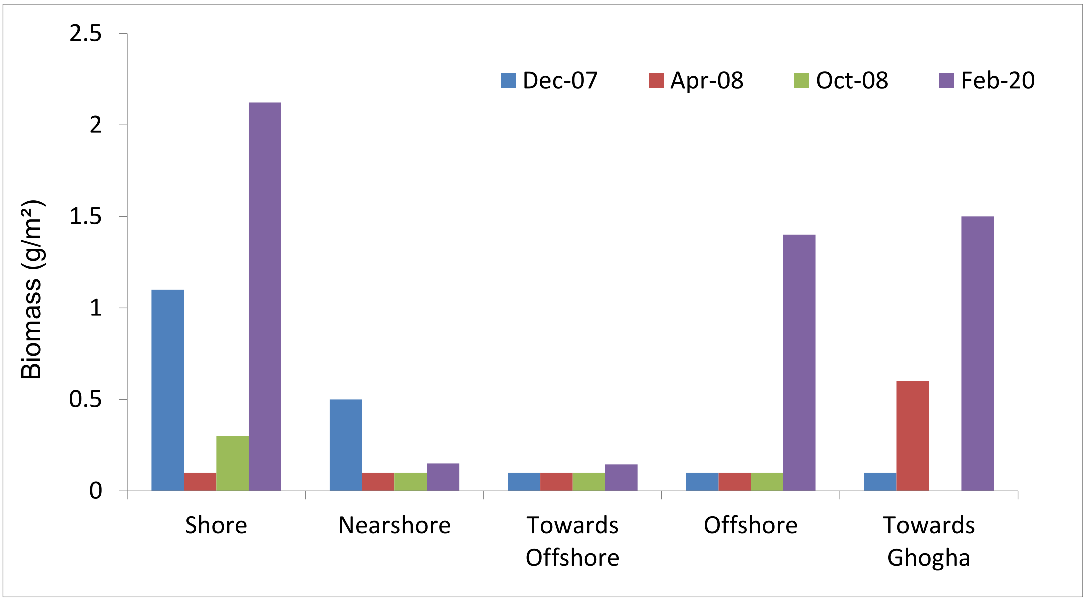


Figure 5.3.11: Distribution of macrobenthic biomass at subtidal segments in the study area.

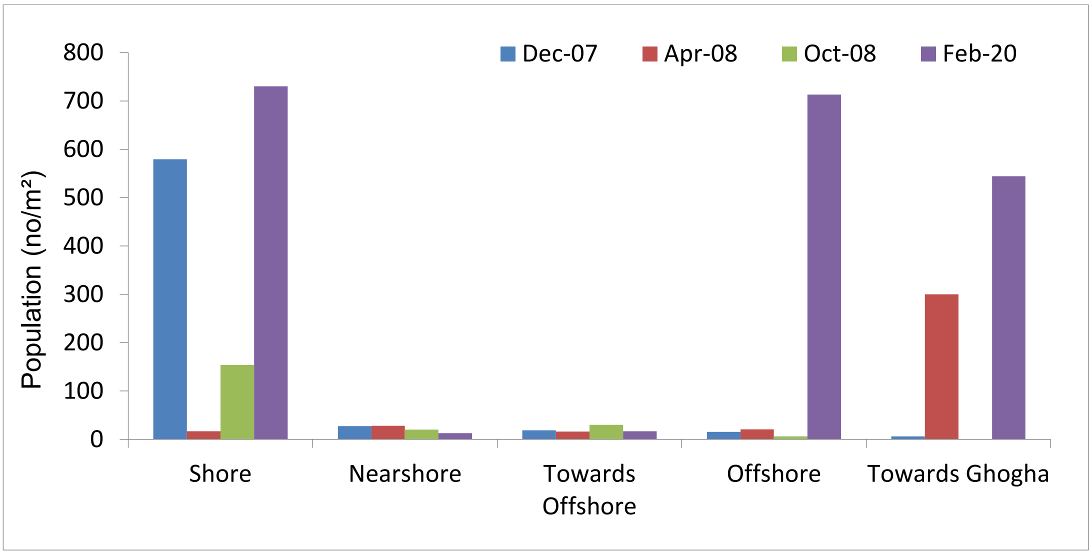


Figure 5.3.12: Distribution of macrobenthic population at subtidal segments in the study area.

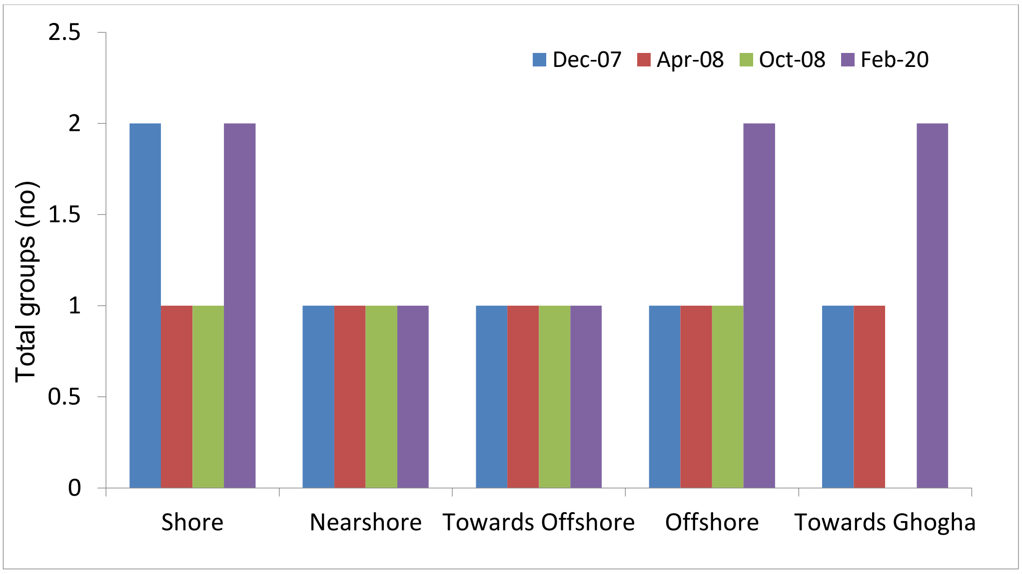


Figure 5.3.13: Distribution of macrobenthic faunal groups at subtidal segments in the study area.

From the above figure (Figure 5.3.11 and 5.3.12) it was evident that presence of a significantly poor macrobenthic standing stock at all segments of the coastal waters of Alang, which can be associated with the strong currents prevailing in the region and hard substratum present in some parts of the study area.

As in the case of phytoplankton and zooplankton, the standing stock of macrobenthos also varied randomly and spatially in the study area. As expected, high biomass was invariably associated with a high population density of macrofauna.

5.3.5 Fishery

Uneven rocky bottom and high turbidity coupled with strong tidal currents make trawling or gill netting difficult and risky in the coastal water of Alang. Evidently, no active commercial fishing exists in this region except for some gill netting or bag–netting or other traditional gears by local fishermen (Figure 5.3.14). Enquiries with the local fishermen also confirmed that the trawlers generally do not operate in this area. About 17 species of finfishes, and 4 species of prawns were identified from the present sampling and is given in the table below.

Sl No.	Species
Fin fishes	
1.	*Arius caelatus*
2.	*Liza parsia*
3.	*Johnieops elongates*
4.	*Johnius glaucus*
5.	*Johnieops macrorhynus*
6.	*Thryssa mystax*
7.	*Valamugil robustus*
8.	*Boleophthalmus boddarti*
9.	*Lutjanus johnii*
10.	*Thryssa vitriostris*
11.	*Harpadon nehereus*
12.	*Trypauchen vagina*
13.	*Saurida tumbil*
14.	*Coilia dussumieri*
15.	*Cynoglossus arel*
16.	*Tylosurus strongylura*
17.	*Stolephorus commersonnii*
Prawns	
1.	*Acetes indicus*
2.	*Exopalaemon styliferus*
3.	*Metapenaeus dobsonii*
4.	*Parapenaeopsis stylifera*
Others	
1.	*Oratosquilla nepa*
2.	*Matuta planipes*

Figure 5.3.14: Fish caught by local fishermen from the Alang

5.3.6 Mangroves

Mangroves are salt–tolerant forest ecosystem of tropical and subtropical intertidal regions of the world. Where conditions are sheltered and suitable, the mangroves may form extensive and productive forests, which are the reservoirs of a large number of species of plants and animals. The role of mangrove forests in stabilizing the shoreline of the coastal zone by preventing soil erosion and arresting encroachment on land by sea is well recognized thereby minimizing waterlogging and formation of saline banks.

The shoreline of the ship–breaking yard at Alang is devoid of mangroves vegetation. Small patches of shunted mangroves were seen entirely out of the project area towards the eastern side of ship breaking yard (Figure 5.3.15).

Figure 5.3.15: A mangrove plant beyond the ship−recycling yard boundary.

5.3.7 Bioaccumulation

The major environmental issues concerning metals are their potential availability and bioaccumulation in the aquatic life. Some metals are essential for metabolic functions in the living organisms. Some of the metals such as Hg have no known metabolic importance and their concentration even in trace quantity becomes toxic for the living organisms. Heavy metal contamination may have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms. Many aquatic organisms have the ability to accumulate and biomagnify contaminants like heavy metals in the environment. The ingestion of these contaminants may affect not only the productivity but ultimately affect the health of man that depends on these organisms as a major source of protein.

As per the record, an average 200 ships are cut on the shore of Alang every year and the metals associated with the body structure of ships are generally spilled on the near shore sediment. The available fishes were analysed to find out bioaccumulation of metals in them. Though it was very difficult to get fish for the analysis of metal contents, since, no fisherman was seen operating fishing net in Alang area, some fishes were obtained from local fishermen operating bag–net. The values of metal accumulation are presented in Table 5.4.1.

To understand the status of bioaccumulation in different organisms and the level of metal contents in their body tissues due to ship–breaking activities, continuous monitoring including the studies on bioaccumulation in the tissues of fishes and other marine organisms of the coastal water of Alang is essential. Concentration of all the metals in fishes analysed during present study was below the specified limit of USEPA and WHO, except Fe values, which are higher site. Although the concentration most of the elements were found to be below specified value, to understand the status of bioaccumulation in different organisms and the level of metal contents in their body tissues due to ship–breaking activities, continuous monitoring including the studies on bioaccumulation in the tissues of fishes and other marine organisms of the coastal water of Alang is essential.

6 IMPACT ASSESSMENT ON MARINE ENIVORNMENT

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Different classes of ships recycled in Alang include general cargo, bulk carriers, refrigerated cargo, oil tankers, passenger ships and cruiser ships (Source: Gujarat Maritime Board and other references). The recycling process of ships usually generates significant quantities of materials those are further reused or recycled and helps in minimizing/eliminating potential waste going into the environment. Steel scrap from demolished ships is a major source of raw material for steel re–rolling mills, which produce plates, bars, and rods that are used in the construction sector (including ship building) and commands a competitive price in the market indicating a strong consumer preference for the quality of steel.

The assessment of marine ecology is based on the comparison of present study of Alang with earlier information available of the project site and the data of neighboring areas viz. Dahej and Bhavnagar. The results of water quality, sediment quality and biological characteristics are compared and discussed below:

6.1 Water quality

i) Temperature

The values of water temperature (ºC) obtained during present study are compared with the values obtained in the surrounding areas in the following Table:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	26.2	25.9
Bhavnagar	27.7	26.9
Average (2007–08)		
Alang	27.6	26.9
Ghogha	27.1	–
Average (2020)		
Alang	23.6	23.3

From the above Table it is evident that the overall average values of water temperature of earlier study were comparable. However, average water temperature during present study was lower than the other values. Such deviation is attributed to difference in season of sample collection.

ii) pH

The overall average pH recorded during present study are compared with the earlier results available in the study area and surrounding in the gulf of Khambhat and the results are presented below

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	7.9	8.0
Bhavnagar	8.0	8.0
Available information (2001)		
Alang	8.1	8.1
Average (2007–08)		
Alang	8.1	8.1
Ghogha	8.1	–
Average (2020)		
Alang	8.1	8.0
Ghogha	8.1	

From the above results it is evident that there is no significant variation in the values of pH. The pH remains more or less same in the entire Gulf for the years and does not indicate any impact of organic load.

iii) Suspended solid (SS)

In general, the water of Gulf of Khambhat sustains the high concentration of SS (mg/l), due to the erosion of bottom sediment during high tidal current and high SS brought by the major rivers draining to the Gulf. The average SS (mg/l) values obtained during present studies are compared with the historical data of surrounding area and the data reported earlier in the study region in the following Table:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	1666	1900
Bhavnagar	716	2275
Available information (2001)		
Alang	545	537
Average (2007–08)		
Alang	492	701
Ghogha	1766	–
Average (2020)		
Alang	1123	1146
Ghogha	3315	

It is evident from the above Table that the SS value in the Alang region is lower compare to the surrounding regions i.e. Dahej, Ghogha and Bhavnagar. The reason for this difference may be because of several rivers and creeks, which drain into the surrounding regions and contribute the high SS there. Alang is comparatively away from direct openings of rivers and creeks. The V–shaped region sustains wide opening; as a result, dilution of SS is expected in the Alang region. Hence, the values of SS are less in the comparison of its surrounding regions. The present SS values at Alang are higher than the earlier data of same region, such variation is expected in such dynamic area, which carries high load of suspended solid and high tidal current churns out the bottom sediment.

iv) Salinity

Salinity (ppt) recorded in the coastal water of Alang and surrounding area is compared in the Table shown below:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	27.1	27.3
Bhavnagar	28.7	26.1
Available information (2001)		
Alang	32.1	33.2
Average (2007–08)		
Alang	30.7	30.5
Ghogha	29.7	–
Average (2020)		

Alang	30.5	30.9
Ghogha	29.3	

As explained in the above section, the surrounding regions are directly in the vicinity of direct opening of major rivers and creeks, which pour fresh water to the Gulf and dilute the seawater. From the above Table it is clear that the Alang contain higher average salinity compared to the surrounding region, which is expected as other regions are in near vicinity of the major rivers flowing to the Gulf, whereas Alang region is near the opening of Gulf, hence in more influenced influx of seawater.

v) DO

Concentration of dissolved oxygen plays key role in assessing the environmental status of any water body. Although in good environmental condition DO concentration remains >6.0 mg/l, to support good aquatic life, DO should not remain below 3 mg/l for prolonged time. Overall average DO values (mg/l) observed during present studies are compared with the values reported earlier as follow:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	6.1	6.4
Bhavnagar	6.4	5.1
Available information (2001)		
Alang	5.6	6.3
Average (2007–08)		
Alang	6.1	6.1
Ghogha	6.1	–
Average (2020)		
Alang	5.8	5.7
Ghogha	6.5	

It is discernible from the above Table that the average values of DO in the Alang area is above 5.5 mg/l and compares well with entire Gulf of Khambhat values, which explains healthy condition of the water quality off the Alang.

vi) BOD

Average values of BOD (mg/l) recorded in the Alang coast and surrounding region is compared as under:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	1.2	1.8
Bhavnagar	1.8	1.6
Available information (2001)		
Alang	2.6	2.1
Average (2007–08)		
Alang	2.6	2.1
Ghogha	1.8	–
Average (2020)		
Alang	3.2	3.1
Ghogha	3.6	

Although the values of BOD in Alang area are slightly higher as compared to the earlier data of surrounding areas, higher BOD also observed in Ghogha during present study indicates common phenomena in the Gulf and not because of Alang ship−recycling work.

vii) Phosphate

Phosphate is one of the most important nutrients for the productivity of the aquatic region. The average values (µmol/l) recorded during the present studies and earlier records are compared and shown below:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	3.4	3.1
Bhavnagar	7.3	5.2
Average (2007–08)		
Alang	3.3	3.8
Ghogha	2.9	–
Average (2020)		
Alang	1.9	1.4
Ghogha	1.9	

The overall scenario indicates that the phosphate values of Alang area are comparable with earlier values found in the Alang region. The concentration of phosphate observed during present study is lower as compared earlier data. However, the impact of ship breaking activities on the concentration of phosphate is not discernible. There was no built up in the level of phosphate in the coastal water of Alang.

viii) Nitrate

Average concentrations of nitrate (µmol/l) recorded during present studies are compared with available data of the region and surrounding areas as below:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	31.2	33.0
Bhavnagar	25.6	38.2
Average (2007–08)		
Alang	33.8	35.7
Ghogha	33.6	–
Average (2020)		
Alang	19.0	31.8
Ghogha	30.9	

The above Table indicates that entire Gulf sustains high concentration of nitrate. The concentration of nitrate recorded in the present study indicates that the nitrogen added to the coastal water of Alang is efficiently oxidized. The level of nitrate is an indicative of sufficient nutrient availability, needed for good phytoplankton productivity in the region. Comparatively lower concentration of nitrate was recorded in the nearshore water off Alang during present study, but offshore concentration was comparable to the results of surrounding region. Availability of good concentration of DO and nitrate in the region indicates that the ship–breaking activities could not influence the concentration these parameters in the coastal water of Alang.

ix) Nitrite

The average values of nitrite (μmol/l) are compared with the available information of the surrounding areas which is shown below:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	0.5	0.4
Bhavnagar	0.6	0.7
Average (2007–08)		
Alang	0.5	0.4
Ghogha	0.5	–
Average (2020)		
Alang	0.2	0.1
Ghogha	0.2	

The above values indicate that there is no buildup of nitrite in the coastal water of Alang similar to other Gulf regions. The level of nitrite lower during present study compare to that of earlier results.

x) Ammonia

The concentration of ammonia (μmol/l) recorded during present study is compared with the available data in Alang region and the surrounding areas as follows:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	0.5	0.4
Bhavnagar	0.6	0.7
Available information (2001)		
Alang	0.2	0.3
Average (2007–08)		
Alang	0.5	0.4
Ghogha	0.5	–
Average (2020)		
Alang	2.3	0.6
Ghogha	1.6	

From the above table, it is evident that concentration of ammonical nitrogen has increased in recent years, both in Alang and Ghogha areas, indicating buildup of ammonia before its oxidation to nitrate with nitrite as intermediate product, which is low throughout the study.

Overall, the concentration of nutrients indicates elevated concentration of some of the nutrients i.e phosphate, nitrate and ammonia, not in the Alang area but throughout the Gulf of Khambhat. Several industries and cities discharge their effluent to the rivers/estuaries like Narmada, Tapi, Mahi and Sabarmati, which ultimately pour to the Gulf of Khambhat, apart from agricultural run off during monsoon. As per modeling studies, the effluent once enter to the upper section of the Gulf, takes more than months to flush out to the open sea (Mitra *et al*. 2020). Hence, the pollutants oscillate in the Gulf and get accumulated with their additional input in the region. Thus, the nutrients generated from these sources get elevated in the area. It indicates that the elevated nutrient concentrations are not due to the ship−recycling activities.

xi) PHc

The overall average values (µg/l) of dissolved petroleum hydrocarbon in the coastal water of Alang are compared with the values recorded in the surrounding region:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	6.8	9.4
Bhavnagar	10.5	11.1
Average (2007–2008)		
Alang	286.5	79.6
Ghogha	104.6	–
Average (2020)		
Alang	82.6	14.8
Ghogha	14.3	

Significantly higher concentration of PHc in the coastal water of Alang as compared to that of surrounding region clearly suggests the input through ship–cutting activities. However, the present value is lower than the earlier values, indicating the effect of in stringent enforcement to curtail the pollution in the ship−recycling area.

xii) Phenols

The average values of phenols (μg/l) of present study are compared with the available information of surrounding areas and presented as follows:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	38.8	31.5
Bhavnagar	59.7	30.0
Average (2007–2008)		
Alang	48.8	48.3
Ghogha	18.8	–
Average (2020)		
Alang	69.1	63.1
Ghogha	61.0	

Comparatively elevated concentration of phenol was recorded in the study area. Such elevated concentration may be attributed to the reason as discussed above.

xiii) Dissolved metal

Concentration of dissolved metals is compared with the values available for other regions, which are as below;

Place	Water body	Cr (µg/l)	Mn (µg/l)	Fe (µg/l)	Co (µg/l)	Ni (µg/l)	Cu (µg/l)	Zn (µg/l)	Hg (µg/l)	References
Alang, Gujarat	Shore	3.46 ±2.04	21.76 ±19.65	31.92 ±18.68	0.34 ±0.1	6.98 ±4.43	3.52 ±2.43	9.09 ±5.5	45.13 ±42.73	Present study, 2020
Alang, Gujarat	Near Shore	2.4 ±1.16	8.98 ±9.29	22.05 ±12.05	0.49 ±0.2	4.21 ±3.36	9.25 ±16.87	6.85 ±3.1	8.5 ±5.88	Present study, 2020
Alang, Gujarat	Towards Offshore	1.13 ±0.42	30.63 ±53.79	11.66 ±11.01	0.49 ±0.08	2.17 ±1.16	2.66 ±1.88	5.35 ±4.09	32.14 ±35.5	Present study, 2020
Alang, Gujarat	Off–Shore	1 ±0	5.3 ±2.4	9 ±2.55	0.55 ±0.07	1.9 ±0.28	2.7 ±0	–	50.7 ±11.17	Present study, 2020
Alang, Gujarat	Gogha	0.7 ±0	1.8 ±0.28	5.55 ±1.2	0.5 ±0	1.2 ±0.14	1.5 ±0	6.45 ±3.32	2.85 ±0.07	Present study, 2020
Tadgam	Beach	0.32 −1.11	0.4 −9.7	43 −214	0.19 −0.37	2.4 −5.43	0.64 −4.51	18 −50	0.1 −0.31	NGT, 2018
Jampore	Beach	0.09 −1.03	0.08 −11.5	26 −198	0.14 −0.35	0.19 −9.24	0.03 −5.53	10 −57	0.1 −0.44	NGT, 2018
Devka	Beach	0.28 −0.6	0.38 −2.21	66 −467	0.13 −0.32	3.01 −5.0	1.98 −5.63	35 −50	0.11 −0.41	NGT, 2018
Tithal	Beach	0.19 −1.86	0.23 −5.21	75 −197	0.21 −0.31	2.57 −5.93	0.14 −4.45	24 −48	0.12 −0.31	NGT, 2018
Mandovi −Zuari	Estuary	−	−	−	−	−	2− 6.3	−	−	Sankarayanan and Reddy,1973
Mandovi −Zuari	Estuary	−	6− 102	−	−	ND	3− 8	6− 42	−	Zingde et al.,1976
Cochin, Kerala	Estuary	−	−	−	−	−	0.8− 7	0.5− 11.3	−	Sankarayanan et al.,1978
Ulhas, Mumbai	Estuary	−	−	−	−	−	−	−	0.04−0.61	Ram et al., 2003
Mumbai	Harbour	20	8	3	0.5	0.5	16	27	−	Patel et al.,1985
Mumbai	Harbour	−	8	3	0.5	0.5	6	27	−	Zingde and Desai.,1987
Uttan	Creek	22− 104	45− 268	0.01− 0.13	−	32− 139	12− 604	16− 109	0.005− 3.420	Pahalawattaarachchi et al.,2012
Mahul	Creek	27− 195	170− 348	0.02− 0.37	−	4− 69	9− 46	29− 88	ND− 0.006	Pahalawattaarachchi et al.,2012
Thane, Mumbai	Creek	−	5− 169	8− 35	ND− 1.5	ND− 9.5	10− 66	17− 121	−	Zingde and Desai.,1987
Thane, Mumbai	Creek	−	3.3− 99.5	16.5− 40.3	2.5− 4.9	6.8− 14.3	5.2− 15.6	38.7− 93.6	−	Bhosale and Sahu.,1991
Mahim, Mumbai	Bay	−	−	14− 16	1− 2	4− 10	10− 16	40− 75	−	Sabnis,1984
Goa	Bay	−	42	19	0.8	5	4	16	−	Zingde and Desai,1987
Velsao, Goa	Bay	13− 16	27− 56	−	ND	6− 8	11	11− 16	−	Zingde et al.,1979
Malvan	Coastal	−	−	−	−	−	0.42− 1.25	1.00− 6.13	−	D'Costa and Pai, 2017
Colva	Coastal	−	−	−	−	−	1.97− 4.82	0.09− 5.52	−	D'Costa and Pai, 2017
Karwar	Coastal	−	−	−	−	−	1.30− 3.16	1.91− 34.19		D'Costa and Pai, 2017
Mahim	Coastal	−	4− 169	−	ND− 1.5	ND− 9.5	10− 66	17− 121	−	Zingde,1985
Tarapur	Coastal	−	8	17	2	1	25	57	−	Zingde and Desai,1987
Mahim	Coastal	−	−	17− 44	0.9− 0.9	3− 6	12− 15	103− 121	−	Sabnis,1984
Karwar	Coastal	−	2.3− 10.2	9− 26.2	−	−	0.8− 4.2	3.1− 20.1	−	Zingde and Singbal,1983

It is evident from the table that the concentration of some of the metals recorded in present study are within the values recorded in some other regions, hence, impact of ship−recycling on the concentration of dissolved metals is not observed.

6.2 Sediment quality

i) Metals

a) Subtidal

The sediment quality of present study is compared with the data available for Alang region and the surrounding areas which are as follows:

Area	Metal	Nearshore	Offshore
Average (1996–2007)			
Dahej	Al (%)	5.8	5.0
	Cr (µg/g)	94	101
	Mn (µg/g)	1261	1078
	Fe (%)	7.2	6.4
	Co (µg/g)	40	44
	Ni (µg/g)	57	60
	Cu (µg/g)	77	77
	Zn (µg/g)	105	105
	Hg (µg/g)	0.07	0.07
Bhavnagar	Al (%)	5.4	4.3
	Cr (µg/g)	138	90
	Mn (µg/g)	1361	1113
	Fe (%)	8.9	7.1
	Co (µg/g)	47	28
	Ni (µg/g)	66	66
	Cu (µg/g)	108	79
	Zn (µg/g)	153	–
	Hg (µg/g)	0.04	0.03
Available information (2001)			
Alang	Al (%)	–	–
	Cr (µg/g)	–	–
	Mn (µg/g)	1488	1012
	Fe (%)	7.5	5.9
	Co (µg/g)	145	26
	Ni (µg/g)	117	46
	Cu (µg/g)	8	2
	Zn (µg/g)	51	39
	Hg (µg/g)	1.56	0.01
Average (2007–2008)			

Alang	Al (%)	7.7	8.8
	Cr (µg/g)	159	134
	Mn (µg/g)	1312	1121
	Fe (%)	10.4	6.2
	Co (µg/g)	39	39
	Ni (µg/g)	78	68
	Cu (µg/g)	127	90
	Zn (µg/g)	266	108
	Hg (µg/g)	0.12	0.05
Ghogha	Al (%)	4.7	–
	Cr (µg/g)	127	–
	Mn (µg/g)	996	–
	Fe (%)	4.6	–
	Co (µg/g)	32	–
	Ni (µg/g)	67	–
	Cu (µg/g)	68	–
	Zn (µg/g)	60	–
	Hg (µg/g)	0.11	–
Average (2020)			
Alang	Al (%)	6.3	3.8
	Cr (µg/g)	135	136
	Mn (µg/g)	886	1302
	Fe (%)	6.9	8.0
	Co (µg/g)	39	46
	Ni (µg/g)	45	43
	Cu (µg/g)	88	99
	Zn (µg/g)	90	104
	Hg (µg/g)	0.07	0.09

It is evident from the above Table that the sediment quality of Alang is more or less comparable to the surrounding region. The average concentration of metals recorded during 2007–2008 indicated elevated concentration of some of the elements. However, during present study, such elevation was not recorded. This is may be due to the precautions taken during recycling as per the enforcement of pollution control norms. However, as discussed in Section 5.2, concentration of metals such as Cr, Fe, Cu, Zn Pb and Hg were higher in the sediment of shore locations, which are under direct influence of ship cutting areas.

b) Intertidal

Metal concentration recorded in the intertidal segment at Alang is compared with available information and discussed below:

Area	Metal	Available information (2004)	Average (2007–08)	Average (2020)
Alang	Al (%)	8.6	7.1	5.4
	Cr (μg/g)	290	187	163
	Mn (μg/g)	4643	1531	1218
	Fe (%)	13.7	12.6	10.0
	Co (μg/g)	53	45	41
	Ni (μg/g)	173	87	57
	Cu (μg/g)	214	140	110
	Zn (μg/g)	1222	279	226
	Hg (μg/g)	1.93	0.15	0.18

The above Table reveals that the concentration of metals reported during 2004 are higher than the present values. Regular monitoring of the intertidal region can confirm the status of metals in the sediment of Alang.

ii) Organic carbon

a) Subtidal

The concentration of total organic carbon (%) recorded in the subtidal sediment during present study is compared with the values in the sediment of surrounding areas, which are as under:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	0.3	0.4
Bhavnagar	0.3	0.2
Average (2007–08)		
Alang	0.7	0.8
Ghogha	0.4	–
Average (2020)		
Alang	0.8	0.5
Ghogha	1.0	

The concentration of organic carbon is low in the sediment and does not show any adverse impact of ship breaking activities on its distribution at Alang.

b) Intertidal

As indicated in the Table below, the concentration of total organic carbon recorded in the present study is lower in the comparison of earlier records of 2004 and 2007–08.

Area	Available information (2004)	Average (2007–08)	Average (2020)
Alang	1.9	0.9	1.2

Thus, the ship breaking activities does not show any role on the concentration of organic carbon during the present study.

iii) Phosphorus

The overall average values of total phosphorus (µg/g) in the subtidal sediment at Alang are compared with the values of subtidal sediment of surrounding region:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	466	425
Bhavnagar	557	–
Average (2007–08)		
Alang	754	726
Ghogha	756	–
Average (2020)		
Alang	740	813
Ghogha	687	

The overall scenario of total phosphorus in sediment indicates that there is no significant buildup of phosphorus in the sediment of Alang similar to that of surrounding region.

iv) PHc

a) Subtidal

Petroleum hydrocarbon (µg/g) in the subtidal sediment of Alang is compared with the values of surrounding areas:

Area	Nearshore	Offshore
Average (1996–2007)		
Dahej	0.3	0.3
Bhavnagar	0.5	0.3
Average (2007–08)		
Alang	2.8	1.2
Ghogha	0.2	–
Average (2020)		
Alang	0.4	1.1
Ghogha	1.0	

It is clear from the above Table that there is a buildup of PHc, which was reported in the sediment of nearshore region of Alang during 2007–08, has gone down and the value is lower than earlier data. Unlike to earlier report, the PHc concentration was high in offshore region during present study. Since the offshore location is more than 15 km away from the shore, it is unlikely that the impact of ship breaking will be taking place at offshore locations.

6.3 Biological characteristics

The results of biological characteristics of the present investigation are compared with the available information of the surrounding region, which is discussed as below:

6.3.1 Phytoplankton

a) Pigments

The overall average values of pigments of present study and available data for the period of 1996–2008 are compared in the Table shown below:

Area	Parameter	Nearshore	Offshore
Average (1996–2007)			
Dahej	Chlorophyll *a* (mg/m^3)	0.7	0.4
	Phaeophytin (mg/m^3)	1.4	1.2
Bhavnagar	Chlorophyll *a* (mg/m^3)	0.6	0.5

	Phaeophytin (mg/m^3)	0.6	1.9
	Available information (2001)		
Alang	Chlorophyll *a* (mg/m^3)	0.2	2.0
	Phaeophytin (mg/m^3)	0.1	0.8
Average (2007–2008)			
Alang	Chlorophyll *a* (mg/m^3)	1.8	0.9
	Phaeophytin (mg/m^3)	1.1	1.5
Ghoga	Chlorophyll *a* (mg/m^3)	0.5	–
	Phaeophytin (mg/m^3)	2.5	–
Average (2020)			
Alang	Chlorophyll *a* (mg/m^3)	0.14	0.17
	Phaeophytin (mg/m^3)	0.34	0.03
Ghogha	Chlorophyll *a* (mg/m^3)	0.11	
	Phaeophytin (mg/m^3)	0.17	

The values as evident in the above Table indicated that the present concentrations of chlorophyll *a* and phaeophytin were lower in the nearshore and offshore segments of Alang as compared to the earlier data recorded during 2007-08. The low values of phytopigments are expected in an area having high suspended load in the water, which prevents penetration of light.

b) Population

The overall values of phytoplankton population are summarized in the Table shown below:

Area	Parameter	Nearshore	Offshore
Average (1997–2007)			
Dahej	Cell count (nox10^3/l)	10.2	8.6
	Total genera (no)	3	5
Bhavnagar	Cell count (nox10^3/l)	11.4	12.4
	Total genera (no)	3	3
	Available information (2001)		
Alang	Cell count (nox10^3/l)	0.3	0.2
	Total genera (no)	19	19
Average (2007–2008)			
Alang	Cell count (nox10^3/l)	60.2	15.6
	Total genera (no)	10	7
Ghoga	Cell count (nox10^3/l)	8.6	–
	Total genera (no)	5	–

Average (2020)			
Alang	Cell count (nox10^3/l)	1.2	1.2
	Total genera (no)	4	4
Ghogha	Cell count (nox10^3/l)	1.3	–
	Total genera (no)	4	–

Phytoplankton population counts in the coastal water of Alang during the present study was higher as compared to 2001 but much lower than 2007-2008 data. However, the 2020 species diversity was lower than 2001 and comparable with 2007-2008.

6.3.2 Zooplankton

The overall scenario of zooplankton standing stock is compared with the earlier studies of the study area of Alang and surrounding regions. The average values are presented in the Table given below:

Area	Parameter	Nearshore	Offshore
Average (1996–2007)			
Dahej	Biomass (ml/100 m^3)	3.8	2.1
	Population (nox10^3/100m^3)	19.9	20.6
	Total group (no)	9	13
Bhavnagar	Biomass (ml/100 m^3)	4.6	6.3
	Population (nox10^3/100m^3)	15.6	26.6
	Total group (no)	10	14
Available information (2001)			
Alang	Biomass (ml/m^3)	7.4	8.3
	Population (nox10^3/m^3)	10.0	58.8
	Total group (no)	3	7

Average (2007–2008)			
Alang	Biomass (ml/100 m^3)	3.4	3.7
	Population (nox10^3/100m^3)	28.6	30.2
	Total group (no)	12	13
Ghoga	Biomass (ml/100m^3)	3.6	–
	Population (nox10^3/100m^3)	11.3	–
	Total group (no)	12	–
Average (2020)			
Alang	Biomass (ml/100m^3)	4.5	1.0
	Population (nox10^3/100m^3)	42.2	12.9
	Total group (no)	11	13
Ghogha	Biomass (ml/100m^3)	0.2	–
	Population (nox10^3/100m^3)	1.7	–
	Total group (no)	9	–

The present zooplankton standing stock in terms of biomass was lower as compared to 2001. The zooplankton abundance of the nearshore area of Aland was higher in the present study whereas in the offshore area this value was lower than historical data. Zooplankton group diversity in the coastal water of Alang were higher in the present year as compared to 2001.

6.3.3 Benthos

The macrobenthic standing stock recorded in the coastal waters of Alang is compared with the historical values as shown below:

a) Intertidal

Area	Parameter	Intertidal
Average (2007–2008)		
Alang	Biomass (g/m^2; wet wt.)	3.3
	Population (no / m^2)	608
	Faunal group (no)	2
Average (2020)		
Alang	Biomass (g/m^2; wet wt.)	2.5
	Population (no / m^2)	642
	Faunal group (no)	2

The overall average values of intertidal macrobenthic standing stock were comparable to that of the earlier data of 2007-08.

b) Subtidal

The average values of subtidal macrobenthic standing stock are compared with the earlier findings and discussed below:

Area	Parameter	Nearshore	Offshore
Average (1996–2007)			
Dahej	Biomass (g/m^2; wet wt.)	0.7	0.2
	Population (no./ m^2)	141	30
	Faunal group (no)	2	1
Bhavnagar	Biomass (g/m^2;wet wt.)	2.8	<0.1
	Population (no./ m^2)	169	13
	Faunal group (no)	3	1
Average (2007–2008)			
Alang	Biomass (g/m^2; wet wt.)	0.4	0.1
	Population (no./ m^2)	138	18
	Faunal group (no)	1	1
Ghoga	Biomass (g/m^2;wet wt.)	0.4	–
	Population (no./ m^2)	153	–
	Faunal group (no)	1	–
Average (2020)			
Alang	Biomass (g/m^2; wet wt.)	0.2	1.4
	Population (no./ m^2)	13	713
	Faunal group (no)	1	2
Ghogha	Biomass (g/m^2; wet wt.)	1.5	

	Population (no./ m^2)	544	
	Faunal group (no)	2	

The overall average scenario of subtidal macrobenthic standing stock in terms of biomass and population recorded in nearshore region during present study is lower than the results of earlier studies and the surrounding region. However, offshore region showed increased biomass and population. In the Gulf of Khambhat, water current often exceeds > 3.0 m/s, it does not allow the bottom sediments to settle, which probably resulted in poor macrobenthic community.

6.3.4 Fishery

Uneven rocky bottom and high turbidity coupled with strong tidal currents make trawling or gill netting difficult and risky in the coastal water of Alang. Evidently, no active commercial fishing exists in this region excepting some gill netting or bag–netting or other traditional gears by local fishermen. Enquiries with the local fishermen also confirm that the trawlers generally do not operate in this area. There are about 17 species of finfishes, and 4 species of prawns were identified from the current sampling.

6.3.5 Mangrove

The intertidal area of Alang was devoid of mangroves vegetation. Thus, the question of adverse impact of ship breaking activities on mangroves does not arise.

6.4 Comparison of Present results with water quality standards

The results of present study are compared with water quality standards for coastal waters for marine outfalls (EPA 1986, GSR 7, Dec 22, 1998) by Central Pollution Control Board (CPCB) shown below:

Sr. No.	Parameter	Standards (SW IV)	Present Value
1	pH	6.5–9.0	7.9–8.1
2	DO	3.0 mg/l or 40% saturation value	5.2–6.7 mg/l
3	Faecal Coliform	500/100ml (PAN)	NG–140 CFU/ml
4	BOD	5 mg/l	2.9–3.7 mg/l
5	Floating matters oil, grease and scum (including petroleum products)	10 mg/l	(PHc) 12.5-614.0 μg/l

It is evident from above Table that the values of pH, DO and BOD are almost in the range of water quality standards suggesting a healthy condition of costal environment of Alang. Floating matters oil, grease and scum (including petroleum products), as standard is 10 mg/l (10,000 μg/l) and PHc value (12.5–614.0 μg/l) is much lower than standard.

7 ASSESSMENT OF ENVIRONMENTAL AND SOCIO-ECONOMIC STATUS OF SHIP RECYCLING YARDS

7 ASSESSMENT OF ENVIRONMENTAL AND SOCIO–ECONOMIC STATUS OF SHIP RECYCLING YARDS

7.1 Physical observations

During field studies, we visited random ship−recycling yards to assess the ongoing ship−recycling activities. During visits, it was observed that around 90% of the yards were having ship either waiting for cutting or busy with recycling process. Some of the selected photographs are given in the plates 7.1.1 and 7.1.2.

Plate 7.1.1: A overview showing Alang ship−recycling yards

Plate7.1.2: Another overview showing Alang ship−recycling yards

7.2 Beaching of ships

Alang–Sosiya situated at the mouth of Gulf of Khambhat, where tidal variation is 10–11 m. taking the advantage of such high amplitude the ships are grounded in the intertidal zone, either under their own power or under, tow during spring tides, thus bringing the ship right up to the edge of developed plots (Plate 7.2.1). In this methodology infrastructure is required is shore based winches, crawler cranes and other material handling equipment.

Plate 7.2.1: A ship Beached at Alang ships recycling yard

7.3 Status of ship−recycling yards

Government of India has accepted to Hong Kong Convention for safe & environmentally sound ship−recycling in last November –2019 and deposited our accession to IMO accordingly. So far after its adoption by IMO in May–2009, as per Article 17 of the convention, it is not yet come into entry into force. Since India has accepted it, ship recyclers at Alang–Sosiya have willingly acquired a statement of compliance to HKC by International Classification Societies as recognized by DG Shipping.

During field collection random number of ship−recycling yards were visited to evaluate the status of recycling yards. During visit it was found that as per the convention followed by recycler, some of yards come under green category, which are shown in the photos below:

Plate 7.3.1: A photo showing yard following green category activities

Plate 7.3.2: A view showing yard following green category activities

Plate 7.3.3: A view showing clean shore line at ship−recycling yard, Alanggreen cutting

Plate 7.3.4: A view showing Green category yards with concrete flooring

Plate 7.3.5: A photo showing collection pit constructed to collect oily waste

Plate 7.3.6: Photo showing sediment collection tanks constructed in yards to arrest sediment of the plot

Although around 70% of the plots were found to be strictly following environmental and safety norms and secondary processes were carried out on the concreted structures (Plates 7.3.4 and all the wastes related washing of floors containing oil were collected in oil pits and Storm–water run–off from industrial facilities are made underground (Plates 7.3.5 and 7.3.6). But some of the plots were operating with minimum care and metal pieces were spread in the intertidal regions (Plates 7.3.7 and 7.3.8).

Plate 7.3.7: A Photo showing none concrete plot

Plate 7.3.8: A view showing spread of waste on the shore

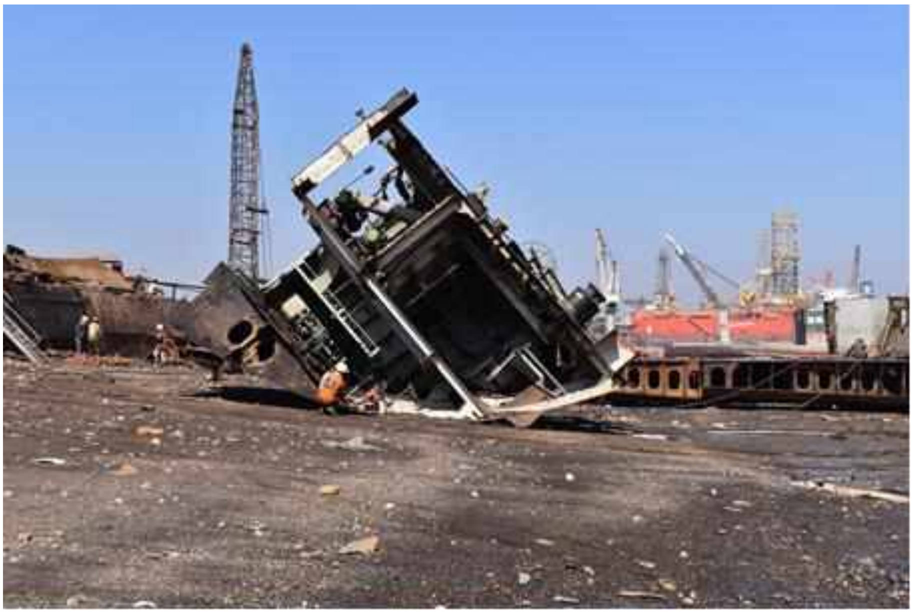

Plate 7.3.9: Photo showing none –green activities

A list showing the plots of HKC complied which are total 90 plots allotted by GMB are given below:

HKC – SOC CERTIFICATE WITH SIGN & STAMP (SELF ATTESTED)			Certificate			
Sr.No.	**Plot No.**	**Plot Name**	**CLASS N K**	**RINA**	**I R CLASS**	**Signed & Stamped**
1	3	KAMDAR & ASSOICATES		YES		**YES**
2	4	SAGAR LAXMI SHIP BREAKERS		YES		**YES**
3	5	SHUBH ARYA STEEL PVT. LTD.		YES		**YES**
4	8	GHASIRAM GOKALCHAND SHIP BREAKING YARD	YES	YES		**YES**
5	9	SHREE RAM GREEN SHIP RECYCLING INDUSTRIES (UNIT II) LLP	YES			**YES**
6	13	BAIJNATH MELARAM	YES			**YES**
7	14	HARIYANA SHIP BREAKERS LTD		YES		**YES**
8	15	ANUPAMA STEEL LTD	YES		YES	**YES**
9	20	PANCHAVATI SHIP BREAKERS		YES		**YES**
10	24	ALANG AUTO & GEN. ENGG.CO.PVT.LTD	YES			**YES**
11	25	BANSAL SHIP BREAKERS PVT.LTD	YES	YES		**YES**
12	33	MADHAV STEEL (S.B.D)			YES	**YES**
13	34	MADHAV INDUSTRIAL CORPORATION		YES	YES	**YES**
14	39	BANSAL SHIP RECYCLERS LLP	YES	YES		**YES**
15	45	INDUCTO STEEL LTD		YES		**YES**
16	52 M	PRAKASH RE–ROLLERS PVT.LTD		YES		**YES**
17	57	LAKSHMI GREEN SHIP RECYCLERS LLP	YES	YES		**YES**
18	65	SACHDEVA STEEL PRODUCTS (SB) LLP	YES			**YES**
19	66	JAI JAGDISH SHIP BREAKERS (P) LTD.	YES			**YES**
20	77	ASHWIN CORPORATION	YES	YES		**YES**
21	78	SHREE RAM VESSEL SCRAP P.LTD	YES			**YES**
22	81	SHREE RAM SHIPPING IND.PVT.LTD	YES			**YES**
23	84/B	P.RAJESH SHIP BREAKING PVT. LTD.		YES		**YES**
24	88	ATAM MANOHAR SHIPBREAKERS P. LTD.	YES			**YES**
25	91	K.P.G. ENTERPRISE RECYCLERS LLP		YES		**YES**
26	94	AKHIL SHIP BREAKERS P.LTD		YES		**YES**
27	113	AGRASEN SHIP BREAKERS PVT.LTD		YES		**YES**
28	127	G. N. SHIP BREAKERS		YES		**YES**
29	128	GURUASHISH SHIP BREAKERS		YES		**YES**
30	V/1	PRIYA BLUE INDUSTRIES P.LTD	YES			**YES**
31	V/4	HARIYANA SHIP DEMOLITION PVT.LTD		YES		**YES**
32	V/6	KHUSHBOO INDIA PVT. LTD.		YES		**YES**
33	V/7	R.K. INDUSTRIES (UNIT–II) LLP	YES			**YES**
34	19	R.L. KALTHIA SHIP BREAKING PVT.LTD	YES			**YES**
35	23	TRIVENI SHIP BREAKERS LLP	YES	YES		**YES**
36	V/2	HOOGHLY SHIPBREAKERS LTD	YES	YES		**YES**
Total			**19**	**23**	**3**	
37	136	M.V. SHIP TRADE PVT.LTD		YES		**YES**
38	67	SALASAR BALAJI SHIP BREAKERS P.LTD	YES			**YES**
39	60	JAWANDAMAL DHANNAMAL	YES			**YES**
40	42	VIRENDRA & COMPANY		YES		**YES**
41	153	NAVYUG SHIP BREAKING CO		YES		**YES**
42	86	KATHIAWAR STEELS		YES		**YES**
43	21	INTERNATIONAL STEEL CORPN		YES		**YES**
44	30	J.R.D. INDUSTRIES	YES			**YES**
Total			**3**	**5**	**0**	
Sub Total			**22**	**28**	**3**	

HKC – SOC CERTIFICATE WITH SIGN & STAMP			Certificate			
Sr.No.	**Plot No.**	**Plot Name**	**CLASS N K**	**RINA**	**I R CLASS**	**Signed & Stamped**
45	161	ASHWIN SHIPBREAKING LLP		YES		**YES**
46	27	SHANTAMANI ENTERPRISE LLP		YES		**YES**
47	84/A	LUCKY STEEL INDUSTRIES (S B D)	YES			**NO**
48	84	DIAMOND INDUSTRIES (SBD)	YES			**NO**
49	61	NBM IRON AND STEEL TRADING PVT. LTD.	YES			**NO**
50	59	Y.S. INVESTMENTS	YES			**NO**
51	35	LEELA GREENSHIP RECYCLING PVT. LTD.	YES			**NO**
52	2	LEELA SHIP RECYCLING PVT. LTD.	YES			**NO**
53	V/5	MAHAVIR INDUCTO MELT PVT.LTD			YES	**NO**
54	63	BHARAT SHIP BREAKERS CORPORATION			YES	**NO**
55	38	GHAZIABAD SHIP BREAKERS PVT.LTD			YES	**NO**
56	32	SAMUDRA ALLOYS PVT.LTD			YES	**NO**
57	29	KASTURI COMMODITIES PVT.LTD			YES	**NO**
58	10	**SHREE SAI BABA SHIP BREAKING CO**		YES		**NO**
59	11	SHRI GAUTAM SHIP BREAKING IND.P. LTD		YES		**NO**
60	18	MAHAVIR SHIP BREAKERS		YES		**NO**
61	22	RAI METAL WORKS PVT.LTD		YES		**NO**
62	23	TRIVENI SHIP BREAKERS		YES		**NO**
63	38	GHAZIABAD SHIP BREAKERS PVT.LTD		YES		**NO**
64	40	SHIRDI STEEL TRADERS		YES		**NO**
65	41	SHANTI SHIP BREAKERS PVT.LTD		YES		**NO**
66	46	P.PATEL SHIP BREAKING COMPANY		YES		**NO**
67	47	MARINE LINES SHIP BREAKERS(P)LTD		YES		**NO**
68	54	RUSHIL INDUSTRIES LTD		YES		**NO**
69	55	HATIMI STEELS		YES		**NO**
70	68	SAUMIL IMPEX PVT.LTD		YES		**NO**
71	84	DIAMOND INDUSTRIES (SBD)		YES		**NO**
72	84/D	SARVAG SHIPPING SERVICES PVT. LTD.		YES		**NO**
73	93	ALANG SHIP BREAKING CORPN		YES		**NO**
74	103	HONEY SHIP BREAKING PRIVATE LIMITED		YES		**NO**
75	133 M	Hari Krishna Steel Corporation		YES		**NO**
76	134	MAHADEV SHIP BREAKERS PVT. LTD.		YES		**NO**
77	138	VIJAYKUMAR & COMPANY		YES		**NO**
78	160 M	VMS INDUSTRIES LTD		YES		**NO**
79	161	A.G.ENTERPRISE		YES		**NO**
80	V/9	RAJENDRA SHIP BREAKERS PVT. LTD.		YES		**NO**
81	88	ATAM MANOHAR SHIPBREAKERS P. LTD.		YES	YES	**NO**
82	67	SALASAR BALAJI SHIP BREAKERS P.LTD			YES	**NO**
83	14	HARIYANA SHIP BREAKERS LTD			YES	**NO**
84	125	MARIYA SHIP BREAKING P.LTD		YES		**NO**
85	65(24L)	M/s. SACHDEVA STEEL PRODUCTS (SB) LLP		YES		**NO**
86	24	ALANG AUTO & GEN. ENGG.CO.PVT.LTD		YES		**NO**
87	84/B	P.RAJESH SHIP BREAKING PVT. LTD	YES			**NO**
88	20	PANCHAVATI SHIP BREAKERS	YES			**NO**
89	4	SAGAR LAXMI SHIP BREAKERS	YES			**NO**
90	5	SHUBH ARYA STEEL PVT. LTD.	YES			**NO**

Source: Gujarat Maritime Board

7.4 Hazardous waste management in the ship−recycling yards

During visit it was found that almost all the yards have their own system of handling hazardous waste handling and storage system before it is collected by GEPIL as given in the photos below:

Plate 7.4.1: Photo showing arrangements made for waste collection

Plate 7.4.2: Photo showing arrangements made for waste collection in recycling yards

7.5 Environmental concern

During field study period of February 2020, it was found that most of the shoreline along the ship−recycling yards were free from oil spill and scrap material. Treatment of Hazardous and solid waste management coming from ship and ship−recycling yards in handled by the Gujarat Enviro Protection and Infrastructure Ltd. (GEPIL), established at Alang. Some of the photographs, taken during field study period are given below:

Plate7.5.1: Photo showing closed land fill pit at Alang

Plate 7.5.2: Photo showing active land fill pit and leachate monitoring well

Plate 7.5.3: A view showing incinerator installed in GEPIL at Alang

Plate 7.5.4: Effluent treatment facility at GEPIL, Alang

7.6 Safety measures in the recycling yards at Alang

It was observed that the workers at ship−recycling yards were well acquainted with safety and security method and all those working in the plots were found wearing helmets, safety jackets and boots.

Plate 7.6.1: Workers working with almost all safety equipment

A training institute has been established by GMB at Alang for the training of workers before their engagement for actual work of ship breaking and other activities.

Plate 7.6.2: A view of ongoing training of ship breaking workers at Alang

Plate 7.6.3: Joint visit of CSIR–NIO Scientists and GMB officials to training Centre at Alang

During our field study, we interviewed some of the workers engaged in ship−recycling work. During interaction, it was found that due to training and awareness in workers and enhanced enforcement of norms, the accident has come down drastically in the ship−recycling yards at Alang–Sosiya.

7.7 Health facilities at Alang

Alang Red Cross Hospitals for Primary Medical Treatment. The hospital is financially assisted by GMB. GMB extended full support to create Multi Speciality Hospital at Alang itself which provides medical services to manpower at Ship Recycling yards and residents of nearby 45 villages around Alang. Another Private Hospital permitted by GMB also known as "Alang Hospital" for Secondary Medical Care. It has 33 beds. It is equipped with an X–ray facility and medical stores. Two doctors are available permanently. For any eventuality, expert doctors are also called to provide treatment to the affected workers.

7.8 Staying facility for ship−recycling workers at Alang

GMB and Ship Recycling Industrial Association have provided housing facility to the workers in first phase for accommodating 1,008 persons. The facility is of the dormitory type comprising of 7 blocks (having a ground floor + 2 stories), canteen building, office building, shops, road, water supply and sanitary facilities with Sewerage Treatment Plant (STP), electrification etc.

However, most of the migratory workers working in most recycling plots live poor life as given in the photographs taken during field studies. These labours are migratory workers and directly related to GMB and ship−recycling operation.

Plate 7.8.1: Photo showing houses of ship−recycling workers, built almost in the creek with the support of wooden pilers.

Plate 7.8.2: Another view of the staying of ship−recycling workers at Alang

8 STUDY OF CRZ COMPLIANCES

8 STUDY OF CRZ COMPLIANCES

The region was assessed based on the CRZ map prepared by NCSCM and provided by GMB. As per the CRZ notification 2011 and map prepared by the NCSCM (Annexure-I), the entire ship recycling activities at Alang-Sosiya come under CRZ I(B), CRZ-III and CRZ-IV.

8.1 Activities in CRZ I (B)

It was observed that the major activities were carried in CRZ–I (B) area are beaching and cutting of the ships as shown in the photos below:

Plate 8.1.1: Ships beached in CRZ –I (B) region for cutting

Plate 8.1.2: Ship cutting in intertidal region

Plate 8.1.3: Ship waiting in CRZ–I (B) region for procedures to be completed before cutting

Plate 8.1.4: Photo showing ship cutting activities in the CRZ–I(B) region

Plate 8.1.5: A photo showing people picking up metals from shore

Thus, it is evident from above photographs and activities that the area around 300m in the CRZ-I (B) is mainly used for beaching and cutting of the ships in recycling yards. Around 70% plots have upgraded recycling yards/plot in green category as per Hong Kong convention and others are in process of upgradation. The ship breaking yards including ship breaking units are listed at 7(b) of schedule of EIA notification, 2006 covered under Category ‘A’, as it comes under the project requiring water front and fore shore facilities. However, by grounding and cutting activities, temporarily disturbance of benthic fauna takes place. Therefore, upgradation of ship recycling yard at Alang is highly required for the preservation of coastal environment.

8.2 Activities in CRZ–III region

All the developed plots and offices are within 120 m from high tide line, hence, in CRZ–III zone.

8.3 Activities in CRZ–IV region

As per information, anchoring of ships by buyers/recyclers is done in CRZ–IV region before beaching. Hence, there are no other activities in the CRZ–IV region.

NIO'S statement on compliance by GMB with reference to EC/CRZ clearance granted by MOEF & CC vide their letter No. IA. III dated 2/11/2016.

MOEF&CC has granted EC/CRZ Clearance to following components

a) Upgradation of existing Ship recycling plots: 70 plots in phase-I and remaining 97 plots in phase-II.
b) Hazardous Material removal Pre-treatment Facility: Construction two dry docks (Dimension: l×b×h = 300m×50m×11.5m) for pre-cleaning of hazardous materials from ships. Dry dock 1 will be at the southern end of the existing yard and Dry-dock 2 about 2km further south. Both the dry-docks may also be used for ship repair and ship building purposes when there are no ships for decontamination.
c) Additional facilities: (1) Waste oil treatment system. (2) Incinerator at the existing TSDF located within Alang Notified Area.
d) Additional Plots: 15 nos. 100 × 90m plots between the two proposed dry-docks.

1. Current status during the study by NIO
   - For component (a) under "Upgradation of existing Ship recycling plots", at present 70 plots have been upgraded and 11 plots were in process of upgradation.
   - For components mentioned under (b), (c) and (d) in EC/CRZ Clearance, so far, no implementation has been undertaken i.e. progress is zero.
2. It is learnt from the local authorities that ship breaking yards have been in operation since 1982 and gradually develop the plot upto 1989-90. So, many structures like admin office, small storage facilities for PPEs and other operational structures are available in the plots as a part of integral activities of the ship recycling.

9 CONCLUSIONS

9 CONCLUSIONS

In general, the ecology of coastal water of Alang is seen similar to that of surrounding area of Bhavnagar and Dahej and it compares well with earlier studies of 2007–08 in Alang area. The adverse impact of ship breaking activities on water quality, sediment quality and biological characteristics was not significant except a certain intertidal region showing high concentration of PHc and some metals. The PHc values were significantly low during present study as compared to 2007–08 values. Phytoplankton and zooplankton values showed natural variability and not influenced by ship breaking activities. Influence of ship–breaking activities on intertidal macrobenthic fauna resulting poor standing stock, was localized at Alang. The results of bioaccumulation suggest that the concentration of all the metals are within the specified values for human consumption, except Fe. To confirm the impact of ship breaking activities on the ecology of Alang, the long–term monitoring is essential.

Present study reveals significant improvement in ship−recycling yards with respect to safety, security, health and environment. However, the living area of most of the shipbreaking workers is poor in regards to the infrastructure and sanitization, that can be prioritised in future. The residential accommodation developed by GMB jointly with shipbreakers association is either insufficient and/or there is no awareness among the workers. Although, around 70% recycling yards have adapted HKC to become to get green category certificate, many yards need to be upgraded to curtail pollution and enhance the security.

10 RECOMMENDATION

10 RECOMMENDATION

To maintain a healthy environment of the coastal water of Alang, the ship–breakers are suggested to avoid the spillage of petroleum products and hazardous wastes and strictly follow the norms of GPCB.

Upgradation of the recycling yards need immediate attention. Periodic monitoring for every year of the coastal ecology including marine biodiversity and bioaccumulation of metals in the marine organisms of Alang is needed. Any adverse impact on the coastal ecology including subtidal and intertidal should be brought .in to the notice of concerned authority so as to take appropriate measures for future care of this region.

GMB should also oversee and ensure that the ship−recycling operation remains in safe & environmentally sound mode and therefore, entire operations be supervised by Environmental Professionals of GMB.

11 REFERENCES

11 REFERENCES

Bhosale, U. and Sahu, K.C., 1991. Heavy metal pollution around the island city of Bombay, India. Part II: Distribution of heavy metals between water, suspended particles and sediments in a polluted aquatic regime. Chemical geology, 90(3–4), 285–305.

Bruland, K. W., Franks, R. P., Knauer, G. A., & Martin, J. H. (1979). Sampling and analytical methods for the determination of copper, cadmium, zinc, and nickel at the nanogram per liter level in sea water. Analytica chimica acta, 105, 233–245

D'Costa, S. and Pai, I.K., 2017. Trace metal variability in nearshore waters along the central west coast of India. Indian Journal of Geo Marine Science 46(2) 304□309.

Grasshoff, K., Kremling, K., & Ehrhardt, M. (Eds.). (2009). Methods of seawater analysis. John Wiley & Sons.

Loring, D. H., & Rantala, R. T. (1992). Manual for the geochemical analyses of marine sediments and suspended particulate matter. Earth□science reviews, 32(4), 235–283.

Mitra, A., Kumar, V. S., & Naidu, V. S. (2020). Circulation in the Gulf of Khambhat—A Lagrangian Perspective. *Journal of Marine Science and Engineering*, *8*(1), 25.

NGT 2018. CSIR– National Institute of Oceanography Technical Report. Monitoring of Tadgam, Tithal, Jampore and Devka Beaches in Valsad District of Gujarat and Union Territory of Daman (Part I, II & III), pp 96.

Pahalawattaarachchi, V., Purushothaman, C.S. and Vennila, A., 2012. Metal status of water in mangrove ecosystem of Maharashtra coast, India. Indian Journal of Marine Science 41(4), 359–368.

Ram, A., Rokade, M.A., Borole, D.V. and Zingde, M.D., 2003. Mercury in sediments of Ulhas estuary. Marine Pollution Bulletin, 46(7), pp.846□857.

Sabnis, M.M., 1984. Studies of some major and minor elements in the polluted Mahim river estuary. (Ph. D. thesis). University of Bombay (now Mumbai), pp.1–288.

Sankaranarayanan, V. N., Purushan, K. S. & Rao, T. S. S. 1978. 191 Concentrations of some of the heavy metals in the Oyster Crassostrea madrasensis (Preston) from the Cochin region. Indian Journal of Marine Sciences 7, 130–131.

Sankaranarayanan, V.N., Reddy C.V.G. 1973. Copper content in the inshore and estuarine waters along the central west coast of India, Current Science 42, 223–224.

USEPA, P.D.M.1979. Sludge Treatment and Disposal. Municipal Environmental Research Laboratory, Cincinnati, Ohio EPA, 625, 1–79.

Walkely, A., & Black, C. A, (1934) An examination of Detjareff methods of determining soil organic matter and proposed modifications of chromic acid titration methods. Soil. Sci, 37, 29–38.

Zingde, M.D. and Desai, B.N., 1987. Pollution status of estuaries of Gujarat□an overview. Goa: National Institute of Oceanography.

Zingde, M.D. and Singbal, S.Y.S., 1983. Characteristics of nearshore waters in Binge Bay, Karwar. Mahasagar, 16(4), pp.423–428.

Zingde, M.D., 1985. Wastewater effluents and coastal marine environment of Bombay. Proceedings of the symposium on Seawater quality demands, Bombay, India,

Zingde, M.D., Singbal, S.Y.S., Moraes C.F., Reddy C.V.G., 1976. Arsenic, Copper, Zinc and Manganese in the marine flora and fauna of coastal and estuarine waters around Goa. Indian Journal of Marine Sciences 5, 212–217.

Zingde, M.D., Trivedi, S.K. and Desai, B.N., 1979. Physicochemical studies on coastal pollution off Bombay. Indian Journal of Marine Sciences 8(4), 271–277.

Table 3.1.1: Water quality (average values) at Lakhigam (Dahej) during 1997 – 2007.

Area	Lakhigam							
Parameter	Nearshore				Offshore			
	1997	1998	2006	2007	1997	1998	2006	2007
WT (^{o}C)	25.6	25.3	24.1	29.0	25.2	24.8	24.0	29.1
AT (^{o}C)	28.6	27.9	26.1	29.3	24.3	27.4	25.1	31.2
pH	8.0	7.9	7.9	7.8	8.0	8.0	7.9	8.0
SS (mg/l)	4886	411	282	1210	5153	1639	1618	927
Salinity (ppt)	29.2	29.3	29.6	21.7	29.8	29.7	29.6	21.3
DO (ml/l)	4.7	4.7	5.5	3.7	4.6	3.9	5.5	3.3
BOD (mg/l)	1.2	1.4	2.4	0.5	2.7	1.5	2.6	1.3
PO_4^{3-}-P (µmol/l)	2.9	2.8	2.7	4.3	3.4	2.4	2.7	4.0
NO_3^--N (µmol/l)	29.1	22.0	38.4	36.2	28.4	24.8	39.5	40.6
NO_2^--N (µmol/l)	0.7	0.4	0.3	0.6	0.7	0.1	0.3	0.5
NH_4^+-N (µmol/l)	1.0	0.7	0.5	1.1	3.9	1.2	0.9	0.6
PHc (µg/l)	12.0	ND	7.0	9.9	11.6	2.6	12.9	17.4
Phenols(µg/l)	29.7	2.7	34.0	63.0	25.3	ND	30.0	76.0

Table 3.1.2: Water quality (average values) at Luhara (Dahej) during 1997 – 2007.

Area	Luhara						
Parameter	Nearshore			Offshore			
	1997	1998	2007	1997	1998	2006	2007
WT (^oC)	25.2	25.5	28.4	25.3	25.7	24.3	28.9
AT (^oC)	27.9	29.4	28.3	25.7	31.4	24.5	30.0
pH	8.0	8.1	7.9	8.1	8.1	7.9	8.0
SS (mg/l)	2809	584	1477	4209	700	206	751
Salinity (ppt)	29.9	28.9	21.4	29.8	28.5	29.9	20.1
DO (ml/l)	4.3	3.4	4.1	4.4	4.6	5.4	4.2
BOD (mg/l)	1.3	1.2	0.6	0.8	2.5	2.1	1.0
PO_4^{3-}-P (µmol/l)	2.9	3.3	4.6	2.4	2.7	3.1	4.1
NO_3^--N (µmol/l)	27.7	25.1	39.7	25.8	24.0	40.5	40.6
NO_2^--N (µmol/l)	0.7	0.6	0.5	0.4	0.4	0.3	0.5
NH_4^+-N (µmol/l)	1.1	1.4	0.8	1.5	1.5	0.3	0.4
PHc (µg/l)	10.3	1.7	7.0	4.9	-	96.7	7.3
Phenols(µg/l)	37	112	93.0	16.3	ND	37.0	67.0

Table 3.1.3: Water quality (average values) at Bhavnagar during 1996 – 2007.

Area	Bhavnagar								
Parameter	Nearshore							Offshore	
	Jan 1996	Oct 1999	Apr 2000	Nov 2001	May 2003	Nov 2006	Mar 2007	Nov 2006	Mar 2007
WT (^oC)	23.5	29.3	27.8	29.4	28.5	26.3	29.0	27.6	26.1
AT (^oC)	-	-	-	-	-	26.3	33.3	27.6	26.8
pH	8.1	8.2	8.1	8.0	7.9	8.0	8.0	8.0	8.0
SS (mg/l)	1437	829	577	610	138	301	1123	1585	2965
Salinity (ppt)	32.1	19	31.4	30.7	34.3	22.9	30.2	22.3	29.8
DO (ml/l)	5.5	4.4	3.7	3.9	4.6	4.7	4.4	3.9	3.2
BOD (mg/l)	1.4	1.5	1.5	3.6	1.9	0.9	1.8	0.7	2.4
PO_4^{3-}-P (µmol/l)	3.4	2.4	2.6	24.7	2.4	3.1	12.8	3.1	7.3
NO_3^--N (µmol/l)	21.6	27.7	13.5	19.7	27.7	35.6	33.5	40.6	35.8
NO_2^--N (µmol/l)	0.7	0.5	0.5	0.5	0.3	1.0	0.7	0.5	0.8
NH_4^+-N (µmol/l)	1.7	0.3	0.7	0.7	1.6	1.1	1.4	1.3	0.8
PHc (µg/l)	2.4	3.2	4.0	0.2	0.1	12.9	50.5	15.0	7.1
Phenols(µg/l)	12	11	21	68	88	87	131	60	ND

Table 3.1.4 Water quality (average values) at Alang during 2007-2008.

Area	Alang					
Parameter	Nearshore			Offshore		
	Dec 2007	Apr 2008	Oct 2008	Dec 2007	Apr 2008	Oct 2008
WT (^oC)	23.3	28.1	28.6	24.3	28.3	29.3
AT (^oC)	25.4	29.2	29.7	26.0	30.5	31.0
pH	8.0	8.2	8.2	8.0	8.1	8.3
SS (mg/l)	813	587	276	840	839	624
Salinity (ppt)	29.0	34.7	29.2	29.6	33.3	28.8
DO (mg/l)	6.8	5.0	6.9	7.6	4.1	6.4
BOD (mg/l)	1.3	3.6	5.9	1.9	3.6	3.2
PO_4^{3-}-P (µmol/l)	2.6	3.3	5.1	2.5	3.8	6.2
NO_3^--N (µmol/l)	45.3	23.3	34.0	46.4	22.5	36.8
NO_2^--N (µmol/l)	0.4	0.5	0.5	0.4	0.5	0.4
NH_4^+-N (µmol/l)	0.8	0.7	1.1	1.8	0.8	0.7
PHc (µg/l)	13.6	32.2	524.3	19.1	12.1	12.1
Phenols (µg/l)	61.0	74.7	51.9	15.4	102.0	37.2

Table 3.2.1: Sediment quality (average values) at Dahej during 1997 – 2007.

Area	Lakhigam							
Parameter	Nearshore				Offshore			
	1997	1998	2006	2007	1997	1998	2006	2007
Al (%)	2.3	12.1	2.8	6.1	5.4	4.5	3.9	6.3
Cr (μg/g)	59	98	90	129	137	36	91	141
Mn (μg/g)	915	967	2007	1083	922	700	1436	1254
Fe (%)	2.4	13.1	6.4	7.0	4.8	7.4	5.4	7.9
Co (μg/g)	27	51	36	44	57	30	41	46
Ni (μg/g)	30	62	67	68	61	30	77	71
Cu (μg/g)	25	105	87	90	80	31	92	103
Zn (μg/g)	89	89	151	91	130	48	131	112
Hg (μg/g)	0.06	0.15	0.05	0.02	0.10	0.12	0.04	0.03
P (μg/g)	493	584	338	448	361	245	464	630
Corg (%)	0.1	0.7	0.1	-	0.4	-	0.3	-
PHc (μg/g)	0.3	0.3	0.2	-	0.2	0.4	0.2	-

Dry wt basis except PHc, which is wet wt basis.

Table 3.2.2: Sediment quality (average values) at Bhavnagar during 1997 -2007.

Area	Bhavnagar						
Parameter	Nearshore					Offshore	
	Nov 2001	May 2003	Oct 2004	Nov 2006	Mar 2007	Nov 2006	Mar 2007
Al (%)	5.8	1.6	7.3	-	6.9	-	4.3
Cr (µg/g)	141	170	146	121	114	92	88
Mn (µg/g)	125	2566	1280	-	1472	-	1113
Fe (%)	9.9	11.1	7.2	-	7.5	-	7.1
Co (µg/g)	34	54	37	31	31	27	29
Ni (µg/g)	33	81	63	75	78	65	67
Cu (µg/g)	77	178	93	85	105	73	85
Zn (µg/g)	74	226	159	-	-	-	-
Hg (µg/g)	0.02	ND	0.07	0.03	0.03	0.03	0.03
P (µg/g)	414	496	760	-	-	-	-
Corg (%)	0.2	0.1	0.5	0.2	0.5	0.2	0.1
PHc (µg/g)	1	0.1	0.8	0.2	0.6	0.2	0.3

Table 3.2.3 Sediment quality (average values) at Alang during 2007-2008.

Area	**Alang**					
Parameter	**Nearshore**			**Offshore**		
	Dec 2007	**Apr 2008**	**Dec 2007**	**Dec 2007**	**Dec 2007**	**Oct 2008**
Al (%)	8.0	9.8	11.7	7.1	8.4	9.9
Cr (µg/g)	121	132	126	134	150	141
Mn (µg/g)	1054	965	1011	1217	1056	1397
Fe (%)	5.9	6.5	7.5	--	6.3	6.1
Co (µg/g)	44	43	30.8	42	43	32
Ni (µg/g)	82	75	51	83	79	40
Cu (µg/g)	94	92	96	94	102	73
Zn (µg/g)	89	82	99	105	189	67
Hg (µg/g)	0.04	0.05	0.01	0.07	0.09	ND
P (µg/g)	637	854	850	717	667	869
C_{org} (%)	0.8	0.7	0.9	0.8	0.3	1.1
PHc (µg/g)	1.6	1.5	2.1	2.7	0.3	0.4

Table 3.3.1: Phytopigments in the coastal water of Dahej and Bhavnagar during 1996-2007.

<table>
<tr><th colspan="10">DAHEJ</th></tr>
<tr><th rowspan="2">Area</th><th>Parameter</th><th colspan="4">Nearshore</th><th colspan="4">Offshore</th></tr>
<tr><th>Year</th><th>1997</th><th>1998</th><th>2006</th><th>2007</th><th>1997</th><th>1998</th><th>2006</th><th>2007</th></tr>
<tr><td rowspan="2">Lakhigam</td><td>Chlorophyll a (mg/m^3)</td><td>0.7</td><td>1.4</td><td>-</td><td>0.6</td><td>0.7</td><td>0.1</td><td>-</td><td>0.7</td></tr>
<tr><td>Phaeophytin (mg/m^3)</td><td>0.6</td><td>1.8</td><td>-</td><td>2.3</td><td>0.6</td><td>1.8</td><td>-</td><td>1.9</td></tr>
<tr><td rowspan="2">Luhara</td><td>Chlorophyll a (mg/m^3)</td><td>0.6</td><td>0.8</td><td>0.4</td><td>0.7</td><td>0.7</td><td>0.1</td><td>0.3</td><td>0.5</td></tr>
<tr><td>Phaeophytin (mg/m^3)</td><td>0.5</td><td>0.4</td><td>2.0</td><td>2.3</td><td>0.6</td><td>1.1</td><td>1.1</td><td>1.4</td></tr>
<tr><th colspan="10">BHAVNAGAR</th></tr>
<tr><td rowspan="4">Bhavnagar</td><th>Parameter</th><th colspan="6">Nearshore</th><th colspan="2">Offshore</th></tr>
<tr><th>Year</th><th>1996</th><th>1999</th><th>2000</th><th>2001</th><th>2003</th><th>2006</th><th>2006</th><th>2007</th></tr>
<tr><td>Chlorophyll a (mg/m^3)</td><td>0.7</td><td>1.5</td><td>0.9</td><td>0.9</td><td>0.3</td><td>0.2</td><td>0.7</td><td>0.3</td></tr>
<tr><td>Phaeophytin (mg/m^3)</td><td>0.3</td><td>0.9</td><td>0.5</td><td>0.7</td><td>0.6</td><td>0.3</td><td>2.3</td><td>1.4</td></tr>
<tr><th colspan="10">ALANG</th></tr>
<tr><td rowspan="4">Alang</td><th rowspan="2">Parameter</th><th colspan="8">Year 2001
(Source: Marine Pollution Bulletin Vol. 42, No. 6,</th></tr>
<tr><th colspan="4">A1</th><th colspan="4">A2</th></tr>
<tr><td>Chlorophyll a (mg/m^3)</td><td colspan="4">0.2</td><td colspan="4">2.0</td></tr>
<tr><td>Phaeophytin (mg/m^3)</td><td colspan="4">0.1</td><td colspan="4">0.8</td></tr>
</table>

Table 3.3.2 Phytopigments in the subtidal water of Alang during 2007-2008.

ALANG							
Area	**Parameter**	**Nearshore**			**Offshore**		
		Dec 2007	**Apr 2008**	**Oct 2008**	**Dec 2007**	**Apr 2008**	**Oct 2008**
Alang	Chlorophyll *a* (mg/m^3)	0.9	1.0	0.8	1.5	1.0	0.5
	Phaeophytin (mg/m^3)	1.0	1.1	0.6	2.5	1.8	1.4

Table 3.3.3: Phytoplankton population in the coastal water of Dahej and Bhavnagar during 1997-2007

DAHEJ									
Area	**Parameter**	**Nearshore**				**Offshore**			
		1997	**1998**	**2006**	**2007**	**1997**	**1998**	**2006**	**2007**
Lakhigam	Cell count (no.x 10^3/l)	11.3	-	19.2	4.4	6.3	-	24	3.8
	Total genera (no.)	3	-	4	4	3	-	5	3
Luhara	Cell count (no.x 10^3/l)	5.1	7.8	20.8	3.0	6.7	6.4	8.8	4.1
	Total genera (no.)	4	3	3	2	2	10	10	3
BHAVNAGAR									
Area	**Parameter**	**Nearshore**						**Offshore**	
		1996	**1999**	**2000**	**2001**	**2003**	**2006**	**2006**	**2007**
Bhavnagar	Cell count (no.x 10^3/l)	1.2	25.3	18.5	3	-	9.1	6.8	18.0
	Total genera (no.)	2	4	4	4	-	3	2	4

Table 3.3.4 Phytoplankton population in the subtidal water of Alang during 2007-2008.

ALANG							
Area	**Year & Parameter**	**Nearshore**			**Offshore**		
		Dec-07	**Apr-08**	**Oct-08**	**Dec-07**	**Apr-08**	**Oct-08**
Alang	Cell Count (no x 10^3/l)	41.1	51.3	33.05	26	23.9	4
	Total genera (no)	11	11	13	7	9	4
	Major genera	*Peridinium, Thalassiothrix Navicula*	*Cyclotella, Bacteriastrum,Thalassiosira,*	*Peridinium, Bacteriastrum, Thalassiosira, Nitzschia*	*Skeletonema, Navicula, Nitzschia*	*Peridinium, Thalassiothrix, Nitzschia, Surirella*	*Peridinium, Planktoneilla, Thalassiosira, Navicula*

Table 3.3.5: Zooplankton in the coastal water of Dahej and Bhavnagar during 1997-2007.

DAHEJ									
Area	Parameter	Nearshore				Offshore			
		1997	1998	2006	2007	1997	1998	2006	2007
Lakhigam	Biomass (ml/100^3)	2.6	3.4	-	9.7	3.2	0.8	-	1.3
	Population (nox10^3/100m^3)	5.9	36.7	-	52.5	4.0	13.3	-	13.9
	Total group (no)	8	7	-	13	7	7	-	13
Luhara	Biomass (ml/100^3)	4.1	7.4	3.2	3.4	1.7	2.6	4.6	2.8
	Population (nox10^3/100m^3)	4.2	9.1	16.9	43.6	10.8	22.4	48.6	27.3
	Total group (no)	9	8	12	12	8	9	12	13
BHAVNAGAR									
Area	Parameter	Nearshore						Offshore	
		1996	1999	2000	2001	2003	2006	2006	2007
Bhavnagar	Biomass (ml/100^3)	7.7	2.1	7.2	4.6	2.4	3.7	3.3	9.3
	Population (nox10^3/100m^3)	22.6	20.0	13.7	0.9	10.2	23.1	32.4	20.7
	Total group (no)	7	10	10	10	14	9	14	13

Table 3.3.6: Zooplankton standing stock in the subtidal water of Alang during 2007-2008.

Area	**Parameter**	**Nearshore**			**Offshore**		
		Dec-07	**Apr-08**	**Oct-08**	**Dec-07**	**Apr-08**	**Oct-08**
Alang	Biomass (ml/100m^3)	1.8	6.6	1.8	3.8	6.2	2.6
	Population (no x 10^3/100m^3)	11.1	53.3	21.6	28	52.1	16.5
	Total groups (no)	12	14	11	13	15	16
	Major group	Copepods, Decapod larvae Lamelli branches	Copepods, Chaetognaths, Lamelli branches	Copepods, Decapod larvae, Chaetognaths	Copepods, Chaetognaths, Decapod larvae	Copepods, Chaetognaths, Lamelli branches	Decapod larvae, Copepods, Chaetognaths

Table 3.3.7: Macrobenthic standing stock at intertidal area of Dahej and Bhavnagar during 1997-2007.

<table>
<tr><th colspan="6">DAHEJ</th></tr>
<tr><th rowspan="2">Area</th><th rowspan="2">Parameter</th><th colspan="4">Year</th></tr>
<tr><th>1997</th><th>1998</th><th colspan="2">2007</th></tr>
<tr><td rowspan="3">Lakhigam</td><td>Biomass (g/m^2 wet wt.)</td><td>4.3</td><td>1.5</td><td colspan="2">-</td></tr>
<tr><td>Population (no x m^2)</td><td>908</td><td>1034</td><td colspan="2">-</td></tr>
<tr><td>Faunal group (no)</td><td>7</td><td>4</td><td colspan="2">-</td></tr>
<tr><td rowspan="3">Luhara</td><td>Biomass (g/m^2 wet wt.)</td><td>3.5</td><td>7.4</td><td colspan="2">0.3</td></tr>
<tr><td>Population (no x m^2)</td><td>465</td><td>1590</td><td colspan="2">149</td></tr>
<tr><td>Faunal group (no)</td><td>6</td><td>4</td><td colspan="2">1</td></tr>
<tr><th colspan="6">BHAVNAGAR</th></tr>
<tr><th rowspan="2">Area</th><th rowspan="2">Parameter</th><th colspan="4">Year</th></tr>
<tr><th>2001</th><th>2003</th><th>2006</th><th>2007</th></tr>
<tr><td rowspan="3">Bhavnagar</td><td>Biomass (g/m^2 wet wt.)</td><td>0.1</td><td>3.3</td><td>0.2</td><td>2.1</td></tr>
<tr><td>Population (no x m^2)</td><td>7</td><td>303</td><td>20</td><td>1502</td></tr>
<tr><td>Faunal group (no)</td><td>1</td><td>2</td><td>1</td><td>2</td></tr>
</table>

Table 3.3.8: Macrobenthic standing stock in coastal water of Dahej and Bhavnagar during 1997-2007.

DAHEJ									
Area	**Parameter**	**Nearshore**				**Offshore**			
		1997	**1998**	**2006**	**2007**	**1997**	**1998**	**2006**	**2007**
Lakhigam	Biomass (g/m^2;wet wt.)	0.6	0.9	-	0.1	<0.1	-	-	-
	Population (no x m^2)	138	126	-	19	26	-	-	-
	Faunal group (no)	3	2	-	1	1	-	-	-
Luhara	Biomass (g/m^2;wet wt.)	-	0.9	1.7	0.1	<0.1	-	0.2	-
	Population (no x m^2)	-	152	384	25	13	-	50	-
	Faunal group (no)	-	3	2	1	1	-	1	-

BHAVNAGAR									
Area	**Parameter**	**Nearshore**				**Offshore**			
		1999	**2001**	**2003**	**2007**	**1997**	**1998**	**2006**	**2007**
Bhavnagar	Biomass (g/m^2;wet wt.)	<0.1	5.6	2.8	<0.1			-	-
	Population (no x m^2)	13	285	209	13			-	-
	Faunal group (no)	1	5	2	1			-	-

Table 3.3.9 Macrobenthic standing stock in the subtidal water of Alang during 2007- 2008.

ALANG							
Area	**Parameter**	**Nearshore**			**Offshore**		
		Dec 2007	**Apr 2008**	**Oct 2008**	**Dec 2007**	**Apr 2008**	**Oct 2008**
Alang	Biomass (g/m^2; wet wt)	0.5	0.1	0.1	<0.1	<0.1	<0.1
	Population (no/m^2)	27	28	20	15.5	21	6
	Faunal group (no)	1	1	1	1	1	1
	Major groups	Polychaetes	Polychaetes	Decapod larvae	Polychaetes	Polychaetes	Fish larvae

Table 5.1.1: Variation in physico-chemical parameters off Alang during February 2020.

Station No / Parameter	Level	1 Avg (n=2)	2 Avg (n=2)	3 Avg (n=2)	4 Avg (n=2)	5 Avg (n=2)	6 Avg (n=2)	7 Avg (n=2)
Temperature (°C)	S	23.0	23.5	23.0	23.0	23.0	23.0	24.5
	B	-	-	-	-	-	-	24.0
	AT	(24.0)	(25.0)	(24.0)	(24.5)	(24.0)	(24.0)	(26.0)
pH	S	7.9	8.0	8.0	8.0	8.0	8.0	8.1
	B	-	-	-	-	-	-	8.1
SS (mg/l)	S	1729*	1464*	564*	392*	484*	434*	1271*
	B	-	-	-	-	-	-	4951*
Turbidity (NTU)	S	2441	2107.0	352.0	64.1	274.5	968.0	531.5
	B	-	-	-	-	-	-	1527.0
Salinity (ppt)	S	30.5	30.7	30.7	30.7	30.7	30.7	30.2
	B	-	-	-	-	-	-	30.1
DO (mg/l)	S	6.3	6.3	5.7	6.0	5.9	6.0	5.8
	B	-	-	-	-	-	-	5.8
BOD (mg/l)	S	3.4*	3.7*	3.0*	3.7*	3.3*	3.5*	3.1*
	B	-	-	-	-	-	-	2.7*
PO_4^{3-}-P (µmol/l)	S	1.9	2.1	1.7	1.5	1.6	1.4	2.0
	B	-	-	-	-	-	-	2.2
NO_3^--N (µmol/l)	S	29.7	31.6	28.2	29.1	26.1	27.8	15.8
	B	-	-	-	-	-	-	23.3
NO_2^--N (µmol/l)	S	0.4	0.3	0.2	0.2	0.2	0.3	0.3
	B	-	-	-	-	-	-	0.3
NH_4^+-N (µmol/l)	S	1.2	1.0	1.0	0.9	0.7	0.9	1.2
	B	-	-	-	-	-	-	1.2
PHc (µg/l)	1m	144.6*	315.1*	614.0*	584.3*	446.9*	342.1*	116.0*
Phenols (µg/l)	S	69.1*	97.1*	100.1*	90.0*	96.2*	80.9*	79.0*

Air temperature (°C) given in parenthesis

*Single value

Table 5.1.2: Variation in physico-chemical parameters off Alang during February 2020.

Station No	Level	8			9	10	11		
Parameter		Min	Max	Avg	Avg (n=2)	Avg (n=2)	Min	Max	Avg
Temperature (°C)	S	23.5	25.5	24.3	23.5	23.5	22.0	25.0	23.7
	B	23.0	25.5	24.2	22.0	23.5	22.5	25.0	23.7
	AT	(24.0)	(26.5)	(25.4)	(23.5)	(25.0)	(24.0)	(26.0)	(25.1)
pH	S	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
	B	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
SS (mg/l)	S	278	2318	1298	269*	69*	191	931	561
	B	2419	3183	2801	1663*	80*	452	452	452
Turbidity (NTU)	S	126.0	1511.0	754.9	1232.0	1151.5	408.0	1294.0	720.8
	B	189.0	1648.0	725.6	1365.5	2007.0	507.0	1402.0	911.1
Salinity (ppt)	S	30.1	30.5	30.3	30.3	30.6	30.6	31.0	30.8
	B	29.3	30.4	30.1	30.3	30.6	30.7	30.9	30.7
DO (mg/l)	S	5.3	6.3	5.8	5.9	5.5	5.3	6.2	5.2
	B	5.2	6.1	5.7	6.3	5.5	5.4	5.7	5.5
BOD (mg/l)	S	3.1	3.3	3.2	3.4*	3.1*	3.0	3.2	3.1
	B	2.9	3.1	3.0	3.4*	3.2*	3.3	3.3	3.3
PO_4^{3-}-P (µmol/l)	S	1.4	1.9	1.7	1.9	2.1	1.6	1.8	1.7
	B	1.6	2.0	1.8	2.0	2.1	1.4	1.9	1.8
NO_3^--N (µmol/l)	S	16.8	43.8	25.9	11.9	11.6	12.0	29.5	17.7
	B	17.6	41.2	28.7	17.2	8.3	10.2	34.8	18.0
NO_2^--N (µmol/l)	S	0.1	0.3	0.2	0.3	0.2	0.1	0.3	0.2
	B	0.2	0.4	0.3	0.3	0.1	0.0	0.3	0.1
NH_4^+-N (µmol/l)	S	0.7	3.4	2.0	1.8	3.7	1.8	3.6	2.8
	B	0.6	2.7	1.5	2.1	2.9	1.5	3.3	2.3
PHc (µg/l)	1m	83.2	110.9	97.1	143.0*	42.7*	60.2	65.4	62.8
Phenols (µg/l)	S	58.1	76.8	67.4	67.7*	43.9*	67.2	91.7	79.4

Air temperature (°C) given in parenthesis

*Single value

Table 5.1.3: Variation in physico-chemical parameters off Alang during February 2020.

Station No	Level	12	13	14	15	16	17	18	19
Parameter		Avg (n=2)	Avg (n=2)	Avg (n=2)	Avg (n=2)	Avg (n=2)	Avg (n=2)	Avg (n=2)	Avg (n=2)
Temperature (°C)	S	23.5	23.5	24.0	22.0	24.5	25.5	25.0	24.5
	B	-	23.5	23.5	22.5	24.0	24.5	25.0	24.0
	AT	(24.0)	(24.0)	(25.0)	(23.5)	(26.0)	(26.0)	(26.0)	(25.0)
pH	S	8.1	8.1	8.1	8.0	8.0	8.0	8.0	8.1
	B	-	8.1	8.1	8.0	8.0	8.0	8.0	8.1
SS (mg/l)	S	29.8*	1906*	213*	1747*	87*	295*	1300*	151*
	B	-	5219*	3739*	3760*	4995*	2451*	2707*	3980*
Turbidity (NTU)	S	859.0	416.5	855.5	61.9	60.0	198.0	1264.5	1114.0
	B	-	478.0	1043.5	1621.0	2359.5	847.5	1345.5	1193.0
Salinity (ppt)	S	30.7	29.8	30.7	31.3	30.6	30.5	30.8	29.4
	B	-	30.3	31.0	31.1	30.6	30.7	30.7	30.4
DO (mg/l)	S	5.8	6.0	5.6	5.9	5.7	5.7	5.7	5.6
	B	-	5.9	5.6	5.7	5.6	5.9	5.8	5.5
BOD (mg/l)	S	3.5*	3.1*	3.2*	3.1*	3.1*	3.0*	3.2*	3.2*
	B	-	3.2*	3.1*	3.1*	3.0*	3.5*	3.3*	3.0*
PO_4^{3-}-P (µmol/l)	S	2.0	1.3	1.3	1.4	1.2	2.0	2.9	1.3
	B	-	1.3	1.4	1.6	1.6	2.5	1.6	1.4
NO_3^--N (µmol/l)	S	14.9	12.4	10.5	27.0	30.9	28.5	30.3	19.0
	B	-	18.6	11.6	26.9	32.6	29.9	29.4	23.6
NO_2^--N (µmol/l)	S	0.2	0.4	0.4	0.1	0.2	0.1	0.1	0.3
	B	-	0.5	0.4	0.1	0.1	0.1	0.1	0.3
NH_4^+-N (µmol/l)	S	3.5	1.2	2.0	0.4	0.6	0.4	0.6	1.9
	B	-	1.4	2.2	0.7	0.8	0.5	0.8	2.0
PHc (µg/l)	1m	34.2*	35.2*	22.9*	42.1*	22.5*	18.5*	26.1*	18.0*
Phenols (µg/l)	S	77.3*	69.4*	57.8*	88.8*	72.2*	101.3*	88.3*	63.8*

Air temperature (°C) given in parenthesis

*Single value

Table 5.1.4: Variation in physico-chemical parameters off Alang during February 2020.

Station No / Parameter	Level	20 Avg (n=2)	21 Avg (n=2)	22 Avg (n=2)	23 Avg (n=2)	24 Avg (n=2)	25 Avg (n=2)	26 Avg (n=2)
Temperature (°C)	S	24.5	23.5	22.5	24.5	23.5	24.0	24.8
	B	24.0	24.0	22.5	24.5	23.0	23.5	-
	AT	(25.5)	(22.5)	(24.0)	(26.0)	(25.0)	(24.5)	(26.0)
pH	S	8.1	8.0	8.0	8.0	8.0	8.1	8.0
	B	8.1	8.0	8.0	8.0	8.0	8.1	-
SS (mg/l)	S	2787*	209*	89*	609*	46*	2529*	802*
	B	3896*	326*	3856*	861*	2246*	4101*	-
Turbidity (NTU)	S	176.5	11.1	55.2	103.0	28.8	1152.0	847.6
	B	2188.0	84.4	1793.0	2206.0	1288.5	2295.5	-
Salinity (ppt)	S	30.4	31.3	31.5	30.8	31.0	29.3	31.1
	B	30.8	31.2	31.2	31.1	30.9	29.3	-
DO (mg/l)	S	6.4	6.4	5.7	5.5	5.7	6.5	5.7
	B	6.4	6.5	5.7	5.9	5.7	6.5	-
BOD (mg/l)	S	3.5*	3.5*	3.0*	3.1*	3.1*	3.6*	3.3*
	B	3.5*	3.6*	3.2*	3.3*	3.1*	3.6*	-
PO_4^{3-}-P (µmol/l)	S	1.6	1.4	1.4	1.8	1.2	1.8	1.7
	B	2.5	1.4	1.6	1.9	1.6	2.0	-
NO_3^--N (µmol/l)	S	30.3	21.7	27.6	29.8	32.3	30.6	29.3
	B	31.1	29.6	29.2	26.4	31.3	31.0	-
NO_2^--N (µmol/l)	S	0.1	0.1	0.1	0.1	0.2	0.2	0.2
	B	0.2	0.1	0.2	0.1	0.1	0.2	-
NH_4^+-N (µmol/l)	S	0.6	0.4	0.5	1.0	0.5	1.6	0.8
	B	0.5	0.4	0.6	1.1	0.7	1.4	-
PHc (µg/l)	1m	14.6*	17.3*	13.3*	12.5*	14.8*	14.3*	-
Phenols (µg/l)	S	69.6*	94.6*	63.4*	66.7*	63.1*	61.0*	54.7*

Air temperature (°C) given in parenthesis

*Single value

Table 5.1.5: Dissolved trace metal concentrations (μg/l) in water of Alang during February 2020.

Stations	Depth	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Cd	Pb
1	S	1.4	55.1	14.2	0.4	2.0	2.6	5.9	1.9	1.2	0.4
2	S	0.56	1.35	67.36	0.19	0.72	1.3	7.45	0.54	0.34	ND
3	S	5.7	13.7	21.4	0.4	10.9	3.9	11.9	1.0	0.9	0.4
4	S	4.9	13.7	34.6	0.4	8.7	3.3	19.0	1.2	1.2	0.5
5	S	4.4	11.8	24.9	0.4	9.4	8.1	4.5	1.2	0.4	0.8
6	S	3.79	34.91	29.07	0.23	10.15	1.91	5.78	0.48	1.15	0.02
7	S	4.1	4.8	23.4	0.6	10.0	2.7	3.8	1.2	0.3	0.1
	B	3.64	2.97	17.38	0.18	5.61	1.64	1.84	0.77	0.17	ND
8 Fl	S	1.2	2.4	9.0	0.5	1.9	1.5	10.9	1.4	0.2	ND
	B	2.0	4.3	26.8	0.6	3.1	2.2	12.0	1.3	0.2	0.1
8 Eb	S	2.1	26.0	12.3	0.5	2.1	10.8	5.9	1.4	0.5	0.6
	B	1.86	26.79	54.1	0.16	1.32	11.41	6.83	0.56	0.4	0.34
9	S	1.1	3.4	6.2	0.5	1.1	1.8	6.3	1.4	0.1	0.0
	B	3.7	6.5	27.9	0.6	3.7	4.5	11.4	1.2	0.3	0.5
10	S	1.6	7.1	25.5	0.6	3.3	10.6	5.4	1.2	0.2	0.5
	B	4.5	25.0	21.3	0.7	12.5	66.5	8.9	1.2	0.4	0.7
11 Fl	S	1.9	4.6	31.2	0.8	2.2	4.7	7.0	1.2	0.5	0.9
	B	3.04	3.22	26.5	0.13	3.35	1.29	4.89	0.79	0.17	ND
11 Eb	S	1.2	5.4	14.7	0.5	6.3	4.1	7.8	1.2	0.3	0.2
12	S	1.6	3.2	12.4	0.5	2.4	5.7	3.0	1.3	1.3	0.2
13	S	1.3	5.6	10.9	0.5	4.1	10.4	8.4	1.3	0.4	0.9
	B	2.3	4.6	18.9	0.5	4.8	3.1	7.3	1.3	1.1	0.2
14	S	2.1	4.8	27.2	0.5	3.5	2.9	5.0	1.3	1.1	0.3
	B	1.2	3.0	11.3	0.5	4.7	3.0	3.1	1.3	0.3	ND
15	S	0.8	22.6	7.4	0.5	2.5	1.8	1.7	1.2	0.3	ND
	B	1.2	5.7	16.0	0.5	1.9	1.8	2.7	1.2	0.2	0.1
16	S	1.6	42.1	22.2	0.5	2.0	2.4	3.4	1.3	0.7	0.2
	B	1.5	17.4	22.1	0.5	2.2	4.0	4.7	1.9	0.9	0.5
17	S	1.1	116.4	5.5	0.6	1.5	2.1	3.6	1.2	0.3	0.1
	B	0.8	2.8	7.0	0.5	1.2	2.8	3.0	1.1	0.3	0.1
18	S	0.9	5.2	7.1	0.5	1.6	2.4	2.8	1.1	0.6	0.1
	B	1.1	2.1	11.0	0.5	2.0	3.1	5.9	1.1	0.4	0.0
19	S	1.0	2.8	2.5	0.5	1.4	1.7	3.8	1.3	0.8	ND
	B	0.7	1.8	0.4	0.5	1.4	1.2	4.2	1.2	0.2	ND
20	S	0.8	53.1	5.2	0.5	2.3	1.9	15.7	1.2	1.4	0.2
	B	0.9	61.4	2.9	0.5	2.8	2.0	17.1	1.3	1.6	ND
21	S	0.8	225.6	6.5	0.5	1.8	3.5	7.7	1.0	0.4	0.4
	B	1.0	1.6	5.9	0.5	1.3	1.6	3.2	1.3	0.1	0.0
22	S	1.21	87.14	49.21	0.15	0.43	1.34	6.38	0.65	0.42	ND
	B	0.8	2.4	3.5	0.5	1.1	1.5	5.5	1.1	0.2	ND
23	S	0.9	1.9	6.9	0.5	1.7	1.9	0.9	1.2	0.2	ND
	B	0.8	3.8	6.8	0.5	1.5	2.1	1.7	1.1	0.3	0.2
24	S	1.0	3.6	7.2	0.5	2.1	2.7	5.2	1.2	1.0	0.1
	B	1.0	7.0	10.8	0.6	1.7	2.7	ND	1.1	0.2	0.2
25	S	0.7	2.0	4.7	0.5	1.3	1.5	8.8	1.1	0.1	ND
	B	0.7	1.6	6.4	0.5	1.1	1.5	4.1	1.0	0.1	ND
26	S	0.8	2.2	4.5	0.5	2.9	1.8	7.2	1.1	0.3	ND
	B	0.8	2.6	4.4	0.5	1.1	2.2	3.3	1.1	0.2	0.2

Table 5.2.1: Sediment quality in the subtidal area off Alang during February 2020.

Station Code	Sand (%)	Silt (%)	Clay (%)	Al (%)	Cr (µg/g)	Mn (µg/g)	Fe (%)	Co (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	As (µg/g)	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)	C_{org} (%)	P (µg/g)	PHc (µg/g)
1	67.0	25.6	7.4	3.68	413	1731	13.9	82	67	92	274	13.4	0.30	0.28	25.4	0.4	812	0.2
2	62.8	31.6	5.6	3.91	156	1220	12.1	39	55	141	375	11.5	0.26	0.06	55.9	0.8	681	15.4
3	7.0	87.4	5.6	6.61	134	995	7.5	36	51	109	164	8.4	0.28	0.22	26.2	1.1	704	0.2
4	0.5	93.1	6.4	6.95	145	1019	7.3	34	56	110	97	6.7	0.19	0.17	14.3	1.4	654	0.2
5	82.5	14.0	3.6	4.93	286	2029	23.4	35	67	227	1214	26.1	0.56	0.21	80.3	0.9	637	0.1
6	34.7	49.2	16.2	5.99	207	1044	8.5	43	50	86	122	11.0	0.18	0.20	17.5	0.8	789	0.7
7	2.1	91.5	6.4	6.39	131	928	6.8	37	45	88	86	6.8	0.21	0.09	14.0	1.1	647	1.2
8	5.2	82.4	12.4	6.14	136	917	6.9	40	44	85	87	15.5	0.28	0.06	27.2	0.9	711	0.1
9	3.7	88.3	8.0	6.22	134	927	7.0	40	43	84	88	7.1	0.14	0.07	12.8	0.7	705	0.1
10	1.5	91.6	7.0	6.40	137	959	7.1	41	46	89	108	6.8	0.41	0.07	16.2	0.9	891	0.5
11	0.1	75.4	24.4	6.50	137	774	6.8	37	46	90	86	4.0	0.19	0.06	12.4	0.4	493	0.3
12	1.2	85.0	13.8	6.31	134	814	6.8	37	46	90	86	6.9	0.16	0.07	14.1	1.0	687	0.3
13	1.9	89.7	8.4	6.58	135	927	6.9	36	48	93	85	7.9	0.15	0.04	13.3	0.9	681	3.1
14	2.9	89.0	8.1	6.07	125	797	6.3	38	40	70	77	7.5	0.13	0.02	13.5	0.7	670	0.9
15	4.0	84.8	11.2	6.25	134	881	6.8	39	43	79	83	8.1	0.14	0.04	13.4	0.7	710	0.1
16	1.3	89.6	9.2	6.09	135	915	6.8	39	44	85	84	7.6	0.16	0.08	13.2	0.8	686	0.3
17	0.6	91.2	8.1	6.27	129	731	7.2	40	45	82	86	6.8	0.15	0.08	13.0	0.8	829	0.2
18	0.2	95.4	4.4	6.50	165	896	6.7	36	52	82	80	7.1	0.15	0.04	12.0	1.0	966	0.1
19	2.9	83.5	13.6	6.23	125	810	6.5	37	40	72	76	7.2	0.14	0.02	13.3	0.7	675	3.5
20	36.9	59.1	4.0	5.11	192	1154	7.7	46	45	85	97	9.0	0.16	0.03	13.3	0.6	659	0.1
21	36.8	49.9	13.3	5.80	100	913	6.5	34	41	79	80	8.9	0.19	0.04	13.7	0.8	693	0.4
22	24.7	70.2	5.1	5.75	94	866	6.1	32	39	73	71	7.7	0.29	0.06	13.8	0.7	664	1.0
23	31.7	60.2	8.1	5.38	86	846	5.8	30	37	66	68	6.6	0.17	0.03	12.7	0.5	659	1.6
24	70.5	23.8	5.7	3.79	136	1302	8.1	46	43	99	104	11.0	0.21	0.09	13.7	0.5	762	1.1
25	0.2	88.4	11.4	6.41	97	893	6.7	32	43	88	80	6.7	0.13	0.10	12.6	1.0	636	1.0
26	0.5	87.1	12.4	6.52	92	863	6.7	32	47	96	84	6.4	0.14	0.10	12.8	0.3	711	1.1

Table 5.2.2: Sediment quality in the intertidal area off Alang during February 2020.

Station Code	Sand (%)	Silt (%)	Clay (%)	Al (%)	Cr (µg/g)	Mn (µg/g)	Fe (%)	Co (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	As (µg/g)	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)	C_{org} (%)	P (µg/g)	PHc (µg/g)
T-I Upper	85.4	11.2	3.4	2.90	219	1764	17.2	55	74	149	608	18.8	0.81	0.55	55.2	4.4	1119	3.2
T-I Mid	85.2	10.7	4.2	2.90	201	1673	16.3	49	69	146	455	16.9	0.34	0.03	66.8	0.7	938	4.1
T-I Lower	84.2	6.6	9.2	4.00	326	1772	14.1	78	69	90	276	9.7	0.30	0.07	22.1	0.2	1066	4.9
T-II Upper	53.6	35.0	11.2	6.30	105	973	7.7	34	52	111	136	7.6	0.26	0.40	21.5	0.6	858	3.6
T-II Mid	53.3	41.3	5.4	5.10	166	1055	9.0	34	51	103	250	10.2	0.39	0.05	41.4	0.9	875	5.5
T-II Lower	47.6	42.2	10.2	6.50	117	991	7.6	34	55	111	151	7.4	0.31	0.06	20.4	1.4	879	5.1
T-III Upper	-	-	-	6.90	122	1104	8.4	36	61	127	174	8.9	0.42	0.47	29.5	0.8	931	4.0
T-III Mid	7.9	86.9	5.2	6.90	112	1074	8.3	33	55	137	174	9.0	0.33	0.04	32.1	1.3	773	4.2
T-III Lower	-	-	-	6.70	120	1081	8.2	35	58	126	179	7.9	0.38	0.07	29.4	1.7	875	4.5
T-IV Upper	97.0	2.0	1.0	6.10	158	1075	8.6	41	53	85	127	9.7	0.28	0.30	16.4	0.8	886	0.1
T-IV Mid	96.4	1.4	2.2	4.90	154	996	6.7	30	37	51	69	8.0	0.19	0.03	9.8	0.6	818	0.1
T-IV Lower	75.2	15.6	9.2	6.00	153	1053	8.1	38	50	85	113	9.2	0.26	0.05	16.1	0.6	880	0.7

Table 5.3.1: Microbial counts in surface water (CFU/ml) at Alang during February 2020.

Type of bacteria	1	2	3	4	5	6	7	8		9	10	11		12	13
	Spot	Spot	Spot	Spot	Spot	Spot	Spot	12 Hrs.		Spot	Spot	12 Hrs.		Spot	Spot
								Ebb	Fld			Ebb	Fld		
TVC (*10^3)	20	1520	10	70	20	10	70	60	60	50	110	40	80	60	20
TC	NG	420	860	NG	NG	NG	NG	NG	NG	10	10	10	50	NG	NG
FC	NG	70	140	NG	NG	NG	NG	NG	NG	NG	10	NG	NG	NG	NG
ECLO	NG	10	20	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SFLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG

Table 5.3.1 (Contd. 2.):

Type of bacteria	14	15	16	17	18	19	20	21	22	23	24	25
	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot
TVC (*10^3)	370	660	430	170	2150	40	160	520	110	90	270	780
TC	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
FC	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
ECLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SFLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG

Table 5.3.2: Microbial counts in sediment (CFU/g) at Alang during February 2020.

Type of bacteria	1	2	3	4	5	6	7	8	9	10	11	12	13
	Spot	Spot	Spot	Spot	Spot	Spot	Spot	12 Hrs.	Spot	Spot	12 Hrs.	Spot	Spot
TVC (*10^4)	120	1860	1060	70	1780	20	60	80	100	20	10	50	10
TC	NG	2000	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
FC	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
ECLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SFLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG

Table 5.3.2 (Contd. 2.):

Type of bacteria	14	15	16	17	18	19	20	21	22	23	24	25
	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot	Spot
TVC (*10^4)	1260	40	20	1830	20	90	850	1110	10	1530	1150	170
TC (*10^3)	72	NG	NG	NG	NG	NG	NG	NG	3.2	NG	NG	NG
FC	56	NG	NG	NG	NG	NG	NG	NG	600	NG	NG	NG
ECLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
SFLO	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG

Table 5.3.3: Distribution of phytopigments in coastal waters at Alang during February, 2020.

Station	Date	Time & Tide	CHLOROPHYLL		PHAEOPHYTIN		RATIO	
			S	B	S	B	S	B
1	2/26/2020	Shore collection	4.72	-	0.23	-	12.42	-
			2.54	-	0.38	-	11.04	-
2	2/26/2020		0.31	-	0.18	-	1.72	-
			0.32	-	0.06	-	5.33	-
3	2/27/2020		0.15	-	0.2	-	0.75	-
			0.16	-	0.21	-	0.76	-
4	2/27/2020		0.19	-	0.03	-	6.33	-
			0.1	-	0.05	-	3.33	-
5	2/27/2020		0.1	-	0.05	-	2	-
			0.15	-	0.02	-	9.38	-
6	2/27/2020		0.23	-	0.26	-	0.88	-
			0.37	-	0.54	-	0.69	-
7	2/23/2020		0.21	0.32	0.38	0.94	0.55	0.34
			0.04	0.24	0.49	0.73	0.08	0.33
8	2/23/2020	915 Fld-Ebb	0.27	0.19	0.99	0.21	0.27	0.9
		1115 Fld-Ebb	0.21	0.19	0.22	0.01	0.95	0.01
		1215 F.Ebb	0.13	0.12	0.04	0.26	3.25	0.46
		1415 Ebb-Fld	0.05	0.1	0.1	0.01	0.5	10
		1615 Ebb-Fld	0.14	0.03	0.12	0.2	1.17	0.15

		1715 Ebb-Fld	0.19	0.2	0.03	0.19	6.33	1.05
9	2/23/2020		0.05	0.05	0.09	0.12	0.56	0.42
			0.16	0.09	0.55	0.13	0.29	0.69
10	2/24/2020		0.01	0.11	0.03	0.38	0.33	0.29
		Ebb-Fld	0.19	0.19	0.31	0.68	0.35	0.8
11	2/24/2020	830 Fl.Ebb	0.05	0.06	0.06	0.01	0.83	0.01
		1030 Fl.Ebb	0.08	0.06	0.15	0.05	0.53	1.2
		1230 F.Ebb	0.08	-	0.1	-	0.8	-
		1430 Ebb-Fld	0.13	0.16	0.16	0.4	0.81	0.4
		1630 Ebb-Fld	0.26	0.08	0.24	0.08	1.08	1
		1830 F.Fld	0.1	0.24	0.02	0.6	5	0.4
12	2/24/2020	1325	0.13	-	0.22	-	0.59	-
		Ebb-Fld	0.27	-	0.73	-	0.37	-
13	2/22/2020	1035	0.24	0.05	0.31	0.2	0.77	0.25

		Fld-Ebb	0.04	0.18	0.5	0.22	0.08	0.82
14	2/22/2020	1730	0.02	0.11	0	0.06	0.01	1.83
		F.Fld	0.07	0.12	0.11	0.1	0.64	1.2
15	2/27/2020	815	0.06	0.23	0.09	0.04	0.67	5.75
		F.Fld	0.27	0.21	1.21	0.04	0.22	5.25
16	2/27/2020	1430	0.17	0.14	*	0.5	*	0.28
		Ebb	0.2	0.02	*	0.01	*	2
17	2/26/2020	1435	0.01	1.38	0.01	0.03	0.01	46
		Ebb	0.14	0.09	0.14	0.22	1	0.41
18	2/26/2020	1548	0.49	0.24	0.13	0.56	3.77	0.43
			0.23	0.09	0.25	0.01	0.92	9
19	2/22/2020	1235	0.15	0.04	0.31	0.02	0.48	2
		Fld-Ebb	0.03	0.08	0.01	0.09	0.01	0.89
20	2/28/2020	1344	0.15	0.09	0.21	0.19	0.71	0.47

		Ebb	0.16	0.21	0.07	0.84	2.29	0.25
21	2/28/2020	918	0.14	0.17	0.03	0.01	4.67	0.01
		Fld-Ebb	0.14	0.15	0.01	0.27	0.01	0.56
22	2/27/2020	1000	0.18	0.11	0.01	0.29	1.64	0.38
		Fld-Ebb	0.18	0.18	0.11	0.01	0.01	0.01
23	2/26/2020	807	0.09	0.03	0.01	0.06	0.01	0.5
		Fld-Ebb	0.18	0.19	0.05	0.02	3.6	9.5
24	2/27/2020	1300	0.19	0.24	0.07	0.01	2.71	0.01
		Ebb	0.19	0.06	0.01	0.04	0.01	1.5
25	2/29/2020	810	0.11	0.09	0.13	0.26	0.85	0.35
		Ebb-Fld	0.16	0.06	0.16	0.12	1	0.5

Table 5.3.4: Range and average (parenthesis) of phytopigments at Alang during February, 2020.

Station	Date	Chlorophyll *a* (mg/m^3)		Phaeophytin (mg/m^3)		Ratio of Chl *a* to Phaeophytin	
		S	B	S	B	S	B
1	26/02/2020	4.72-2.54 (3.63)	-	0.23-0.38 (0.31)	-	11.04-12.42 (11.73)	-
2	26/02/2020	0.31-0.32 (0.32)	-	0.06-0.18 (0.12)	-	1.72-5.33 (3.53)	-
3	27/02/2020	0.15-0.16 (0.16)	-	0.20-0.21 (0.21)	-	0.75-0.76 (0.76)	-
4	27/02/2020	0.10-0.19 (0.15)	-	0.03-0.05 (0.03)	-	3.33-6.33 (4.83)	-
5	27/02/2020	0.10-0.15 (0.13)	-	0.02-0.05 (0.03)	-	2.00-9.38 (5.69)	-
6	27/02/2020	0.23-0.37 (0.30)	-	0.26-0.54 (0.40)	-	0.69-0.88 (0.78)	-
7	23/02/2020	0.04-0.21 (0.13)	0.24-0.32 (0.28)	0.38-0.49 (0.44)	0.73-0.94 (0.84)	0.08-0.55 (0.32)	0.33-0.34 (0.33)
8	23/02/2020	0.05-0.27 (0.17)	0.03-0.20 (0.14)	0.03-0.99 (0.29)	0.01-0.26 (0.15)	0.27-6.33 (2.08)	0.01-10.0 (2.09)
9	24/02/2020	0.05-0.16 (0.11)	0.05-0.09 (0.07)	0.09-0.55 (0.32)	0.12-0.13 (0.13)	0.29-0.56 (0.42)	0.42-0.69 (0.55)
10	24/02/2020	0.01-0.19 (0.06)	0.11-0.19 (0.15)	0.03-0.31 (0.17)	0.38-0.68 (0.53)	0.33-0.35 (0.34)	0.28-0.29 (0.28)
11	24/02/2020	0.05-0.26 (0.11)	0.06-0.24 (0.12)	0.06-0.24 (0.17)	0.06-0.26 (0.13)	0.83-1.08 (0.98)	0.92-1.00 (0.99)
12	24/02/2020	0.13-0.27 (0.20)	-	0.22-0.73 (0.48)	-	0.37-0.59 (0.48)	-
13	22/02/2020	0.04-0.24 (0.14)	0.05-0.18 (0.12)	0.31-0.50 (0.41)	0.20-0.22 (0.21)	0.08-0.77 (0.43)	0.25-0.82 (0.53)
14	22/02/2020	0.02-0.07 (0.05)	0.11-0.12 (0.12)	0.00-0.11 (0.06)	0.06-0.10 (0.08)	0.01-0.64 (0.32)	1.20-1.83 (1.52)

15	27/02/2020	0.06-0.27 (0.17)	0.21-0.23 (0.22)	0.09-1.21 (0.65)	0.04-0.04 (0.04)	0.22-0.67 (0.44)	5.25-5.75 (5.50)
16	27/02/2020	0.17-0.20 (0.19)	0.02-0.14 (0.22)	Below detection	0.01-0.50 (0.26)	Below detection	0.28-2.00 (1.14)
17	26/02/2020	0.01-0.14 (0.08)	0.09-1.38 (0.74)	0.01-0.14 (0.07)	0.03-0.22 (0.13)	0.01-1.00 (0.50)	0.41-46.00 (23.2)
18	26/02/2020	0.23-0.49 (0.36)	0.09-0.24 (0.17)	0.13-0.25 (0.19)	0.01-0.56 (0.29)	0.92-3.77 (2.34)	0.43-9.00 (4.71)
19	22/02/2020	0.03-0.15 (0.09)	0.04-0.08 (0.06)	0.01-0.31 (0.16)	0.02-0.09 (0.06)	0.01-0.48 (0.24)	0.89-2.00 (1.44)
20	28/02/2020	0.15-0.16 (0.16)	0.09-0.21 (0.15)	0.07-0.21 (0.14)	0.19-0.84 (0.52)	0.71-2.29 (1.50)	0.25-0.47 (0.36)
21	28/02/2020	0.14-0.14 (0.14)	0.15-0.17 (0.16)	0.01-0.03 (0.02)	0.01-0.27 (0.14)	0.01-4.67 (2.33)	0.01-0.56 (0.28)
22	27/02/2020	0.18-0.18 (0.18)	0.11-0.18 (0.15)	0.01-0.11 (0.06)	0.01-0.29 (0.15)	0.01-1.64 (0.82)	0.01-0.38 (0.19)
23	26/02/2020	0.09-0.18 (0.14)	0.03-0.19 (0.11)	0.01-0.05 (0.03)	0.02-0.06 (0.04)	0.01-3.60 (1.80)	0.50-9.50 (5.00)
24	27/02/2020	0.19-0.19 (0.19)	0.06-0.24 (0.15)	0.01-0.07 (0.04)	0.01-0.04 (0.02)	0.01-2.71 (1.36)	0.01-1.50 (0.75)
25	29/02/2020	0.11-0.16 (0.14)	0.06-0.09 (0.08)	0.13-0.16 (0.15)	0.12-0.26 (0.19)	0.85-1.00 (0.92)	0.35-0.50 (0.42)

Table 5.3.5: Distribution of phytoplankton population at Alang during February, 2020.

Station	Date	Time & Tide	Cell count (no x 10^3 Cells/ l)		Total genera	
			S	B	S	B
1	2/26/2020	Shore collection	4.00	-	10	-
2	2/26/2020		2.20	-	6	-
3	2/27/2020		1.80	-	6	-
4	2/27/2020		1.40	-	5	-
5	2/27/2020		1.60	-	5	-
6	2/27/2020		1.60	-	3	-
7	2/23/2020		1.20	0.80	2	2
8	2/23/2020	1215 F.Ebb	1.40	0.80	5	3
		1715 F.Fld	0.60	1.20	2	3
9	2/23/2020		1.40	1.00	5	5
10	2/24/2020	Ebb-Fld	1.60	1.40	6	6
11	2/24/2020	1230 F.Ebb	1.20	-	3	-
		1830 F.Fld	0.80	0.80	4	3
12	2/24/2020	1325 Ebb-Fld	1.20	-	4	-
13	2/22/2020	1035 Fld-Ebb	0.60	0.80	2	3
14	2/22/2020	1730 F.Fld	1.20	1.00	3	4
15	2/27/2020	815 F.Fld	1.20	1.00	4	4

16	2/27/2020	1430 Ebb	1.00	1.00	4	3
17	2/26/2020	1435 Ebb	1.20	1.20	3	5
18	2/26/2020	1548	1.40	0.80	3	3
19	2/22/2020	1235 Fld-Ebb	0.60	1.40	2	4
20	2/28/2020	1344 Ebb	1.20	0.80	5	3
21	2/28/2020	918 Fld-Ebb	1.20	1.40	3	4
22	2/27/2020	1000 Fld-Ebb	1.20	1.20	5	4
23	2/26/2020	807 Fld-Ebb	1.20	0.80	3	3
24	2/27/2020	1300 Ebb	1.40	1.00	3	4
25	2/29/2020	810 Ebb-Fld	1.20	1.40	4	4
Overall		Total	36.60	19.80	110	70
		Average	1.36	1.04	4	4
		Min	0.60	0.80	2	2
		Max	4.00	1.40	10	6

Table 5.3.6: Range and average (parenthesis) of phytoplankton cell count and genera in coastal waters of Alang during February, 2020.

Station	Date	Cell count (x 10^3 Cells L^{-1})		Total Genera (nos.)		Major genera	
		S	B	S	B	S	B
1	26/02/2020	4.0	-	10	-	*Rhizosolenia* *Peridinium*	-
2	26/02/2020	2.2	-	6.0	-	*Navicula* *Thalassiosira*	-
3	27/02/2020	1.8	-	6	-	*Peridinium* *Thalassinema*	-
4	27/02/2020	1.4	-	5	-	*Nitzschia* *Peridinium*	-
5	27/02/2020	1.6	-	5	-	*Peridinium* *Navicula*	-
6	27/02/2020	1.6	-	3	-	*Nitzschia* *Coscinodiscus*	-
7	23/02/2020	1.2	0.8	2	3	*Peridinium* *Thalassiothrix*	*Thalassionema* *Chaetoceros*
8	23/02/2020	0.6-1.4 (1.0)	0.8-1.2 (1.0)	2-5 (4)	3 (3)	*Nitzschia* *Cyclotella*	*Cyclotella* *Thalassiosira*
9	24/02/2020	1.4	1.0	5	5	*Thalassiothrix* *Coscinodiscus*	*Cosinodiscus* *Thalassiosira*
10	24/02/2020	1.6	1.4	6	6	*Thalassiothrix* *Thalassionema*	*Thalassionema* *Thalassiothrix*
11	24/02/2020	0.8-1.2 (1.0)	0-0.8 (0.4)	3-4 (4)	0-3 (2)	*Thalassiothrix* *Peridinium*	*Navicula* *Cyclotella*
12	24/02/2020	1.2	-	4	-	*Peridinium* *Thalassionema*	-
13	22/02/2020	0.6	0.8	2	3	*Cyclotella* *Coscinodiscus*	*Peridinium* *Thalassionema*
14	22/02/2020	1.2	1.0	3	4	*Thalassiosira* *Cyclotella*	*Peridinium* *Thalassionema*
15	27/02/2020	1.2	1.0	4	4	*Thalassiosira* *Peridinium*	*Coscinodiscus* *Peridinium*
16	27/02/2020	1.0	1.0	4	3	*Skeletonema* *Peridinium*	*Thalassiothrix* *Navicula*
17	26/02/2020	1.2	1.2	3	5	*Cyclotella* *Thalassiosira*	*Cyclotella* *Coscinodiscus*
18	26/02/2020	1.4	0.8	3	3	*Coscinodiscus* *Phormidium*	*Thalassiothrix* *Cyclotella*

19	22/02/2020	0.6	1.4	2	4	*Coscinodiscus Thalassiosira*	*Coscinodiscus Peridinium*
20	28/02/2020	1.2	1.4	3	4	*Coscinodiscus Thalassiosira*	*Navicula Peridinium*
21	28/02/2020	1.2	1.4	3	4	*Thalassiosria Thalassiothrix*	*Thalassiothrix Thalassiosria*
22	27/02/2020	1.2	1.2	5	4	*Cyclotella Navicula*	*Navicula Thalassiosira*
23	26/02/2020	1.2	0.8	3	3	*Navicula Peridinium*	*Thalassiothrix Thalassiosira*
24	27/02/2020	1.4	1.0	3	3	*Navicula Peridinium*	*Nitzschia Thalassiosira*
25	29/02/2020	1.2	1.4	4	4	*Thalassiosira Navicula*	*Peridinium Thalassiothrix*

Table 5.3.7: Percentage composition of phytoplankton population at Alang during February, 2020.

Stations	1	2	3	4	5	6	7	8	9	10	11	12	13
Genera name													
Diatom													
Amphiprora	5.00	18.18	11.11										
Chaetoceros							20.00						
Coscinodiscus	10.00				12.50	25.00			25.00		7.14	16.67	14.29
Cyclotella						12.50		33.3	8.33	13.04	14.29		28.57
Cymbella	10.00		11.11										
Gyrosigma	5.00				12.50								
Navicula	5.00	36.36			25.00				16.67	8.70	28.57	16.67	
Nitzschia	10.00			42.86		62.50				4.35	7.14		
Pleurosigma	10.00	9.09											
Rhizosolenia	20.00		11.11	14.29									
Skeletonema													
Streptotheca													
Surirella		9.09			25.00								
Thalassionema			22.22	14.29			20.00			26.09		33.33	14.29
Thalassiosira	10.00	18.18						50.0	16.67				14.29
Thalassiothrix		9.09		14.29			30.00		16.67	21.74	21.43		
Dinoflagellate													
Alexandrium										4.35			
Cochlodinium			11.11										
Peridinium	15.00		33.33	14.29	25.00		30.00	16.7	16.67	13.04	21.43	33.33	28.57
Prorocentrum										8.70			
Cyanobacteria													
Phormidium													
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 5.3.7 (contd. 2):

Stations / Genera name	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Total Avg.**
Diatom													
Amphiprora													1.37
Chaetoceros													0.80
Coscinodiscus	9.09	27.2			27.27	50.00		7.69		10.00			9.68
Cyclotella	18.18	9.09	13.33	41.67	9.09		10.00	15.38	16.67		8.33	15.38	10.69
Cymbella													0.84
Gyrosigma									8.33				1.03
Navicula	9.09	9.09	13.33		9.09		40.00		25.00	30.00	25.00	23.08	12.83
Nitzschia									8.33		16.67	7.69	6.38
Pleurosigma	18.18								8.33		16.67		2.49
Rhizosolenia													1.82
Skeletonema			33.33			10.00					8.33		2.07
Streptotheca				8.33									0.33
Surirella					9.09				8.33				2.06
Thalassionema									8.33				5.54
Thalassiosira	36.36	18.1		25.00		20.00		38.46	16.67	20.00	8.33	15.38	12.30
Thalassiothrix	9.09	9.09	26.67		18.18		20.00	38.46		20.00		15.38	10.80
Dinoflagellate													
Alexandrium													0.17
Cochlodinium													0.44
Peridinium		27.2	13.33	16.67		20.00	20.00			20.00	16.67	23.08	16.17
Prorocentrum				8.33									0.68
Cyanobacteria													
Phormidium					27.27		10.00						1.49
Total	100.0	100.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5.3.8: Distribution of zooplankton at Alang during February, 2020.

Station (Date)	Time(h)/Tide	Biomass (ml/100m^3)	Population (nox10^3/100m^3)	Total Groups (no)	Major group (%)
7(1) (23/02/2020)	1430 Eb-Fl	6.2	34.4	10	Copepods (77.8), Chaetognaths (9.5), Decapod larvae (8.6), Fish Eggs (1.4), Fish Larvae (1.2), Polychaetes (0.6), Mysids (0.4), SIphonophores (0.3), Lamellibranchs (0.1), Amphipods (0.1), Others (0.1).
7(2) (23/02/2020)	1440 Eb-Fl	5.0	39.3	10	Copepods (77.2), Chaetognaths (11.3), Decapod larvae (6.6), Fish Eggs (1.9), Fish Larvae (1.4), Mysids (0.4), Polychaetes (0.4), SIphonophores (0.3), Lamellibranchs (0.2), Amphipods (0.1), Others (0.1).
8 (1) (23/02/2020)	0915 Fl-Eb	3.4	53.0	9	Copepods (67.4), Decapod larvae (25.9), Fish Larvae (2.8), Chaetognaths (2.3), SIphonophores (1.1), Polychaetes (0.3), Lamellibranchs (0.3), Others (0.1).
8 (2) (23/02/2020)	1215 F.Eb	4.0	60.6	10	Copepods (68.2), Decapod larvae (25.0), Ctenophores (2.8), Fish Larvae (1.9), SIphonophores (1.5), Lamellibranchs (0.3), Chaetognaths (0.30), Fish Eggs (0.1), Others (0.1).
8 (3) (23/02/2020)	1515 Eb-Fl	8.2	139.3	13	Copepods (94.3), Decapod larvae (2.0), Chaetognaths (1.7), Fish Larvae (0.6), Mysids (0.6),

					SIphonophores (0.3), Fish Eggs (0.2), Lamellibranchs (0.1), Polychaetes (0.1), Others (0.1).
8 (4) (23/02/2020)	1715 F.Fl	13.7	134.8	16	Copepods (93.40), Chaetognaths (3.60), Fish Larvae (1.3), SIphonophores (0.7), Decapod larvae (0.60), Lamellibranchs (0.30), Others (0.1).
9 (1) (23/02/2020)	0830 Eb-Fl	1.4	18.2	11	Copepods (71.1), Decapod larvae (23.9), Fish Larvae (2.6), Chaetognaths (1.0), Polychaetes (0.5), Amphipods (0.3), SIphonophores (0.3), Fish Eggs (0.1), Medusae (0.1), Mysids (0.1), Lamellibranchs (0.1) Others (0.1).
9 (2) (23/02/2020)	0845 Eb-Fl	5.0	13.7	11	Copepods (70.6), Decapod larvae (22.6), Fish Larvae (4.1), Polychaetes (0.8), Chaetognaths (0.7), SIphonophores (0.4), Fish Eggs (0.3), Lamellibranchs (0.2), Medusae (0.2), Mysids (0.1), AAmphipods (0.1), Others (0.1).
10(1) (24/02/2020)	0203 Eb-Fl	0.8	5.5	12	Copepods (88.4), Chaetognaths (8.0), SIphonophores (1.1), Polychaetes (0.7), Lamellibranchs (0.6), Decapod larvae (0.5), Fish Larvae (0.2), Amphipods (0.1), Cumaceans (0.1), Mysids (0.1), Isopods (0.1) Others (0.1).

10(2) (24/02/2020)	0203 Eb-Fl	0.6	4.1	13	Copepods (90.0), Chaetognaths (6.40), SIphonophores (0.9), Lamellibranchs (0.7), Decapod larvae (0.6), Polychaetes (0.6), Fish Larvae (0.30, Mysids (0.2), cumaceans (0.1), Gastropods (0.1), Amphipods (0.1) others (0.1).
11(1) (24/02/2020)	0830 Fl-Eb	2.0	1.2	9	Copepods (91.1), Fish Larvae (3.5), Polychaetes (2.2), Decapod larvae (1.2), Chaetognaths (0.8), SIphonophores (0.6), Lamellibranchs (0.4), Gastropods (0.1), Isopods (0.1), others (0.1).
11(2) (24/02/2020)	1830 F.Fl	4.2	2.0	8	Copepods (94.2), Fish Larvae (1.9), Polychaetes (1.8), SIphonophores (0.7), Chaetognaths (0.5), Decapod larvae (0.5), Gastropods (0.2), Lamellibranchs (0.2), others (0.1).
13(1) (22/02/2020)	1035 Fl-Eb	0.6	6.3	9	Copepods (82.9), Decapod larvae (10.3), SIphonophores (3.4), Chaetognaths (2.9), Fish Larvae (0.3), Lamellibranchs (0.1), others (0.1).
13(2) (22/02/2020)	1345 Fl-Eb	0.8	8.3	9	Copepods (81.9), Decapod larvae (11.4), SIphonophores (3.8), Chaetognaths (2.1), Fish Larvae (0.4), Lamellibranchs (0.1), Fish Eggs (0.1), Polychaetes (0.1), Amphipods (0.1), others (0.1).

14(1) (22/02/2020)	1730 F.Fl	1.4	5.5	12	Copepods (93.1), Decapod larvae (3.0), Chaetognaths (2.4), Fish Larvae (0.8), SIphonophores (0.3), Lamellibranchs (0.3), ostracods (0.1), others (0.1).
14(2) (22/02/2020)	1750 F.Fl	1.1	3.9	13	Copepods (91.7), Decapod larvae (3.3), Chaetognaths (2.9), Fish Larvae (1.1), SIphonophores (0.3), Lamellibranchs (0.3), Fish Eggs (0.1), Polychaetes (0.1), ostracods (0.1), Amphipods (0.1), Stomatopods (0.1), others (0.1).
15(1) (27/02/2020)	0815 F.Fl	1.8	26.9	11	Copepods (77.6), Decapod larvae (21.3), Chaetognaths (0.7), Fish Larvae (0.3), SIphonophores (0.1), Lamellibranchs (0.1), others (0.1).
15(2) (27/02/2020)	0825 F.Fl	1.5	26.6	10	Copepods (78.7), Decapod larvae (20.1), Chaetognaths (0.8), Fish Larvae (0.3), SIphonophores (0.1), others (0.1).
16(1) (27/02/2020)	1430 Eb	1.5	6.7	10	Copepods (85.3), Decapod larvae (9.9), Chaetognaths (1.8), SIphonophores (1.5), Fish Larvae (1.1), Lamellibranchs (0.2), ostracods (0.1), Fish Eggs (0.1), others (0.1).
16(2) (27/02/2020)	1445 Eb	1.5	7.5	11	Copepods (73.6), Chaetognaths (16.6), Decapod larvae (7.2), Fish Larvae (1.2), SIphonophores (0.9), Lamellibranchs (0.2), Fish Eggs (0.1), Amphipods (0.1),

					Polychaetes (0.1), Ostracods (0.1), others (0.1).
17(1) (26/02/2020)	1435 Eb	2.3	38.2	15	Copepods (84.9), Decapod larvae (11.9), Chaetognaths (2.0), SIphonophores (0.5), Fish Larvae (0.3), Lamellibranchs (0.2), others (0.1).
17(2) (26/02/2020)	1445 Eb	2.1	39.6	15	Copepods (86.8), Decapod larvae (10.4), Chaetognaths (1.8), Iphonophores (0.4), Lamellibranchs (0.3), Fish Larvae (0.2), others (0.1).
18(1) (26/02/2020)	1548 Eb	2.5	13.0	14	Copepods (94.7), Chaetognaths (1.8), SIphonophores (1.1), Polychaetes (0.9), Decapod larvae (0.7), Fish Larvae (0.3), Lamellibranchs (0.2), medusae (0.1), cumaceans (0.1), Amphipods (0.1), Fish Eggs (0.1), others (0.1).
18(2) (26/02/2020)	1555 Eb	1.6	9.5	14	Copepods (95.6), ctenophores (1.3), Polychaetes (1.3), SIphonophores (0.8), Decapod larvae (0.4), Fish Larvae (0.3), Lamellibranchs (0.1), Fish Eggs (0.1), others (0.1).
19(1) (22/02/2020)	1235 Fl-Eb	1.1	5.1	10	Copepods (93.8), Decapod larvae (2.6), Chaetognaths (1.8), Amphipods (0.7), SIphonophores (0.5), Polychaetes (0.2), Gastropods (0.2), Fish Larvae (0.1), Fish Eggs (0.1), Marine Insects (0.1),

					others (0.1).
19(2) (22/02/2020)	1245 Fl-Eb	1.2	5.2	9	Copepods (93.5), Decapod larvae (3.1), Chaetognaths (2.2), SIphonophores (0.4), Amphipods (0.3), Lamellibranchs (0.2), Fish Larvae (0.2), Fish Eggs (0.1), Polychaetes (0.1), others (0.1).
20(1) (28/02/2020)	1344 Eb	3.5	35.0	13	Copepods (91.2), Chaetognaths (3.9), Decapod larvae (2.0), Fish Larvae (1.4), SIphonophores (1.3), Lamellibranchs (0.2), others (0.1).
20(2) (28/02/2020)	1355 Eb	2.2	24.5	14	Copepods (91.5), Chaetognaths (3.9), Decapod larvae (1.8), Fish Larvae (1.3), SIphonophores (1.2), Lamellibranchs (0.2), Amphipods (0.1), others (0.1).
21(1) (28/02/2020)	0918 Fl-Eb	2.2	5.1	12	Copepods (89.3), Decapod larvae (6.8), Chaetognaths (1.9), SIphonophores (0.8), Lamellibranchs (0.7), Fish Larvae (0.2), Amphipods (0.1), Fish Eggs (0.1), medusae (0.1), others (0.1).
21(2) (28/02/2020)	0925 Fl-Eb	2.2	0.6	13	Copepods (86.6), Decapod larvae (7.9), Chaetognaths (2.4), SIphonophores(1.1), Lamellibranchs(1.1), Fish Larvae (0.2), Amphipods (0.2), Fish Eggs (0.2), medusae (0.1), Gastropods (0.1), others (0.1).

22(1) (27/02/2020)	1000 Fl-Eb	2.3	21.0	11	Copepods (72.2), Decapod larvae (21.9), Chaetognaths (2.1), Fish Larvae (1.8), SIphonophores (1.7), Amphipods (0.1), Lamellibranchs (0.1), others (0.1).
22(2) (27/02/2020)	1010 Fl-Eb	1.3	7.6	13	Copepods (72.1) Decapod larvae (21.2) Chaetognaths (2.1) SIphonophores (2.1) Fish Larvae (2.1) Amphipods (0.1) Lamellibranchs (0.1) Fish Eggs (0.1) others (0.1).
23(1) (26/02/2020)	0807 Fl-Eb	0.3	9.9	11	Copepods (92.6), Chaetognaths (3.1), Decapod larvae (2.4), SIphonophores (0.8), Fish Larvae (0.7), Lamellibranchs (0.3), others (0.1).
23(2) (26/02/2020)	0815 Fl-Eb	0.5	10.2	12	Copepods (92.0), Chaetognaths (3.2), Decapod larvae (2.5), SIphonophores (1.0), Fish Larvae (0.8), Lamellibranchs (0.2), others (0.1).
24(1) (27/02/2020)	1300 Eb	0.7	10.0	12	Copepods (73.3), Decapod larvae (23.0), Chaetognaths (1.4), Fish Larvae (1.0), SIphonophores (0.6), Amphipods (0.4), Lamellibranchs (0.1), Fish Eggs (0.1), others (0.1).
24(2) (27/02/2020)	1310 Eb	1.2	15.7	13	Copepods (77.1), Decapod larvae (19.4), Chaetognaths (1.3), Fish Larvae (1.0), SIphonophores (0.7), Amphipods (0.1), Lamellibranchs (0.1), Polychaetes (0.1), Fish Eggs (0.1), ostracods (0.1),

					others (0.1).
25(1) (29/02/2020)	0810 Eb-Fl	0.2	2.2	8	Copepods (80.1), Decapod larvae (16.5), Chaetognaths (1.9), Fish Larvae (0.9), Fish Eggs (0.3), Amphipods (0.1), Lamellibranchs (0.1), SIphonophores (0.1), others (0.1).
25(2) (29/02/2020)	0818 Eb-Fl	0.1	1.1	9	Copepods (95.9), Chaetognaths (2.0), Fish Larvae (0.8), SIphonophores (0.3), Fish Eggs (0.3), Amphipods (0.3), Lamellibranchs (0.2), cumaceans (0.1), Mysids (0.1), others (0.1).

Table 5.3.9: Range and average (parenthesis) of zooplankton at different stations of Alang during February 2020.

Station (Date)	Biomass (ml/100m3)	Population (nox103/100m3)	Total Groups (no)	Major group (%)
7 (23/02/2020)	5.0-6.2 (5.6)	34.4-39.3 (36.8)	10-10 (10)	Copepods (77.5), Chaetognaths (10.5), Decapod larvae (7.6), Fish Eggs (1.7), Fish Larvae (1.3), Polychaetes (0.5), Mysids (0.4), SIphonophores (0.3), Lamellibranchs(0.2), Amphipods (0.1), others (0.1).
8 (23/02/2020)	3.4-13.7 (7.3)	53.0-139.4 (96.9)	9-16 (12)	Copepods (86.2), Decapod larvae (8.3), Chaetognaths (2.2), Fish Larvae (1.3), SIphonophores (0.7), ctenophores (0.4), Lamellibranchs (0.2), Mysids (0.2), Fish Eggs (0.1), Polychaetes (0.1), others (0.1).
9 (23/02/2020)	1.4-5.0 (3.2)	13.7-18.2 (16.0)	11-11 (11)	Copepods (70.9), Decapod larvae (23.3), Fish Larvae (3.2), Chaetognaths (0.9), Polychaetes (0.6), SIphonophores (0.3), Amphipods (0.2), Fish Eggs (0.2), Lamellibranchs (0.1), medusae (0.1), Mysids (0.1), others (0.1).
10 (24/02/2020)	0.6-0.8 (0.7)	4.1-5.5 (4.8)	12-13 (13)	Copepods (89.1), Chaetognaths (7.3), SIphonophores (1.0), Lamellibranchs (0.7), Polychaetes (0.6), Decapod larvae (0.6), Fish Larvae (0.2), Mysids(0.1), Amphipods (0.1),

				cumaceans (0.1), Gastropods (0.1), Isopods (0.1), others (0.1).
11 (24/02/2020)	2.0-4.2 (3.1)	1.2-2.1 (1.6)	9-8 (9)	Copepods (93.0), Fish Larvae (2.5), Polychaetes (2.0), Decapod larvae (0.7), SIphonophores (0.7), Chaetognaths (0.6), Lamellibranchs (0.3), Gastropods (0.2), others (0.1).
13 (22/02/2020)	0.6-0.8 (0.7)	6.3-8.3 (7.3)	9-9 (9)	Copepods (82.3), Decapod larvae (10.9), SIphonophores (3.6), Chaetognaths (2.5), Fish Larvae (0.3), Lamellibranchs (0.1), Fish Eggs (0.1), Polychaetes (0.1), Amphipods (0.1), others (0.1).
14 (22/02/2020)	1.1-1.4 (1.3)	3.9-5.5 (4.7)	12-13 (13)	Copepods (92.5), Decapod larvae (3.1), Chaetognaths (2.6), Fish Larvae (0.9), SIphonophores (0.3), Lamellibranchs (0.3), Fish Eggs (0.1), ostracods (0.1), Polychaetes (0.1), others (0.1).
15 (27/02/2020)	1.5-1.8 (1.7)	26.6-26.9 (26.7)	10-11 (11)	Copepods (78.1), Decapod larvae (20.7), Chaetognaths (0.7), Fish Larvae (0.3), SIphonophores (0.1), Lamellibranchs (0.1), others (0.1).
16 (27/02/2020)	1.5-1.8 (1.7)	6.7-7.5 (7.1)	10-11 (11)	Copepods (79.1), Chaetognaths (9.6), Decapod larvae (8.5), SIphonophores (1.2), Fish Larvae (1.2), Lamellibranchs (0.2), Fish Eggs (0.1), ostracods (0.1), Amphipods (0.1),

				others (0.1).
17(1) (26/02/2020)	2.1-2.3 (2.2)	38.2-39.6 (38.9)	15-15 (15)	Copepods (85.9), Decapod larvae (5.8), Lucifer sp. (5.3), Chaetognaths (1.9), SIphonophores (0.5), Fish Larvae (0.3), Lamellibranchs (0.2), others (0.1).
18(1) (26/02/2020)	1.6-2.5 (2.1)	9.5-13.0 (11.2)	14-14 (14)	Copepods (95.1), Polychaetes (1.1), Chaetognaths (1.0), SIphonophores (1.0), Decapod larvae (0.6), ctenophores (0.5), Fish Larvae (0.3), Lamellibranchs (0.2), Fish Eggs (0.1) others (0.1).
19 (22/02/2020)	1.1-1.2 (1.2)	5.1-5.2 (5.2)	9-10 (10)	Copepods (93.6), Decapod larvae (2.9), Chaetognaths (2.0), Amphipods (0.5), SIphonophores (0.4), Fish Larvae (0.2), Fish Eggs (0.1), Polychaetes (0.1), Lamellibranchs (0.1), Gastropods (0.1), others (0.1).
20 (28/02/2020)	2.2-3.5 (2.9)	24.5-35.0 (29.7)	13-14 (14)	Copepods (91.3), Chaetognaths (3.9), Decapod larvae (1.9), Fish Larvae (1.3), SIphonophores (1.3), Lamellibranchs (0.2), others (0.1).

21 (28/02/2020)	0.6-2.2 (1.4)	5.1-6.4 (5.8)	12-13 (12)	Copepods (87.8), Decapod larvae (7.4), Chaetognaths (2.2), SIphonophores (1.0), Lamellibranchs (0.9), Fish Larvae (0.2), Amphipods (0.1), Fish Eggs (0.1), medusae (0.1), Gastropods(0.1), others (0.1).
22 (27/02/2020)	1.3-2.3 (1.8)	7.6-21.0 (14.3)	11-13 (12)	Copepods (72.2), Decapod larvae (21.7), Chaetognaths (2.1), Fish Larvae (1.9), SIphonophores (1.8), Amphipods (0.1), Lamellibranchs (0.1), others (0.1).
23 (26/02/2020)	0.3-0.5 (0.4)	9.9-10.2 (10.1)	11-12 (12)	Copepods (92.3), Chaetognaths (3.2), Decapod larvae (2.5), SIphonophores (0.9), Fish Larvae (0.8), Lamellibranchs (0.3), others (0.1).
24 (27/02/2020)	0.7-1.2 (1.0)	10.0-15.7 (12.9)	12-13 (13)	Copepods (75.6), Decapod larvae (20.8), Chaetognaths (1.3), Fish Larvae (1.0), SIphonophores (0.7), Amphipods (0.2), Lamellibranchs (0.1), Fish Eggs (0.1), others (0.1).
25 (29/02/2020)	0.1-0.2 (0.2)	1.1-2.2 (1.7)	8-9 (9)	Copepods (85.2), Decapod larvae (11.2), Chaetognaths (1.9), Fish Larvae (0.8), Fish Eggs (0.3), Amphipods (0.2), Lamellibranchs (0.2), SIphonophores (0.1), others (0.1).

Table 5.3.10: Percentage composition of zooplankton at Alang during February, 2020.

Faunal groups	7	8	9	10	11	13	14	15	16	17	18	19	20	21	22	23	24	25	%
Foraminiferans	-	<0.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1
SIphonophores	0.3	0.7	0.3	1.0	0.7	3.6	0.3	0.1	1.2	0.5	1.0	0.4	1.3	1.0	1.8	0.9	0.7	0.1	0.8
Medusae	-	<0.	0.1	-	-	-	-	-	-	<0.	<0.	-	<0.	0.1	-	-	-	-	<0.1
Ctenophores	-	0.4	-	-	-	-	-	-	-	<0.	0.5	-	<0.	-	-	-	-	-	0.1
Chaetognaths	10.	2.2	0.9	7.3	0.6	2.5	2.6	0.7	9.6	1.9	1.0	2.0	3.9	2.2	2.1	3.2	1.3	1.9	3.2
Polychaetes	0.5	0.1	0.6	0.6	2.0	0.1	<0.	<0.	<0.	<0.	1.1	0.1	<0.	<0.	<0.	<0.	<0.	-	0.2
Cladocerans	-	-	-	-	-	-	<0.	-	-	-	-	-	-	-	-	-	-	-	<0.1
Ostracods	-	0.0	-	-	-	-	0.1	-	0.1	-	-	-	-	-	<0.	<0.	<0.	-	<0.1
Copepods	77.	86.	70.	89.	93.	82.	92.	78.	79.	85.	95.	93.	91.	87.	72.	92.	75.	85.	83.8
Cumaceans	-	<0.	-	0.1	-	-	-	-	-	<0.	<0.	-	-	-	-	-	-	<0.	<0.1
Amphipods	0.1	<0.	0.2	0.1	-	0.1	<0.	<0.	0.1	<0.	<0.	0.5	<0.	0.1	0.1	<0.	0.2	0.2	0.1
Mysids	0.4	0.2	0.1	0.1	-	-	-	-	-	-	-	-	-	-	<0.	<0.	<0.	<0.	0.1
Lucifer sp.	-	-	-	-	-	-	<0.	-	-	5.3	-	-	-	-	-	-	<0.	-	0.6
Decapod larvae	7.6	8.3	23.	0.6	0.7	10.	3.1	20.	8.5	5.8	0.6	2.9	1.9	7.4	21.	2.5	20.	11.	9.5
Stomatopods	-	<0.	-	-	-	-	<0.	-	-	-	-	-	-	-	-	-	-	-	<0.1
Gastropods	-	<0.	-	0.1	0.2	-	-	<0.	-	<0.	<0.	0.1	<0.	0.1	<0.	<0.	<0.	-	<0.1
Lamellibranchs	0.2	0.2	0.1	0.7	0.3	0.1	0.3	0.1	0.2	0.2	0.2	0.1	0.2	0.9	0.1	0.3	0.1	0.2	0.2
Doliolids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.	-	-	-	<0.1
Fish Eggs	1.7	0.1	0.2	<0.	-	0.1	0.1	-	0.1	<0.	0.1	0.1	-	0.1	<0.	<0.	0.1	0.3	0.2
Fish Larvae	1.3	1.3	3.2	0.2	2.5	0.3	0.9	0.3	1.2	0.3	0.3	0.2	1.3	0.2	1.9	0.8	1.0	0.8	1.1
Isopods	-	-	-	0.1	<0.	-	-	<0.	<0.	<0.	<0.	-	<0.	<0.	-	-	<0.	-	<0.1
Marine Insects	-	<0.	-	-	-	-	-	<0.	-	-	<0.	<0.	<0.	<0.	-	-	<0.	-	<0.1

Table 5.3.11: Occurance (+ indicate Present and - indicate Absent) of zooplankton at Alang during February, 2020.

Faunal groups	7	8	9	10	11	13	14	15	16	17	18	19	20	21	22	23	24	25
Foraminiferans	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SIphonophores	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Medusae	-	+	+	-	-	-	-	-	-	+	+	-	+	+	-	-	-	-
Ctenophores	-	+	-	-	-	-	-	-	-	+	+	-	+	-	-	-	-	-
Chaetognaths	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Polychaetes	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
Cladocerans	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Ostracods	-	+	-	-	-	-	+	-	+	-	-	-	-	-	+	+	+	-
Copepods	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cumaceans	-	+	-	+	-	-	-	-	-	+	+	-	-	-	-	-	-	+
Amphipods	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
Mysids	+	+	+	+	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Lucifer sp.	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	+	-
Decapod larvae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stomatopods	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Gastropods	-	+	-	+	+	-	-	+	-	+	+	+	+	+	+	+	+	-
Lamellibranchs	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Doliolids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Fish Eggs	+	+	+	+	-	+	+	-	+	+	+	+	-	+	+	+	+	+
Fish Larvae	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Isopods	-	-	-	+	+	-	-	+	+	+	+	-	+	+	-	-	+	-
Marine Insects	-	+	-	-	-	-	-	+	-	-	+	+	+	+	-	-	+	-

Table 5.3.12: Range and average of intertidal macrobenthos at different water level at Alang during February, 2020.

Transect	Date	Biomass (wet wt.; g/m^2)	Population (no./m^2)	Faunal Group (no.)	Major Group
T-I HW	26/02/2020	0.0-0.1 (0.03)	0- 125 (31)	0-1 (1)	Polychaetes
T-I MW	26/02/2020	6.1-20.3 (10.7)	2475-5275 (3506)	2-3 (2)	Polychaetes, Brachyurans
T-I LW	26/02/2020	1.8-10.8 (4.8)	725-1650 (1319)	2-4 (3)	Polychaetes
T-II HW	27/02/2020	0-0.3 (0.01)	0-25 (6)	0-1 (1)	Polychaetes
T-II MW	27/02/2020	0.7-2.1 (2.0)	175-775 (500)	2-3 (2)	Polychaetes, Brachyurans
T-II LW	27/02/2020	0.02-0.8 (0.3)	25-275 (131)	1*	Polychaetes
T-III HW	27/02/2020	0.0-0.1 (0.03)	0-100 (25)	0-2 (1)	Polychaetes, Isopods
T-III MW	27/02/2020	0.0-0.2 (0.1)	0-150 (56)	0-1 (1)	Polychaetes
T-III LW	27/02/2020	0.9-7.6 (3.1)	525-2975 (1388)	1-2 (2)	Polychaetes
T-IV HW	27/02/2020	NIL			
T-IV MW	27/02/2020	0.1-0.3 (3.4)	50-250 (119)	1-3 (2)	Brachyurans, Polychaetes, Isopods
T-IV LW	27/02/2020	3.6-7.3 (5.3)	450-825 (619)	2-3 (3)	Polychaetes, Pelecypods

Table 5.3.13: Range and average of intertidal macrobenthos at different transects at Alang during February, 2020.

Transect	**Date**	**Biomass** (wet wt.; g/m^2)	**Population** (no/m^2)	**Faunal Group** (no)	**Major Groups**
T-I	26/02/2020	0.0-20.3 (5.2)	0-5275 (1619)	0-4 (2)	Polychaetes, Brachyurans
T-II	27/02/2020	0.0-2.1 (0.8)	0-775 (212)	0-3 (1)	Polychaetes, Brachyurans
T-III	27/02/2020	0.0-7.6 (1.1)	0-2975 (490)	0-2 (1)	Polychaetes, Isopods
T-IV	27/02/2020	0.0-7.3 (2.9)	0-825 (246)	0-3 (2)	Polychaetes, Brachyurans, Isopods
OVERALL AVERAGE		0.0-20.3 (2.5)	0-5275 (642)	0-4 (2)	Polychaetes, Brachyurans

Table 5.3.14: Composition (%) of intertidal macrobenthos at Alang during February 2020.

Faunal Groups	**T-I**			**T-II**			**T-III**			**T-IV**			**Av**
	HW	**MW**	**LW**	**HW**	**MW**	**LW**	**HW**	**MW**	**LW**	**HW**	**MW**	**LW**	
Phylum Mollusca													
Pelecypods	0.0	0.0	6.2	0.0	0.0	0.0	0.0	0.0	0.5		0.0	24.2	**3.1**
Phylum Annelida													
Polychaetes	100.0	87.4	92.8	100.0	85.0	100.0	75.0	100.0	99.0		31.6	66.6	**88.1**
Phylum Arthropoda													
Amphipods	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	N	0.0	2.1	**0.3**
Brachyurans	0.0	12.4	0.5	0.0	13.7	0.0	0.0	0.0	0.0	I	36.8	0.0	**7.2**
Penaeids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	L	0.0	6.1	**0.5**
Isopods	0.0	0.2	0.0	0.0	0.0	0.0	25.0	0.0	0.0		31.6	0.0	**0.7**
Phylum Chordata													
Fish larva	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5		0.0	1.0	**0.2**

Table 5.3.15: Range and average of Subtidal macrobenthos at Alang during February 2020.

Station	Date	Biomass (wet wt ;g/m^2)	Population (no./m^2)	Faunal Group (no.)	Major Group
1	26/02/2020	0.03-13.6 (6.9)	75-4200 (2038)	1-4 (3)	Polychaetes, Isopods
2	26/02/2020	0.6-2.6 (1.2)	300-550 (394)	1-4 (3)	Polychaetes
3	27/02/2020	0.0-3.8 (2.0)	0-1025 (444)	0-2 (1)	Polychaetes, Brachyurans
4	27/02/2020	2.0-3.2 (2.5)	675-2275 (1456)	1-2 (1)	Polychaetes
5	27/02/2020	0.0-0.14 (0.04)	0-50 (13)	0-1 (1)	Polychaetes
6	27/02/2020	0.0-0.2 (0.1)	0-100 (38)	0-3 (1)	Polychaetes, Isopods, Brachyurans
7	23/02/2020	NIL			
8	23/02/2020	NIL			
9	23/02/2020	0.0-0.4 (0.2)	0-25 (13)	0-1 (1)	Polychaetes
10	24/02/2020	NO COLLECTION DUE TO HIGH WATER CURRENTS			
11	24/02/2020	0.0-0.2 (0.1)	0-50 (12)	0-2 (1)	Polychaetes, Brachyurans
12	24/02/2020	NIL			

13	22/02/2020	NIL			
14	22/02/2020	0.0-0.5 (0.1)	0-25 (19)	0-1 (1)	Pelecypods
15	27/02/2020	0.0-0.02 (0.01)	0-25 (8)	0-1 (1)	Polychaetes
16	27/02/2020	NIL			
17	26/02/2020	NIL			
18	26/02/2020	NIL			
19	22/02/2020	0.0-0.01 (0.003)	0-25 (8)	0-1 (1)	Polychaetes
20	28/02/2020	0.0-1.2 (0.5)	0-75 (31)	0-3 (1)	Polychaetes, Pelecypods
21	28/02/2020	0.0-0.2 (0.1)	0-50 (25)	0-1 (1)	Polychaetes
22	27/02/2020	0.0-0.5 (0.2)	0-25 (8)	0-1 (1)	Pelecypods
23	26/02/2020	0.0-0.2 (0.1)	0-50 (19)	0-1 (1)	Polychaetes
24	27/02/2020	0.0-4.8 (1.4)	0-2825 (713)	0-5 (2)	Polychaetes
25	29/02/2020	0.6-2.8 (1.5)	425-675 (544)	1-3 (2)	Polychaetes
OVERALL AVERAGE		0.0 -13.6 (0.7)	0-4200 (241)	0-5 (1)	Polychaetes

Table 5.3.16: Composition (%) of Subtidal macrobenthos at Alang during February 2020.

Faunal Groups	Stations																									Av
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Phylum Sipuncula																										
Sipunculids	0.3	0.0	0.0	0.0	0.0	0.0			0.0	-	0.0			0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**
Phylum Mollusca																										
Pelecypods	0.3	7.9	0.0	0.0	0.0	0.0			0.0	-	0.0			100	0.0				0.0	20.0	0.0	0.0	0.0	1.8	1.1	**1.5**
Phylum Annelida																										
Polychaetes	89.6	82.6	84.5	99.6	100	67.6			100	-	50.0			0	100				100	60.0	100	100	100	79.8	97.8	**90.2**
Phylum Arthropoda																										
Amphipods	0.0	0.0	0.0	0.4	0.0	0.0	N	N	0.0	-	0.0	N	N	0.0	0.0	N	N	N	0.0	0.0	0.0	0.0	0.0	4.4	1.1	**0.7**
Anomurans	0.3	0.0	0.0	0.0	0.0	0.0			0.0		0.0			0.0	0.0				0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**
Brachyurans	0.3	6.3	15.5	0.0	0.0	16.2			0.0		50.0			0.0	0.0				0.0	0.0	0.0	0.0	0.0	4.4	0.0	**2.5**
Isopods	9.2	3.2	0.0	0.0	0.0	16.2			0.0		0.0			0.0	0.0				0.0	0.0	0.0	0.0	0.0	9.6	0.0	**4.8**
Phylum Chordata																										
Fish larva	0.0	0.0	0.0	0.0	0.0	0.0			0.0	N	0.0			0.0	0.0				0.0	20.0	0.0	0.0	0.0	0.0	0.0	**0.1**

N: Nil

Table 5.4.1: Concentration of selected metals (µg/g; dry wt basis) in the tissues of selected species collected from Alang area during February 2020.

Fish - Species	Co	Cr	Cu	Fe	Mn	Ni	Zn	As	Cd	Pb
JohniusMacropterus	0.29	0.58	2.86	288.7	3.23	0.32	14.2	11.5	0.09	ND
Liza Parsia	0.09	0.40	7.90	160.2	1.89	0.37	35.9	1.2	0.06	ND
Arius Sona	0.28	0.50	3.77	477.3	5.26	0.47	36.0	1.8	0.09	ND
JohnieopsMacrorhynus	0.39	1.62	3.06	439.9	2.84	0.69	15.4	21.7	0.06	ND
Anchovy	0.28	0.96	4.62	484.5	13.38	0.64	91.8	2.1	0.41	ND
Skippers	0.19	0.43	1.96	138.7	3.84	0.36	33.5	4.0	0.15	0.07
Thryssa	0.06	0.62	1.50	100.0	4.60	0.29	29.0	39.5	0.11	ND
Johnieops	0.14	1.22	1.87	130.6	1.78	0.55	13.8	4.3	0.09	ND
Skippers	0.10	0.37	2.52	201.3	3.71	0.37	30.7	4.1	0.14	ND
Gerres	0.08	0.73	2.33	297.4	2.60	0.41	24.3	4.7	0.10	0.10

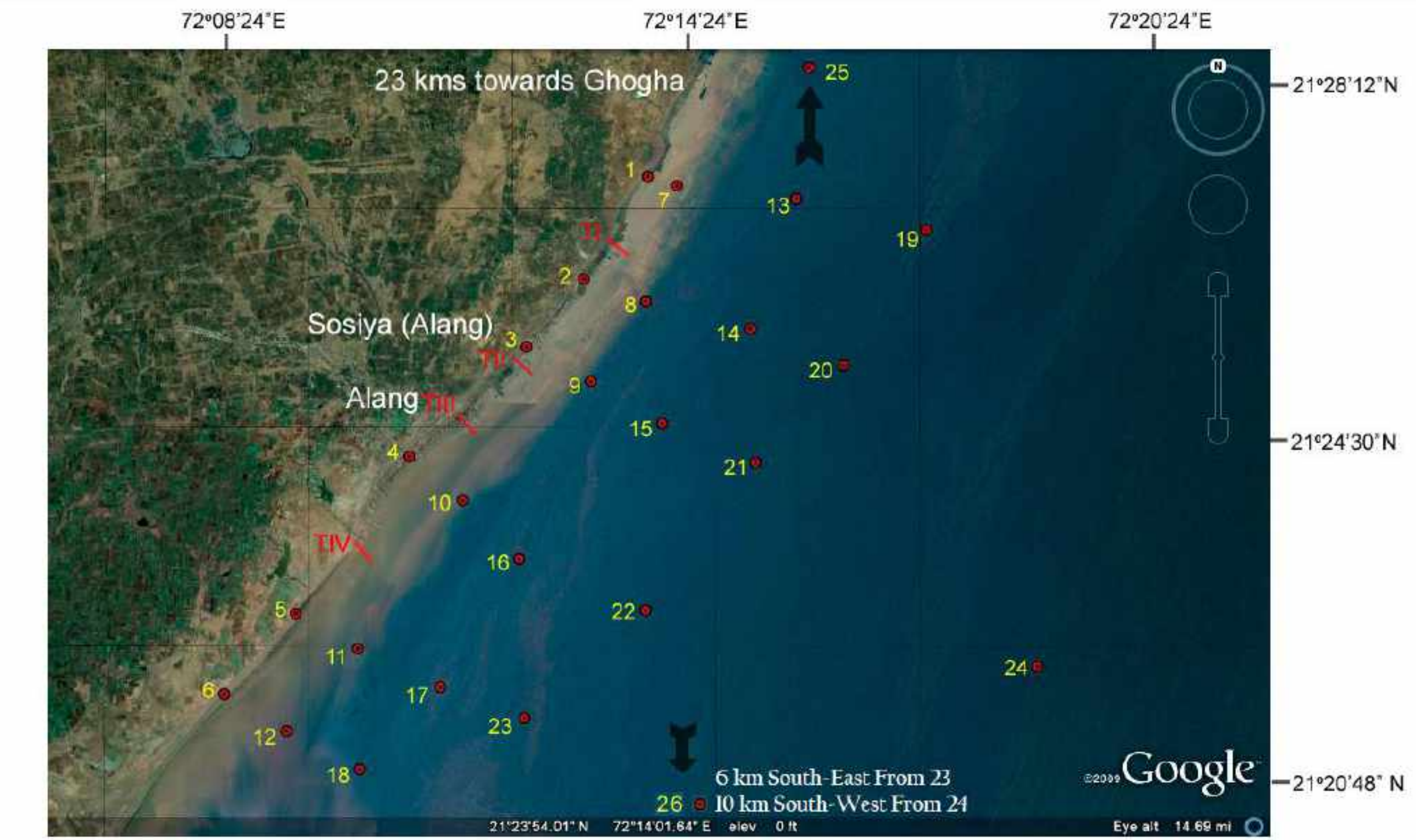

Figure 4.1.1: Sampling location at Alang