2.1. Introduction

Water is essential to human life and the health of the environment. As a valuable natural resource, it comprises marine, estuarine, freshwater (river and lakes) and groundwater environments that stretch across coastal and inland areas. Aquatic ecosystems are an integral part of our environment. The hydrological study is a prerequisite in any aquatic system for the assessment of its potential and to understand the relations between its different trophic levels and food webs.

Water quality is commonly defined by its physical, chemical, biological and aesthetic (appearance and smell) characteristics. A healthy environment is one in which the water quality supports a rich and varied community of organisms. The marine hydrography is much complicated due to the dynamic nature of this ecosystem. The coastal seas and bays are the most valuable and vulnerable habitats (Jickells, 1998). Water quality in a body of water influences the way in which communities use the water for activities such as drinking, swimming or commercial purposes. More specifically, the water may be used by the community for: supplying drinking water, recreation (swimming, boating), irrigating crops and watering stock industrial processes, navigation and shipping, production of edible fish, shellfish and crustaceans, protection of aquatic ecosystems and wildlife habitats, scientific study and education. In recent years, rapid economic growth and the increase in the population of the coastal areas have exercised a great impact on the ecological environment of the coast. Disposal of untreated anthropogenic wastes and sewage into enclosed bay and coastal areas are the factors that could pose potential threat to human health. They need to be maintained if the environment is to continue to support people.
2.1.1. Geographical location

The abundance, diversity and growth of marine organisms, including fouling organisms, depend on geographical location like tropical, subtropical and temperate. The area of the sampling or deployment site is very important to understand the nature of the fouling assemblage. Sampling site may be influenced either qualitatively or quantitatively, sometimes both, by the external environments like river mouth, industrial effluents, agricultural wastes etc. (Borade et al., 2014). Although certain fouling species are universally distributed, typically there are geographic boundaries that limit the occurrence of the majority of these organisms. On open, rocky shores, fouling intensity is high. Often the importance of the geographical distribution of fouling species is overlooked (Callow and Callow, 2002). For example, the seasonal and bio-geographical variance of shipping paths implies that antifouling coating which is effective in temperate waters may be ineffective in tropical waters due to the different variety of species present.

2.1.2. Water Quality Parameters

Natural fouling communities can be grouped according to the physical exposure of the site, i.e., open sea, coast, sheltered marine environment, and estuarine environment, each of which includes a characteristic group of organisms (June and Ross, 1982). The marine environment, as a complex system is mainly influenced by various physical, chemical and biological processes. In an aquatic environment the hydrography is a basic and important tool for any kind of activities like agriculture, recreational, research, desalination, etc. (Murthy et al., 2005; Abdelzaher et al., 2010; Manikannan et al., 2011; Subramanian, 2011). Changes in the hydrographical parameters such as salinity, dissolved oxygen, dissolved carbon dioxide, nutrients,
etc. affect the activities and growth of the organisms in the ecosystem (Sridhar et al., 2008). The optimum physical conditions preferred by fouling organisms are listed in table 1. Among the various parameters, changes in salinity, temperature and pH can be considered as the three main variables which pose a threat to the biota in an aquatic environment (Kannan and Kannan, 1996; Mascarenhas, 2004).

The most characteristic feature of seawater is its high salt content, which forms a complicated solution containing the majority of the known elements. This fact is quantified through the concept of salinity. There are several reasons for the higher divergence of the salinity values near the surface but, among these, rainfall and evaporation are the dominant processes (Yebra, 2004). Temperature and season play an important role in the fouling composition. An increase in community growth rate is generally observed with an increase in temperature. The temperature of the surface waters of the oceans tends to vary directly with the latitude and ranges from -2°C at the poles to 28°C right on the Equator (Pickard, 1982), although temperatures up to 35°C can be reached locally (Chandler, 1985). Compared to the landmass, the water temperature is less affected by the weather. In temperate zones the variations amount to around 10°C and up to 18°C in areas under continental influences (close to the continents, small Mediterranean areas, marginal seas, etc.) or 2°C in equatorial and Polar regions. The diurnal variations of temperature in the open sea are rarely greater than 0.4°C.

Temperature change in surface waters is mainly influenced by land runoff, i.e. colder in winter/cold season and warmer in summer. Strong wind also affects temperature change by bringing up the colder water from the bottom to the surface and reducing the heating up of surface waters, solar radiation absorption and ocean surface radiation emission to the air (Capurro, 1970). Seawater is normally alkaline and the
pH of the surface layers of the ocean, where the water is in equilibrium with the carbon dioxide of the atmosphere, lies between 8.0 and 8.3, and in the open ocean it is, again, a very constant property. The presence of the carbonate system (CO$_2$, HCO$_3^-$, CO$_3^{2-}$) imparts a buffer capacity to seawater. In areas with considerable microbiological activity, there may be some variations due to production of hydrogen sulphide (lower pH) or removal of CO$_2$ by algae (rise of pH). The temperature also modifies the pH value, usually lowering it as the temperature rises unless too much CO$_2$ is desorbed, which leads to an increase in the pH. Slightly different pH values may be found in strongly contaminated waters mixed with the sea (Capurro, 1970; Chandler, 1985).

In general the bacterial diversity and density will be varied in coastal waters due to the inconsistent physical properties by the seasonal changes. For example all rivers drain into the sea during raining season, causing change in physical properties. Hence it is necessary to monitor the physical properties of the seawater periodically as these factors are highly important to microbial growth and biodegradation of materials (Artham et al., 2008; Sahu et al., 2012). Eutrophication and harmful algal bloom are global issues affecting the coastal environments, often as a result of anthropogenically driven increase in nutrients (Anderson et al., 2002). The open ocean is more stable compared to the near shore waters, where the interaction with the terrestrial zone is more effective in bringing about variations in different physicochemical parameters. The settlement of some organisms is strongly dependent on the water currents and tidal actions which bring the larvae from the shore to the site. A low seawater flow rate will support initially the formation of a biofilm on a surface, but will limit its subsequent growth. On the contrary, strong flow rates and thus significant shear forces on the surfaces will slow down bacterial adhesion but will allow a fast growth
of biofilm due to a significant contribution of nutrients. The nutrient level in coastal waters is generally richer than oceanic waters due to domestic or industrial effluents. Thus, fouling rate is higher at coastal areas. Moreover, coastal masses contain more quantities of fouling larvae than ocean waters. The organic matter produced by plants serves as food for animals. Living microorganisms (bacteria, protozoa, diatoms) or detritus brought by currents may also constitute nutrition for sessile animals. Nitrate, nitrite, phosphate, silicate and ammonia are the major nutrients sources for the living organisms.

Hence, a thorough knowledge of hydrography is imperative to estimate the quality of the environment and to know the interrelationships between the organisms and the environmental parameters in order to evaluate the stability and function of ecosystem (Bhadja and Kundu, 2012).

**Table: 1 Influence of physical parameters on fouling organisms**

<table>
<thead>
<tr>
<th>Organisms</th>
<th>Optimum Temperature (ºC)</th>
<th>Light</th>
<th>Oxygen (ppm)</th>
<th>Optimum pH</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria 0.5-1µm</td>
<td>Psychrophiles 15</td>
<td>Mesophiles 35</td>
<td>Thermophiles 55</td>
<td>It doesn’t affect</td>
<td>Aerobic &gt;4 Anaerobic &lt;4 Facultative:</td>
</tr>
<tr>
<td>Fungi 10 µm</td>
<td>22-30</td>
<td>Fungus Tmax = 65</td>
<td>Yeasts Tmax = 45</td>
<td>It affects spore germination</td>
<td>Doesn't affect Fungus&gt;4 Doesn’t affect Yeast</td>
</tr>
<tr>
<td>Algae &gt;100 µm</td>
<td>&lt;35 for green algae</td>
<td>Necessary</td>
<td>Necessary</td>
<td>4.5-9.0</td>
<td>Necessary</td>
</tr>
<tr>
<td>Protozoa 10-1000 µm</td>
<td>20</td>
<td>It doesn’t affect</td>
<td>Aerobic &gt;2 Anaerobic &lt;2</td>
<td>6.5-7.5</td>
<td>Necessary</td>
</tr>
</tbody>
</table>
2.1.3. Materials for marine testing

A number of materials have been used for the various kinds of purposes in marine environment since many decades. The materials include fibre reinforced plastic (FRP), high density polyethylene (HDPE), stainless steel, aluminium, mild steel, galvanized iron (GI), glass, polypropylene (PP), acrylic, copper, cupro-nickel, etc. These materials have been undergoing different type of modification qualitatively and quantitatively when being immersed in the sea. Generally mild steel has been used in wide range of applications such as ship, plate heat exchanger, water pipe line, chains, anchors etc. Ship hulls are frequently fouled in marine environment made up of metals like steel and composite (Chen and Soares 2007). Materials like FRP, glass, poly propylene and poly carbonate acrylic have been used for the development of marine sensors, fish aggregating devices, data buoys, etc. (Nittis et al., 2007; Artham et al., 2008; Sokimi 2012; Xu et al., 2013). Similarly, HDPE is being used in the manufacture of sea cages for aquaculture purposes. Marine aquafarming or cultivating the marine animals in sea cages is being practiced since many decades. Open sea cage is a floating system made up of either HDPE or GI and has long been used for the cultivation of finfishes and crustaceans in aquaculture industry (both freshwater and mariculture). These cage systems also consist of mild steel anchors, chains and polypropylene rope, nylon nets, etc. (Vijayakumaran et al., 2009; Can and Tuan, 2012). These materials are often fouled and further corroded by micro and macro organisms when exposed to seawater. Usually the nature of fouling pattern varies temporally and spatially. Hence, deployment of test coupons of the particular material in particular place during the particular time or season gives a clear picture about the status of the environment. Further, this testing will be useful for designing preventive measures.
2.2. Methodology

In the current study, HDPE pipes and sheets, nylon net and PP rope were used as test coupons to analyse the biofouling process. The basic and indispensible physico-chemical parameters were also monitored during the study period.

2.2.1. Sampling site

The test coupons were deployed in the coastal area of Kothachathiram village, Kavali taluk, Nellore district, Andhra Pradesh, India (Fig. 6). The geographical position of the sampling points (±3 m) were recorded (Lat. 14°56'51.88'' Long. 80°05'02.37'') (Fig. 6) using a hand held GPS (Garmin etrex-Vista H). The boat facility and local fisherman with all safety equipments were arranged to reach the sampling point from the shore regularly.

Figure: 6. A Schematic diagram showing the site of test coupons immersed in sea for fouling studies.
2.2.2. Sampling design

The materials used for the open sea cages were made into test coupons and tied with frames and immersed in sea for biofouling studies. Fouled test coupons were brought to the laboratory in sterile condition for nutrient and microbiological analysis. Some of the physical parameters like Temperature, Salinity, and pH were measured at site immediately. All other parameters were tested in laboratory. Monthly sampling was conducted and the sampling program was continued up to 18 months from May 2012 to October 2013. The study area experiences rainfall from late July to November, the rest of the year being mostly arid. Hence the sampling from July to November can be accounted as monsoon, December to February as post-monsoon and March to June as pre-monsoon.

2.2.3. Test coupon preparation and deployment

The materials used in this study namely, HDPE pipe and sheet, nylon net and PP ropes are commercially available and were purchased from the local market (Chennai-600100, India). These are mainly used in marine applications. The materials were cut into test coupons (150 X 100 X 3 mm HDPE Sheet), (100 X 60 X 3 mm HDPE Pipe), (150 X 100 X 2 mm Nylon Net) and (100 X 15 mm PP rope) (Fig. 7). The coupons were cleaned with 70% v/v ethanol and dried in a hot air oven at 50°C for 24 h. They were left at room temperature and weighed with Sartorius balance (Germany). These coupons were fastened to acrylic frames and made as panels (Fig. 8). The racks were fixed between the sea cages which were deployed in the sea with multipoint mooring system by the Earth System Science Organisation - National Institute of Ocean Technology (ESSO-NIOT), Chennai. The test coupons were immersed in the sea off-Kavali, Kothachathiram coastal area of Bay of Bengal at a depth of 1 m (Lat.
Hydrography and deployment of test coupons

14°56'51.88", Long. 80°05'02.37"; Fig. 6) from May 2012 to October 2013. The coupons were deployed during the beginning of each month and retrieved for sampling at the end of the month.

Figure: 7. The model test coupons used for the fouling studies

Figure: 8. Test Coupons were tied to acrylic frames.
2.2.4. Physico-Chemical Parameters

The analysis of pH, temperature, salinity and dissolved oxygen (DO) was carried out for the surface seawater at the study area. All analyses have been done using standard procedure and instruments. Water temperature was measured \textit{in situ} using a mercury
thermometer (Brannan) with an accuracy of ±0.1°C. The in situ measurements of pH of seawater samples were done using a calibrated pH meter (HI9828, HANNA). The instrument was calibrated by calibration solutions of buffer 4, 7 and 10 (Merck, India) before each sampling. Salinity was determined using pre-calibrated Refractrometer (Atago, Japan). The total suspended solid (TSS) in the seawater was estimated from the sample based on the method reported by Parsons et al. (1984). A sample of 10 ml was filtered through a pre-weighed GF/C filter (47 mm, 0.22 µm) dried at 100°C for 1 h. The concentration of TSS was measured by subtracting the post weight of the filter paper with the pre-weight. The values were expressed in mg/L. The water samples were collected separately for DO by Winkler’s method (1888). The DO samples were fixed immediately with Winkler’s reagents A (Manganese chloride) and B (Potassium iodide and Sodium hydroxide). The fixed samples were analysed by titration against standard sodium thiosulfate solution using starch as indicator. The results of DO were expressed in mg/L.

For the analysis of nutrients, water samples were collected in polypropylene bottles and transported immediately in cool preserved condition in a mobile refrigerator (Euroengel, Italy) to the laboratory. The samples were analysed following the standard method of Grasshoff et al. (1999) using spectrophotometer (Thermospectronic, Unicam UV 300). All the nutrient values were expressed in µmol/L. Calibration and standardization procedure were also followed based on the above methodology. Duplicates were maintained for each sample analysis. The precisions of nitrate, nitrite, ammonium, phosphate and silicate were ±0.02, ±0.02, ±0.05, ±0.01 and ±2.5% µmol/L, respectively. The data quality was checked by standardisation and procedural blank measurements.
Nitrite content in the seawater was estimated through reaction with sulfanilamide to form diazo compound, which was reacted with N-(1-naphthyl) ethylene diamine to form high colour azodye. The colour of solution was measured at 543 nm in spectrophotometer. Nitrate content in the seawater was converted into nitrite by passing through the column containing cadmium granules coated with metallic copper (copper sulfate). The converted nitrite content was estimated based on the same method of nitrite-nitrogen. Ammonia in seawater was treated with hypochlorite to form monochloramine in moderately alkaline medium, which reacted with phenol and nitroprusside to form an indophenol blue. The absorbance of resultant solution was measured at 630 nm in spectrophotometer. Phosphate in seawater was estimated by allowing the water to react with a composite reagent containing ammonium molybdate tetra hydrate solution, sulfuric acid, ascorbic acid and potassium antimonyl-tartrate solution. The resulting complex was reduced to give a blue solution, which was measured at 880 nm in spectrophotometer. The estimation of silicate-silicon depends on the formation of silico-molybdic complex within wide limits of reagent concentration and acidity. When the silicate was treated with an acid-molybdate reagent, yellow coloured silico-molybdic complex was formed in the presence of a reducing agent, ascorbic acid. Hence, oxalic acid was added to avoid the reduction of excess molybdate and to eliminate the influence of phosphate present in the sample. The intensity of colour was measured after 20 minutes at the wavelength of 810 nm against a reagent blank.
2.2.5. Monitoring of Test Coupons

The test coupons were frequently monitored using Self Contained Under Water Breathing Apparatus (SCUBA) diving, in order to check the progression of biofilm and biofouling during the study period.

2.2.6. Fouling assemblage

The immersed test coupons were retrieved and stored in sterile sample bottles containing filtered (0.2 µm, Millipore) and autoclaved (120°C for 20 min at a pressure of 15 psi) seawater. The sample bottles were transported immediately to the lab in preserved condition in a mobile refrigerator (Euroengel, Italy). The fouling assemblages on the test coupons were recorded.

2.3. Results

Monthly sampling of the four different test coupons immersed in the sea off-Kavali, Kothachathiram coastal area was undertaken for biofilm and biofouling studies. The results of physico-chemical and nutrient parameters of seawater from the particular study area are presented herein.

2.3.1. Physico-Chemical Parameters

Physicochemical characteristics of surface seawater samples from coastal area of Kothachathiram are represented in Figures 11 and 12. The pH ranged from 8.02 to 8.12. The maximum pH level (8.12) was observed in December, February, March and April months, while the minimum pH of 8.02 was observed in October 2012. Temperature was measured immediately after the collection of samples. There was difference in temperature ranging from 27.7-29.4°C. The minimum temperature of
27.7°C was observed in July, 2012. Salinity ranged from 30 to 33.5 ppt. Highest salinity of 33.5 ppt was observed in March and April months of 2012 while the lowest salinity level of 30 ppt was observed in September 2013. Dissolved oxygen level ranged between 5.8 and 6.98 mg/l. The lowest DO (5.8 mg/l) content was observed in July 2012 while the highest DO (6.98 mg/l) was observed in November, 2012. Further, the maximum TSS content (14.28 mg/l) was recorded in April, 2013 and the minimum concentration (6.06 mg/l) was observed during November, 2012.

Figure: 11. Variations in hydrographic parameters in the study area
Figure: 12. The presence of total suspended solids in the study area

The concentration of nutrients, like nitrate, nitrite, phosphate, silicate and ammonia ranged from 0.79–2.62, 0.05–1.12, 0.51 - 0.82, 1.3–2.7 and 0.09–0.58 µmol/L, respectively (Fig. 13). The nitrate content was >2 µmol/L in the months of May and June during both 2012 and 2013, while the lowest nitrate concentration (0.79µmol/L) was observed in October, 2012. Similarly, during October 2013 also, minimum concentration of nitrate (0.84µmol/L) was observed. The maximum concentration of nitrite (~1µmol/L) was observed during May and June in 2012 and 2013. The minimum nitrite concentration (0.06 µmol/L) was recorded in November, 2012. Ammonia content in the seawater was very keenly observed, as it can cause toxicity to the organisms. The Highest ammonia concentration (0.58µmol/L) was observed in August 2012 and the lowest (0.08 µmol/L) during September, 2013. In general, the silicate content was higher during the monsoon season. The maximum concentration (2.7µmol/L) of silicate was observed in January, 2013 while the minimum concentration (1.3µmol/L) was observed in May 2012. Likewise, the minimum inorganic phosphate (IP, 0.51µmol/L) was recorded in February, 2013 and the
maximum concentration (0.82 and 0.73 µmol/L) was observed during May and April 2012, respectively.

Figure: 13. Variations in nutrient parameters in the study area
2.3.2. Fouling on test coupons

The test coupon frames were retrieved at the end of each month of experimental period and the new frames were immersed for the next month. It was visually observed that different types of flora and fauna were attached on the coupons (Fig. 14, 15, 16, 17, 18). High fouling assemblage was observed in pre-monsoon season on test coupons, but less in both monsoon and post-monsoon. Biofoulers consisted mainly of barnacles, followed by amphipods. The detailed information about the flora and fauna of the fouling assemblage is presented in chapter 6.

Figure: 14. Under water images of test coupons during the experiment.
A. HDPE Sheet; B. HDPE Pipe; C. Nylon Net; D. PP Rope
Figure: 15. Fouled HDPE sheet test coupons
Figure: 16. Fouled HDPE pipe coupons
Figure 17. Fouled Nylon net coupons
Figure: 18. Fouled PP rope coupons
2.4. Discussion

Water quality parameters are an important factor in the oceans, especially in the coastal areas, making and managing all the desirable changes such as abundance and diversity of flora and fauna. The quality of surface seawater is continuously being affected by natural processes as well as by anthropogenic inputs. It is a well-known fact that the coastal waters are being polluted by the urban runoff in rivers, channels, sewage discharge points, port activities and aquaculture wastes that discharge into the sea. The variations in temperature of water body have great bearing on the biological productivity. It was observed clearly that there were fluctuations in temperature and the lowest temperature (27.7°C) was recorded in monsoon season of August, 2012. Seasonal fluctuations in water temperature distribution play an important role in influencing biological processes. Temperature affects the organisms through direct physiological mechanisms (Kankal and Warudkar, 2012). There was not much difference in pH, but slight changes were observed in monsoon season. The maximum level of pH (8.12) and temperature (29.4) was observed in the months pertaining to pre-monsoon period. Hydrogen ion concentration (pH) is inter-linked with other environmental parameters; it gets changed with time due to changes in temperature, salinity and biological activity. Moreover sea surface temperature and pH vary by the influence of various parameters, like sunshine, evaporation of water, cool freshwater influx from land and flow from the adjoining neritic waters (Gnanam et al., 2013). Temperature increment in summer months and decrement in monsoon months of the present study substantiates the findings of Subramanian and Mohanachandran (1990) from Chennai coastal water and Mohanraj et al. (2007) from coastal zone of Muttukadu estuary, all lying along the coast of Bay of Bengal.
Salinity was observed higher (33.5 ppt) during pre-monsoon months while reduced (30 ppt) during monsoon, which can be attributed to the high freshwater influx. The presence of oxygen maxima and minima appears to be governed mostly by water movement, circulation and mixing besides biological processes. The productivity of any aquatic system mainly is influenced by the presence of DO. Dissolved oxygen content of the study area was mostly maintained above 6 mg/l in all the months, the reason for which might be the fact that the study area is neither close to the estuary nor is it enclosed, but it is in the open sea. Hence the constant DO content was maintained throughout the year. Nitrate and nitrite content was observed more in monsoon and pre-monsoon seasons when compared to the post monsoon. Generally it was observed in this region that TSS content was less in monsoon season and high in pre-monsoon season. The water turbidity was high in pre-monsoon period while the water flow was observed from north to south direction. An increased turbidity level tends to reduce the fouling assemblage (Mckenzie et al., 2011). The average TSS content was 9.75 mg/l. Similarly, Patra et al. (2009) observed the TSS content (~10mg/l) in coastal water of Odissa. Fluctuations in parameters like temperature, pH, salinity, DO, etc. usually depends on season, geographical location, sampling time and the temperature of the effluent entering in to stream (Borade et al., 2014).

Nutrients are the essential sources for the all flora and fauna of the ecosystem influencing growth, reproduction and metabolic activities (Nedumaran and Perumal, 2009; Kalaiaarasi et al., 2012). Inorganic substances are necessary to support the life of organisms in sea but the role of nitrogen and phosphorus are considered as very important in marine ecosystem (Sahu et al., 2012). The presence of nitrate $\geq 4\mu$mol/l is an indicator of sewage contamination (Rajakumari et al., 2010). Relatively high
concentration of nitrate (2-3µmol/l) was observed in May and June month (pre-
monsoon season) of both years; this might be due to urban sewage runoff during
south-east monsoon period. Similar nitrate pattern was observed during the monsoon
period of both years. Post monsoon values are relatively low as compared to other
seasons. Nitrates are the major nitrogen source for plankton growth and proliferation.
In early post monsoon period nitrate content was reduced, which can be attributed to
consumption by plankton. Similar observations were done by many researchers
(Mohanty et al., 2014; Muthukumar et al., 2011; Kankal and Warudkar, 2012;
Archana and Ramesh Babu, 2013). Seasonal distribution of nitrite was similar to that
of nitrate. Inorganic nitrite concentration was observed to be lower than nitrate
possibly due to its very unstable nature. The nitrite content might be converted to
ammonia or nitrate or evaporated (Jacob et al., 1994). The average of 0.64µmol/L
phosphate content was maintained in all the seasons. The study area was open sea and
therefore, water current, turbulence and mixing of water are also attributed to the
regeneration and release of total phosphorus from the bottom mud (Gouda and
Panigraph, 1996). Maximum quantity of silicate content was observed in monsoon
season. The mixing of water from the land to sea during the raining season might
have influenced the silicate content during the monsoon period. The presence of
ammonia is very toxic to the animals. The value of ammonia was high in pre-
monsoon season and then it gradually reduced. This could be due to the conversion of
nitrite to ammonia or effluent discharge from the fish processes industry located near
coastal areas.

Visible difference in fouling was observed on all the sample coupons compared to the
control (Fig. 14, 15, 16, 17, 18). The extent of biofouling on the coupon materials
varied with duration of exposure. Coupons were covered by different kinds of slimes, solids, flora and fauna. Similar observations were recorded by Sudhakar et al. (2007) and Artham et al. (2008) on HDPE, Low Density Poly Ethylene (LDPE), PP and polycarbonate materials. Seasonal variations were observed between the different types of samples. Turbidity, temperature and the availability of nutrients could be the reason for these changes. Water current was high in North to South direction during monsoon period, which could be the reason for the presence of less solid contents on test coupons during the samplings pertaining to monsoon. Spatial and temporal variations in the fouling assemblage are discussed in detail in chapter 6.