3. HYDROGRAPHIC CONDITIONS PREVAILING IN THONDI AND KARANGADU COAST WITH SPECIAL REFERENCE TO METAL DISTRIBUTION IN WATER AND SEDIMENT

3.1 INTRODUCTION

Oceans, seas and coastal waters have an important influence on our lifestyle. These ecosystems provide mankind with food, transport and recreation, but also ultimately receive our waste. The major source of marine pollution is from land-based human activities, these anthropogenic sources being responsible for around 77% of the pollutants that enter into the oceans and seas (Welling 2001).

All oceans and seas are now experiencing serious threats due to pollution (De Valk 2001). Marine water quality has therefore become a matter of serious concern for mankind because of its effects on human health and aquatic ecosystems, including the rich array of marine life that is often exploited for human use. Water quality characteristics of an aquatic environment are of great significance for the proper understanding of distribution, growth and physiological function of the biotic community inhabiting the area. Understanding of water quality is also a very important factor in the semi-enclosed systems where nutrients and pollutants may be concentrated and where the growth and proliferation of plankton is largely
dependent on the environmental and physico-chemical variables which can either support or limit their production capacities (Mustafa 2005).

Marine pelagic systems are quite dynamical and persistent with respect to nutrient enrichment. The coastal zone is recipient of nutrients of human origin, but the main sources of nutrients are natural supply from deepwater. Enrichment of nutrients caused eutrophication that results in reduced water quality is a recognised problem in most coastal countries of Europe (Rousseau et al., 2000).

Sediment is a matrix of materials, made up of detritus, inorganic and organic particles, and is relatively heterogeneous in terms of its physical, chemical and biological characteristics (Sarkar et al. 2004) and consist of a wide range of particle sizes, including gravels, sand, silt and clay (Fergusson 1990). Sediments are well known to act as a major sink for many of the more persistent organic and inorganic chemicals introduced into the aquatic environment by atmospheric deposition, erosion of the geological matrix, or from anthropogenic sources (such as industrial effluents, mining wastes, etc.) (Calace et al. 2005). Sediments also act as potential sources of pollution for the surrounding water and benthic flora and fauna by releasing sorbed contaminants back to the overlying water column should remobilization occur through any disturbance (Adamo et al. 2005).

The study of marine sediments provides useful information in marine, environmental and geochemical research about pollution of the marine environment (Calace et al. 2005). Urban developments and industrial activities contribute to the introduction of significant amounts of
contaminants (among them trace metals) into the marine environment and affect directly the coastal systems where they are often deposited (Dassenakis et al. 2003). The growing apprehension about the potential effects of sediment toxicity poses to marine fauna and flora and the risk posed to the environment by the contaminants accumulated by the sediments have aroused an increase in research interests in marine sediments (Calace et al. 2005).

Sediments play a useful role in the assessment of heavy metal contamination (Gangaiya et al. 2001). The partitioning behavior of heavy metals is such that they tend to accumulate in sediments to levels that are several orders of magnitude higher than in the surrounding water (Denton et al. 1997). Further, their deposition rates are generally related to their rates of input in the surrounding water (Forstner 1990). The analysis of heavy metals in the sediments permits detection of contaminants that may be either absent or in low concentrations in the water column, and their distribution in coastal sediments provides a record of the spatial and temporal history of pollution in a particular area or ecosystem (Binning and Baird 2001). Therefore, the chemical analysis of sediments is very important from the environmental pollution point of view because sediment concentrates metals from aquatic systems, and represents an appropriate medium in monitoring of environmental pollution (Sarkar et al. 2004).

The main heavy metals forming the focus of this study are copper, lead, zinc and iron. The reason for focusing on these particular metals is that they are known to be present in a greater quantities and pose significant threat to the fauna in the environment. To adequately interpret results of any contaminant analysis, it is necessary to know the spatial and temporal
variance in the objective area (Birch et al., 2001). Temporal variation at a site includes natural variance associated with physical, chemical and biological processes. Small-scale spatial variations of contaminant distribution in an urban estuarine environment influenced by point sources of pollution in conjunction with urban surface water runoff may hinder accurate interpretation of temporal contamination. If these are excessive, larger local and regional trends may be obscured. When temporal trends are large, a single synoptic survey may be insufficient to determine contaminant loading, degradation and circulation over time.

The surface water of the Palk strait is an important region in which to study the complex interactions of biological processes with natural episodic injections of metals into the photic zone. In addition, because of the deferential solubility of oxidised and reduced forms of metals, the subsurface, sub-oxic water of the region may play a significant role in moderating the normal chemical separation of Fe from N and P during the remineralisation of organic matter. The degree to which each of these processes interact in this ocean region will be of use in elucidating chemical and biological interactions in other, more iron impoverished, oceanic regimes. The present study investigates the physico-chemical characteristics of water and distribution of heavy metals such as Cu, pb, Zn, Fe in water and sediments in Thondi and Karanagadu. It is based on determination and the distribution of various forms and the concentrations of metals, to asses their potential biological effects and the extent to which this distribution is related to biological systems in this region.
3.2 MATERIALS AND METHODS

Estimation of physico-chemical parameters

On-the-field recording of date, and collection of samples for laboratory analysis, were done between 8 and 10 am on a monthly basis. All required precautions were taken during collection and documentation. All recordings of data were done three times at each station on every month and mean value was taken. Collection of samples was done using clean non-corrosive plastic containers and buckets (Laxen and Harrison, 1981). The study period was from March 2005 to February 2006, 12 months duration, divided, for convenience, into post-monsoon (January – March), summer (April – June), pre-monsoon (July – September) and monsoon (October – December) seasons.

Determination of surface water temperature

Using the standard Celsius thermometer the temperature of the surface water was recorded and the mean temperature was recorded.

Measurement of pH

An Elico LI 120 model pH meter was precalibrated with standard buffer solutions of pH 4.0, 7.0 and 9.2. Water samples collected from 2 locations were used to measure pH.

Estimation of salinity

The Classical Mohr Titration method (Strickland and Parsons, 1972), was adopted to estimate salinity of water samples collected from the
stations. Initially, chlorinity was estimated. Using Knudsen’s equation, salinity was established.

**Estimation of dissolved oxygen**

Winkler’s method (Strickland and Parsons, 1972), was adopted to estimate the dissolved Oxygen content in the water samples collected from the stations. The water samples were fixed in the stations and titrations were done by adopting routine procedures in the laboratory, and the readings were recorded.

**Estimation of Nitrite**

Nitrite was determined by the Azo Dye method. The determination of nitrite is based on the classical Greiss’s reaction in which the nitrification at pH 1.5 – 2.0 is coupled with N (1-naphthyl) ethylenediamine to form a highly coloured azo dye. This was measured spectrophotometrically at an absorption maximum of 545 nm (Grasshoff et al, 1983).

**Estimation of Nitrate**

Nitrate is estimated using cadmium reduction column. The nitrate is reduced almost quantitatively to nitrite by passing though a column containing copperised cadmium filing. The nitrite thus produced is determined by diazotizing with sulphanilamide and coupling with N-(1-naphthyl)-ethylenediamine. Nitrite in the sample passes through the column without quantitative change. Hence the total nitrate plus nitrite was determined by the method. The difference between the two values indicated the total nitrate content of the sample (Grasshoff et al, 1983).
**Estimation of Inorganic Phosphate**

The inorganic phosphate was estimated using the method. The inorganic phosphate ions in sea water react with acidified molybdate reagent to yield phosphomolybdate complex, which is reduced to molybdenum blue. The colour was measured spectrophotometrically at 880 nm (Grasshoff et al, 1983).

**Estimation of Silicate**

Silicate in the sample was estimated by the method of Strickland and Parsons (1972). The water sample is made to react with ammonium molybdate to form the yellow β-silico molybdic acid, which is then reduced by ascorbic acid to molybdenum blue. The optimum acidity is 0.07 – 0.13 N. To suppress the interferences or phosphate, oxalic acid was added. The absorbance of the blue complex was measured at 810 nm using a spectrophotometer.

**Analyses of trace metals**

The flame atomic absorption spectrophotometer has been used for heavy or trace metal analysis, which is based on the principal of estimation of the capacity of an atom to absorb very specific wave length of light as it enters an excited state in a process of atomic absorption. The instrument measures the amount of light absorbed at the resonant wavelength, as the light passes through a cloud of atoms. As the number of atoms in the light path increases, the amount of light absorbed increases in a predictable way. By
measuring the amount of light absorbed, a quantitative determination of the amount of analyte present can be made.

**Surface water samples**

Care was taken to collect surface water from the 2 stations, in containers that were kept ready, using the standard procedures (Grasshoff *et al.*, 1983). Collections were done every month during the study period. pH was adjusted to 4.00 (± 0.1) after the water samples collected from the study area were filtered using 0.45µ millipore HA membrane filters. Standard solutions of Cu, Pb, Zn and Fe were prepared in the optimum concentration range, with mill-Q water. The concentrations of the metals, in the sea water samples collected for analysis, selected for analysis, were analysed using the preconcentration procedure. Computer-controlled flame atomic absorption spectrophotometer was used. Calibration curves, using which metal concentrations were calculated, were drawn by plotting the absorbance against the concentration of the working solutions for each of the metals analysed. The concentration of metals in samples were expressed as µg/l.

**Sediment samples**

Samples of sediment were collected every month using a Vanveen grab. The samples thus collected were packed in polythene bags and stored in a freezer adjusted to about -20\(^0\) C. For estimation of the metals in the sediment samples, the frozen samples were thawed and dried at specified temperatures, before the samples can be used for analysis of Cu, Pb, Zn and Fe using computer-controlled flame atomic absorption spectrophotometry (AAS). The amount of metals in the samples was expressed as µg/g.
Statistical analyses

The data generated during the one year period of study were subjected to statistical analysis, to extract inferences and to be able to interpret the relationships between variables. Statistical Package for Social Scientists (SPSS) 10.0.1 version, which is a comprehensive statistical package, was employed. This package is programmed for multivariate analysis and is an efficient tool to be employed for ANOVA and graphs were performed using MS Excel software. 2-way analysis of variance (ANOVA) with habitat (stations) and time (months) as fixed factors, were used to compare the equality of mean numbers per sampling. Correlations between all the parameters were worked out.
3.3 RESULTS

3.3.1 Physico-chemical parameters

3.3.1.1 Water temperature

Water temperature varies in accordance with ambient air temperature. In Thondi, a minimum (30°C) and maximum (33.9°C) water temperature were recorded during monsoon and summer months respectively, with a mean water temperature of 32.175°C. In Karangadu, temperature showed a mean of 29.7°C during monsoon and a maximum of 33.6°C during summer, with the minimum of 32.23°C (Table 1, Figure 4).

Statistical analysis revealed a highly significant variation (p<0.01) between seasons and an insignificant variation between stations (p>0.05).

3.3.1.2 Salinity

Salinity varied over a narrow range of 30.6-34.8‰. In both the study area, salinity recorded the minimum (30.6‰) and maximum (34.8‰) during monsoon and summer months, respectively with a mean salinity of 32.93‰.

Statistical analysis on salinity showed a highly significant variation between seasons (p<0.01) and insignificant variation between stations (p>0.05) (Table 1, Figure 5).
Variations in pH were very meager during the study period of 2005-2006 along the Palk Strait region. The minimum (7.6) pH was recorded during premonsoon and monsoon seasons and maximum (8.6) pH was recorded during and summer months, with a mean pH of 8.108. In Karangadu, pH showed the minimum of 7.6 and the maximum of 8.4 were recorded during premonsoon and summer seasons respectively, with the mean of 8.058 (Table 1, Figure 6).

The variation of pH of water samples collected from Thondi and Karangadu revealed a highly significant variation between seasons (p<0.01) and insignificant variation between stations (P>0.05).

Fluctuations in DO were wide in the two studied areas in different seasons of the year. In Thondi, minimum (4.7 mg/L) and maximum (6.2 mg/L) DO was recorded during monsoon and post monsoon seasons respectively, with a mean DO of 5.4 mg/L. Whereas in Karangadu, DO showed the minimum of 3.98 mg/l and maximum of 5.9 mg/l during summer and late premonsoon respectively with the mean values of 4.536 mg/l. (Table 1, Figure 7).

Statistical analysis on the DO content of water revealed an insignificant variation (p>0.05) between seasons and highly significant variation between stations (p<0.01).
3.3.1.5 Nitrite

Nitrite content varied in accordance with total nitrogen content of the seawater. In Thondi, nitrite showed the minimum (0.04 µM/L) and maximum (0.84 µM/L) levels during summer and premonsoon months, respectively, with a mean value of 0.44 µM/L. However, in Karangadu, the minimum of 0.06 µM/L and a maximum of 0.98 µM/L nitrite levels were recorded during post monsoon and premonsoon seasons respectively with the mean value of 0.555 µM/L. (Table 1, Figure 8).

Statistical analysis on the nitrite content of water sample exists a highly significant variation between seasons as well as stations in the study area (p<0.01).

3.3.1.6 Nitrate

Fluctuation in nitrate varied over a wide range in the study area. The concentration of nitrate in Thondi showed minimum (0.12 µM/L) during post monsoon season and maximum (2.52 µM/L) during premonsoon season. During the one year monitoring study nitrate recorded the mean of 1.32 µM/L. Similarly, in Karangadu, the concentration of nitrate recorded the minimum of 0.36 µM/L and a maximum of 7.56 µM/L during post monsoon season and premonsoon season respectively with the mean value of 3.96 µM/L. Among the two stations studied, Karangadu tend to recorded the maximum level of nitrate compared to Thondi coastal waters. (Table 1, Figure 9).
Statistical analysis on the distribution of nitrate in the water samples revealed a highly significant variation due to seasons and also the stations (p<0.01).

3.3.1.7 **Inorganic phosphate**

There was a great fluctuations has been observed in inorganic phosphate content of Thondi and Karangadu during different seasons of the study period. The minimum (0.73 µM/L) and maximum (1.74 µM/L) inorganic phosphate levels were observed during premonsoon and monsoon seasons respectively with a mean value of 1.05 µM/L. However, in karangadu inorganic phosphate showed the minimum of 0.89 µM/L during post monsoon and a maximum of 2.13 µM/L during monsoon season with a mean value of 1.351 µM/L. Inorganic phosphate values showed the similar fluctuations during the study period in the two stations. (Table 1, Figure 10).

Inorganic phosphate distribution in the water samples collected from Thondi and Karangadu showed a highly significant variation due to seasons as well as stations (p<0.01).

3.3.1.8 **Silicate**

Variations in silicate content were very large during the study period. In Thondi, the minimum (7.43 µM/L) silicate recorded during premonsoon and maximum (14.43 µM/L) silicate content were recorded during monsoon months with a mean value of 10.801 µM/L. In Karangadu, silicate reported to be the minimum of 8.32 µM/L during postmonsoon season. However the maximum silicate content (12.97 µM/L) was recorded
during monsoon season with the mean value of 10.241 µM/L. Of the two stations examined, the maximum silicate content was observed in the coastal waters of Thondi compared to Karangadu (Table 1, Figure 11).

Variation of silicate content in the water samples revealed a highly significant variation due to season (p<0.01) and significant variation between stations (p<0.05).

3.3.2 Metal content in seawater

3.3.2.1 Copper

There was a sudden decrease and a steep increase has been observed in the copper content in the water samples of Thondi and Karangadu. In Thondi copper content recorded a minimum of 0.714 µg/L during summer and a maximum of 1.992 µg/L during monsoon seasons. The concentration of copper in Karangadu showed the minimum (1.087 µg/L) in summer and a maximum (2.189 µg/L) in post monsoon season. Of the two stations studied, Karangadu recorded maximum copper content (Table 2, Figure 12).

Statistical analysis on the distribution of copper content in the water samples revealed a highly significant variation between between season as well as stations (p<0.01).

3.3.2.2 Lead

Lead content showed the variation in a similar fashion throughout the study period in the water samples of Thondi and Karangadu. In Thondi lead content recorded a minimum of 0.089 µg/L during summer and a
maximum of 0.187 µg/L during monsoon seasons. The concentration of copper in Karangadu showed the minimum (0.114 µg/L) in summer and a maximum (0.399 µg/L) in monsoon season. Of the two stations studied, Karangadu recorded maximum lead content (Table 2, Figure 13).

The distribution of lead in the water samples collected from Thondi and Karangadu showed a significant variation between seasons (p<0.05) and highly significant variation between stations (p<0.01).

3.3.2.3 Zinc

Zinc content showed similar fluctuations throughout the study period in the water samples of Thondi and Karangadu. In Thondi zinc content recorded a minimum of 2.483 µg/L during summer and a maximum of 3.113 µg/L during postmonsoon seasons. The concentration of zinc in Karangadu showed a minimum (3.867 µg/L) in postmonsoon 2005 and a maximum (4.923 µg/L) in postmonsoon season 2006. Of the two stations studied, Karangadu recorded maximum lead content (Table 2, Figure 14).

Zinc content in the water sample showed a highly significant variation both due to seasons as well as stations of Thondi and Karangadu (p<0.01).

3.3.2.4 Iron

Iron content also showed similar seasonal fluctuations throughout the study period in the water samples of Thondi and Karangadu. In Thondi iron content recorded a minimum of 3.187 µg/L during postmonsoon 2005 and a maximum of 4.89 µg/L during monsoon seasons. The concentration of
iron in Karangadu showed a minimum (4.798 µg/L) in postmonsoon 2005 and a maximum (5.982 µg/L) in monsoon seasons. Of the two stations studied, Karangadu recorded maximum lead content (Table 2, Figure 15).

Statistical analysis on the distribution of iron in the water samples collected from Thondi and Karangadu showed a highly significant variation both between seasons as well as stations (p<0.01).

3.3.3 Metal content in sediments

3.3.3.1 Copper

Copper concentration found in the sediment was quite high than water samples. In, Thondi, copper concentration recorded a minimum value of 0.789 µg/g during premonsoon season and a maximum of 1.379 µg/g during monsoon season. However in Karangadu, it showed a minimum of 1.349 µg/g during summer and a maximum of 2.689 µg/g during monsoon season. Among the two stations examined, Karangadu recorded the maximum copper content in the sediment (Table 2, Figure 16).

Statistical analysis on the accumulation of copper in the sediment samples collected from Thondi and karangadu revealed a highly significant variation both between seasons as well as stations (p<0.01).

3.3.3.2 Lead

Lead concentration found in the sediment was quite high than water samples and it showed a similar manner of fluctuation. In, Thondi, lead concentration recorded a minimum value of 0.116 µg/g during summer season
and a maximum of 0.299 µg/g during monsoon season. However in Karangadu, it showed a minimum of 0.315 µg/g during postmonsoon season and a maximum of 2.689 µg/g during monsoon season. Among the two stations examined, Karangadu recorded the maximum lead content in the sediment (Table 2, Figure 17).

The variation of lead content in the sediment samples collected from Thondi and Karangadu showed a highly significant variation between seasons as well as stations (p<0.01).

### 3.3.3.3 Zinc

Zinc concentration found in the sediment was quite high than water samples. In, Thondi, zinc concentration recorded a minimum value of 2.184 µg/g during postmonsoon season and a maximum of 2.937 µg/g during monsoon season. However in Karangadu, it showed a minimum of 3.065 µg/g during premonsoon and a maximum of 5.925 µg/g during monsoon season. Among the two stations examined, Karangadu recorded the maximum zinc content in the sediment (Table 2, Figure 18).

The accumulation of zinc in the sediment samples collected from Thondi and Karangadu varied significantly between seasons as well as stations (p<0.05).

### 3.3.3.4 Iron

Iron concentration found in the sediment was quite high than water samples. In, Thondi, iron concentration recorded a minimum value of
3.198 µg/g during postmonsoon season and a maximum of 5.249 µg/g during monsoon season. However in Karangadu, it showed a minimum of 6.245 µg/g during postmonsoon and a maximum of 7.994 µg/g during monsoon season. Among the two stations examined, Karangadu recorded the maximum iron content in the sediment (Table 2, Figure 19).

The accumulation of iron content in the sediment sample collected from Thondi and Karangadu showed a highly significant variation both between seasons as well as stations (p<0.01).
### Table 1  Variation of physico-chemical parameters in Thondi and Karangadu during the study period (2005-2006)

<table>
<thead>
<tr>
<th>Months</th>
<th>temperature</th>
<th>Salinity</th>
<th>pH</th>
<th>Dissolved oxygen</th>
<th>Nitrite</th>
<th>Nitrate</th>
<th>Inorganic phosphate</th>
<th>Silicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stations</td>
<td>SI</td>
<td>SII</td>
<td>SI</td>
<td>SII</td>
<td>SI</td>
<td>SII</td>
<td>SI</td>
<td>SII</td>
</tr>
<tr>
<td>Minimum</td>
<td>30</td>
<td>29.7</td>
<td>30.6</td>
<td>30.6</td>
<td>7.6</td>
<td>7.6</td>
<td>4.7</td>
<td>3.98</td>
</tr>
<tr>
<td>Maximum</td>
<td>33.9</td>
<td>33.6</td>
<td>34.8</td>
<td>34.8</td>
<td>8.6</td>
<td>8.4</td>
<td>6.2</td>
<td>5.9</td>
</tr>
<tr>
<td>Mean</td>
<td>32.17</td>
<td>32.23</td>
<td>32.93</td>
<td>32.9</td>
<td>8.10</td>
<td>8.05</td>
<td>5.4</td>
<td>4.53</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.455</td>
<td>1.33</td>
<td>1.39</td>
<td>1.40</td>
<td>0.34</td>
<td>0.25</td>
<td>0.52</td>
<td>0.62</td>
</tr>
</tbody>
</table>

SI : Thondi; SII : Karangadu

### Table 2  Variation of heavy metals in water and sediment samples of Thondi and Karangadu during the study period (2005-2006)

<table>
<thead>
<tr>
<th>Metal content in water samples</th>
<th>Metal content in sediment samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Months</td>
<td>Months</td>
</tr>
<tr>
<td>Copper</td>
<td>Lead</td>
</tr>
<tr>
<td>Stations</td>
<td>SI</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.713</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.992</td>
</tr>
<tr>
<td>Mean</td>
<td>1.195</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.454</td>
</tr>
</tbody>
</table>

SI : Thondi; SII : Karangadu
Coastal ecosystems, especially in the tropical regions, have been known for their richness in biological productivity. The physico-chemical characteristics of an aquatic ecosystem undergo changes due to the action of tides, inflow of domestic and industrial effluents and during rainfall; consequently, the biological characteristics are also likely to change. Rainfall results in the inflow of fresh water from rivers and estuaries. Run-off increases pollution load along the coasts, and wind and wave action can disperse these materials sea-ward. During cyclonic storms, rivers and estuaries express a washed appearance due to flow into the sea and wave action. Seasonal variations brought about by monsoon cycles and tidal rhythms have been known to be responsible for natural variations in the physical, chemical and biological characteristics of the coastal ecosystem (Kumary et al., 2001; Keesing and Irvine, 2005).

In addition, anthropogenic inputs have altered the character of the coast adversely and resulted in biodiversity hot-spots. Palk Strait region falls within the temperate subtropical margin that displays limited variation in water temperature. The range of water temperature in the present study is comparable with the earlier records in this area. Among the two stations sampled, lowest (29.7°C) and highest temperature (33.9°C) was recorded at Thondi and Karangadu respectively. The significant positive correlations of water temperature with DO during summer in contrast with the significant negative correlations of the water temperature with DO during monsoon clearly defines the critical role of temperature controlling the water chemistry that increases and decreases DO levels in monsoon and summer seasons,
respectively. This is exemplified by conditions during summer when small bubbles, which are always present in the sea associated with organic matter, grow in the presence of high oxygen saturations (Ramsey 1962). Much work has been done in recent years to explore the relationship between economic development and environmental quality (Hale et al., 2001).

The horizontal distributions of salinity are more prominent in the Palk strait region. Salinity levels in these two areas were identical in all the seasons. High salinity, (34.8‰) values recorded during summer seasons and low (30.6‰) values obtained during monsoon seasons. Variations in salinity were observed to be due to rainfall and flow of freshwater into the sea and Canal during changing tides. The low salinity associated with the anthropogenic freshwater inputs (Saunders et al 2007). Significant negative correlations between salinity, nitrate and inorganic phosphate has been observed. The salinity is lowest at this station is probably due to the huge volume of fresh water, but also an indication that within a saline system the input of considerable freshwater could be considered a pollutant (Saunders et al 2007). Such characteristics are common in Indian estuaries where nutrient levels are controlled by anthropogenic discharge (De-Sousa 1999). Oceans and seas are in reality one single body of water; yet, their waters are not homogeneous (Fitzsimons 2001). The density of ocean seawater varies with depth and temperature, where it increases with ocean depth (Nelson 2001) and becomes denser as seawater becomes colder. Grasshoff (1983) revealed that salinity variation is mainly influenced by anthropogenic fresh water influx rather than prevailing regime.
pH values showed seasonal variations and variations between stations during the study period. In the present study, pH showed minimum during monsoon and maximum during summer. Very large variations in pH observed specifically during monsoon and summer indicate that the water is often alkaline. Generally, higher pH values may be attributed to sea water mixing and redox variations in sediment and water column; while lower pH values are observed during monsoon and due to influx of freshwater, and tide action. The values of pH during summer are relatively higher than the recorded levels closest to Dubai [Abu Dhabi creek (Abu-Hilal & Adam 1995) and the UAE coastal waters (Shriadah & Al-Ghais 1999). The high pH in Thondi mainly influenced by high and low photosynthetic activities, that contributes to an elevation of the level of pH. The significant difference of pH is attributed to low and high primary productivity zones, respectively. The relationship of high pH and high primary productivity has been defined as the phenomenon of stagnant aquatic environments with examples such as lake (Chilka Lake) and saline reservoirs (Salt pans- Mumbai) in India (Mustafa 2005 and Nayak et al 2004).

Dissolved oxygen content in an aquatic system is an essential factor influencing factor for aquatic life. The available DO is derived from the atmosphere and photosynthesis. Organic matter oxidation contributes to the depletion of oxygen in the water body. Changing the balance between the oxygen supply and consumption leads to a characteristic DO profile. Increasing DO values during monsoon are due to high solubility of oxygen in lower water temperatures and increasing turbulence, while the falling DO values during summer are attributed to high water temperature that is
increasing the rate of organic matter decomposition in the coastal and creek waters (Shriadah & Al-Ghais 1999).

Therefore, under aerobic conditions the oxygen content is one of the most suitable measures related to the state of the water body. Current results for DO based on the seasonal variation gives a comprehensive picture of the oxygen behavior in Palk Starit region. The low values (3.98mg/l) at Karangadu compared to Thondi was expected due to respiration and chemical reactions, whereas the high DO values (6.2mg/l) at Thondi during postmonsoon were due to air diffusion at the airwater interface, high photosynthetic activity and less mixing due to low surface turbulence and anthropogenic contaminants as in the case of Karangadu. The observed high monsoonal values might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing (Das et al., 1997). The observed stratification in DO levels correspond to the earlier records that show a high variation (0.02-10.30 mg/L) that is a clear indicative of high stratification (Al-Zahed 2005).

Nutrients levels have been recorded to increase as a result of monsoons. This increase may be attributed to (i) large-scale discharge from land runoff, and (ii) release of sediment-entrapped nutrients due to monsoon turbulences and wave action (Satpathy, 1996). Generally nutrients are stable and comparatively low in summer whereas these levels are fluctuating and high in monsoon in all the two stations. Phosphate concentration observed the maximum of 2.13µM/l in Karangadu during monsoon season of the study period. Phosphate concentration of 0.3 mg/L will support plankton growth, while concentrations of 1.0-3.2 mg/L phosphate will trigger blooms (USEPA
Subramanyan (1959) reported that considerable quantity of phosphate is locked up in the sea bottom mud and this goes into solution during the south-west monsoon season or during the period’s high velocity.

Dissolved nitrogen and phosphorus compounds are present in low concentrations in seawater. Nitrogen is mainly present as NO$_3$-N with low concentrations of (nitrite) NO$_2$-N and NH$_4$-N, while the major inorganic species of phosphorus is PO$_4$-P. Nitrite content in the sea water showed a wide fluctuation due to seasons. In Thondi and Karangadu, nitrite recorded the maximum of 0.84 and 0.98 µM/l respectively during premonsoon seasons. High concentrations of these nutrients in water however can lead to excessive growth of algae resulting in eutrophication (Lundberg 2005). However, the nitrate content showed elevated in the sea waters of Palk Starit region. Thondi and Karangadu reported the maximum (2.52 and 7.56 µM/l) during premonsoon seasons. These high levels in Karangadu could be attributed to the low rate of photosynthesis that requires less nutrient supply. Generally, the nutrient increase from the channel to the lagoon indicates that the lagoon area is heavily vulnerable to eutrophication (El-Sammak, 2001).

In both the study area, silicate recorded maximum during monsoon season. The silicate content was higher than that of the other nutrients and the recorded high monsoon values may be due to heavy inflow of monsoonal fresh water derived from land drainage carrying silicate leach out from rocks. Further, due to the turbulent nature of water, the silicate from the bottom sediment might have been exchanged with overlying water in this estuarine environment (Govindasamy and Kannan, 1996; Rajasegar, 2003). The observed low post-monsoonal values (8.3 µM/l) could be attributed to uptake
of silicates by phytoplankton for their biological activity (Mishra et al., 1993; Ramakrishnan et al., 1999).

Heavy metals cause the greatest damage to the aquatic system in the vicinity of industries in countries that are developing (Choudri and Chavadi, 2000a). Their typical characteristics include environmental persistence, non-biodegradability, toxicity even at low concentrations, ability to be incorporated into the food chain and bioaccumulation in aquatic organisms. Hence, of the many pollutants that are let out into the aquatic system along with effluents, heavy metals constitute the major anthropogenic contaminants of estuarine and coastal habitats (Negilski, 1976).

In the present investigation, the heavy metals such as copper, lead, zinc and iron has been studied in the water and sediment of Thondi and Karangadu, Palk Starit region from 2005-2006. Choudri and Chavadi (2001), have analysed the sediment collected around an industrial area in Karnataka, India, and have reported that there was a two-fold increase in levels of Cd, Pb, Ni, Cu, Zn, Mn, Fe and Cr, as compared to sediment collected from relatively un-polluted areas, away from the industrial belt. Previous studies had also demonstrated that municipal and/or industrial wastewater discharges into coastal zones are the most important sources for contamination of water and sediment with heavy metals (Gonzalez and Brugmann, 1991).

Among the two stations studied, Karangadu observed to be the maximum concentration of metals both in water and sediment. Mitra et al., (2008) have studied the monthly variations of Zn, Cu and Pb observed
between dissolved metals and sediment metals. This is attributed to the exchange of heavy metals influenced by salinity and pH in the area.

The changes in the quality of water as a result of addition of aquaculture pond effluents and agriculture activities enriched along Karangadu region have an immediate effect on the distribution of high metal content both in water and sediment compared to Thondi. Iron is of course the most abundant element in the earth crust. It is also one of the essential elements for human. The concentration of iron recorded maximum (350.48 mg g\(^{-1}\)) in sediments under reducing condition, the iron from biotite mica and laterites are leached into solution in ferrous state. According to Singhal and Gupta (1999) iron content in groundwater is mainly due to the dissolution of iron oxides. This probably indicates location variation of variable release rates of trace elements from sediments to the marine environment.

Next to iron, zinc recorded the maximum of 5.925µg/g and 4.923 µg/l in sediment and water of Karangadu respectively. Cu and Zn showed the influence of organic wastes from aquaculture effluents and sewage entering Karangadu region. The total metal content in the sediment was always greater than that measured in the water. Copper concentration in the sediments is known to form soluble and insoluble metal chelates in the presence of high organic matter and this is responsible for the high concentration of copper in the waters (Subramanyan and Kumari, 1990). In the study area, copper concentration recorded maximum during monsoon season. Bryan and Langston (1992) confirmed that the higher levels of copper in sea water and have explained that a large fraction of dissolved copper may adsorb to particulate matter and concentrate in the bottom sediment in estuaries.
The comparison of the metal levels in the sediments and water from Karangadu indicated that there is a detectable anthropogenic input to the ecosystem. However, the distribution pattern of metals in water and sediment samples are in the order of Fe > Zn > Cu > Pb. The accumulation effects are greatly dependent on the sediment composition and structure. High metal concentrations such as particulate Fe and Zn in water column and sediment, found in this study implied temporary discharge of aquaculture pond effluents and agricultural wastes from the surrounding areas of Karangadu with high metal concentrations. The present study highlights the status of the physico-chemical characteristics of the ecosystem.