CHAPTER V

SUSPENDED MATTER AND PARTICULATE TRACE METALS
V. Suspended Matter and Particulate trace metals

5.1 Introduction

Suspended matter in lakes, rivers and estuaries plays a vital role in the transfer of materials from land to sea. The main contributors of suspended matter are weathering of rocks, industrial effluents and agricultural runoff. Particulate matter generated by biological productivity may also important in the supply of suspended matters in lakes and also in the lower portion of the estuaries (Biggs, 1970). Solid waste particles may also cause an appreciable metal enrichment of the suspended load in water. It has been proved that the suspended matters act as scavengers of various pollutants. When the suspended matter in the freshwater mixed with saline water the trace metals in the suspended matter may be displaced by major cations of sea water.

The role of suspended particulate in an estuary is important in controlling trace metal content in the system. Metals get associated with the particulates through mechanisms such as adsorption, chelation and coprecipitation. Geochemical behaviour of particulate material in estuaries is complex owing to the numerous possibilities for metal transport into this environment. Due to prevailing hydrographic condition the metals associated with the suspended sediments get destabilized when they reach the estuarine water. The suspended sediments in saline water flocculate and settle to the bottom to form the estuarine sediments. The metals associated with the bottom sediment become readily available to the overlying water.
depending upon changes in the electro-kinetic charges. Similarly the river discharge transport many toxic substances in association with particulate materials which are also adsorbed by the estuarine sediments.

From the biologic and health point of view, suspended material forms natural food for the filter feeding organisms and hence the pollutants scavenged by the suspended material can adversely affect many varieties of sea foods. An increase in suspended matter can cause turbidity within the water body affecting adversely light penetration and hence productivity. Moreover high suspended matter leads to clogging in respiratory organs of aquatic organisms. Hence knowledge about the suspended sediments in an aquatic body can throw light upon various pollutants associated with it. The mechanism of transport of suspended materials can be used to estimate the fate of many pollutants in estuaries and oceans and can help to adopt methods to divert or decrease the detrimental turbidity in regions of sea food harvesting.

Particulates are dominant pathway for many toxic contaminants (Walling and Webb, 1985). The study of particulate suspended matter is important in understanding about the origin of sediments, transport and disposal of suspended matter into a basin, the relative contribution of biogeneous and chemogeneous material to suspended matter. The knowledge about the particulate matter is important in forecasting the fishery resources of a particular region, as the particulate matter forms part of food material for a large variety of marine life. So an understanding of suspended solids and particulates are very important for rational
management of the estuaries. Hence in the present study, an attempt is made to examine the distribution of toxic heavy metals associated with suspended sediments from November 2000 to August 2001 in the study area.

5.2 Review of Literature

Extensive studies on suspended sediments in the estuaries were carried out elsewhere.

Klein (1973) reported that salts of many metals like copper, zinc, lead, nickel and mercury constitute the main effluents from industries and mining. Groot (1966) observed the transport of heavy metals in sediments and various process affecting heavy metals in estuarine sediments.

Kharkar et al. (1968) investigated the adsorption-desorption of trace metals on clay minerals and oxide coatings of iron, manganese during estuarine water mixing to the oceans. Estuarine sediments derived due to landward transport of marine sediments were reported by Meade (1972). Das et al. (1972) made extensive investigations on the hydrography, circulation and suspended sediment distribution of the Zuari and Mandovi estuarine system. Krank (1974) reported the role of flocculation in the transport of particulate pollutants in the marine environment. Extensive studies on suspended sediment distribution in the estuaries were carried out by Varma et al. (1975), Gibbs (1976) and Allen et al. (1976).

Cherian et al. (1975) made investigations on the relation between various hydrographic parameters and suspended sediment load near Marmugao harbour.
Gibbs (1977) carried out extensive studies to elucidate transport mechanisms of trace metals in Amazon and Yukon rivers. Heavy metal concentration in the particulate matter of the Cochin backwater from the marine zone to the freshwater zone was reported by Sankaranarayanan and Stephen (1978). Sampling and analytical method for the determination of copper, zinc, cadmium and nickel in sea water was documented by Bruland et al. (1979). Paul and Pillay (1983) investigated the association of trace metals in the sediments of Varapuzha estuary. Rajendran et al. (1982) reported that the rivers bring in trace metals both as dissolved species and also as adsorbed on to finally divided detrital matter. They also reported that trace metals in the suspended matter are displaced by major cations of sea water. Schoer et al. (1983) investigated the variations in chemical forms of iron, manganese and zinc in the suspended sediment. In a generalized review on heavy metals transport by particulate, Golterman et al. (1983) indicated the average ratio between dissolved and particulate associated transport in rivers is between 0.5 : 1 for copper and mercury on particles.

Studies undertaken on the lower reaches of the Bow and Oldman rivers in Alberta by Blachford and Ongly (1984) revealed that for all metals suspended matter is the major carrier phase. The comparative study on the suspended sediment load of the sea water with an adjoining estuary was carried out by Kurian (1987). Azis and Nair (1987) reported that trace metals are transported both as dissolved and particulate forms in the river Kallada which joins the Ashtamudi estuary. Sengupta and Kureishy (1987) reported that under favourable temperature the adsorption on to
suspended particles takes place, sink to the bottom resulting in a high concentration of sediments.

Ramesh et al. (1989) worked on the elemental chemistry of sediments and heavy metal distribution in Krishna river basin. Ouseph and Nair (1989) observed that the concentration of particulate contaminant increases with increase in salinity in Cochin estuary. Alain et al. (1994) investigated that the concentrations of particulate trace metal was higher in the Lot River. Nair (1997) reported that particulate metal concentrations were found to be higher in Beypore estuary.

5.3 Materials and Methods

Suspended Sediment

The surface water samples (500 ml) were filtered through pre-weighed Millipore filter paper of 0.45 μ pore size and a diameter of 47 mm. The filtering was carried out at 25 cm of mercury vacuum. After filtration, the fillers were rinsed with distilled water and dried at 60°C, cooled in desiccator and weighed. The difference in the initial and final weights gave the suspended sediment weight.

Particulate Trace metals

The dried filters containing the suspended sediments were used for Particulate Trace metals. Each filter paper was transferred to a conical flask containing 1 ml of perchloric acid. After evaporation the residue was digested with diluted HNO₃ and dried. The residue was then treated with 1 drop of concentrated HCl and dissolved in 0.1 N HCl and the volume was made up to 10 ml [FAO, 1975].
Blank filter papers were also treated similarly. Trace metals were analysed using AAS.

5.4 Results

5.4.1 Suspended Sediment

The suspended sediments measured during the study period, at stations I to VII are presented in Table 5a and are graphically represented in Fig. 5.1.

The amount of suspended sediment ranged from 2.42 mg/l (January) to 15.2 mg/l (August) at station I, from 4.8 mg/l (May) to 39.0 mg/l (August) at station II, from 0.4 mg/l (January) to 21.4 mg/l (August) at station III, and from 1.2 mg/l (January) to 38 mg/l (August) at station IV. The amount was between 0.6 mg/l (January) and 40 mg/l (August) at station V, between 2.0 mg/l (February) and 38.6 mg/l (August) at station VI, and between 3.3 mg/l (December) and 12.8 mg/l (August) at station VII.

In the present study, low amount of suspended sediment was recorded at station I and station VII. During the study time, a high value of 40 mg/l was observed at station V during August and a low value of 0.4 mg/l was recorded at station III during January. Seasonal average values of suspended sediment amount was maximum during monsoon and postmonsoon period, minimum during premonsoon season.

On comparing the suspended sediment load in stations at coastal zones, the estuary recorded higher values than bar mouth.
Table 5a. Longitudinal variation of suspended matter (mg/l)

<table>
<thead>
<tr>
<th>Station</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
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<td>3.6</td>
<td>2.42</td>
<td>3.6</td>
<td>7.6</td>
<td>6.4</td>
<td>8.2</td>
<td>5.8</td>
<td>6.28</td>
<td>15.2</td>
<td>6.39</td>
</tr>
<tr>
<td>II</td>
<td>7.13</td>
<td>24.0</td>
<td>8.0</td>
<td>14.8</td>
<td>10.0</td>
<td>6.0</td>
<td>4.8</td>
<td>8.02</td>
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<td>14.535</td>
</tr>
<tr>
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<td>0.4</td>
<td>13.6</td>
<td>10.6</td>
<td>11.7</td>
<td>12.0</td>
<td>14.6</td>
<td>18.2</td>
<td>21.4</td>
<td>11.99</td>
</tr>
<tr>
<td>IV</td>
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<td>30.0</td>
<td>1.2</td>
<td>4.0</td>
<td>4.8</td>
<td>4.9</td>
<td>10.0</td>
<td>3.0</td>
<td>23.0</td>
<td>38.0</td>
<td>13.89</td>
</tr>
<tr>
<td>V</td>
<td>32.4</td>
<td>20.8</td>
<td>0.6</td>
<td>2.8</td>
<td>12.6</td>
<td>12.0</td>
<td>6.0</td>
<td>11.5</td>
<td>27.5</td>
<td>40.0</td>
<td>16.64</td>
</tr>
<tr>
<td>VI</td>
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<td>3.2</td>
<td>18.4</td>
<td>2.0</td>
<td>2.4</td>
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<td>8.0</td>
<td>16.0</td>
<td>38.6</td>
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</tr>
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<td>6.02</td>
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<td>3.8</td>
<td>3.6</td>
<td>7.2</td>
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<td>9.0</td>
<td>8.5</td>
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<td>6.812</td>
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<tr>
<td>Mean</td>
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<td>6.34</td>
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<td>7.01</td>
<td>7.73</td>
<td>8.56</td>
<td>17.58</td>
<td>29.28</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 5.1 Longitudinal variation of suspended matter

1. November
2. December
3. January
4. February
5. March
6. April
7. May
8. June
9. July
10. August

Stations 1, 2, 3, 4, 5, 6, 7
Suspended matter (mg/l)

Stations 1, 2, 3, 4, 5, 6, 7
Suspended matter (mg/l)

Stations 1, 2, 3, 4, 5, 6, 7
Suspended matter (mg/l)
5.4.2 Particulate copper

The data obtained for monthly variations of particulate copper at stations I to VII during the study period are presented in Table 5b and are graphically represented in Fig. 5.2.

The concentration of copper particulate in the surface suspended sediment ranged between 0.10 mg/l (June) and 3.46 mg/l (November) at station I, between 0.09 mg/l (July) and 2.09 mg/l (November) at station II, between 0.11 mg/l (May) and 4.0 mg/l (November) at station III and between 0.28 mg/l (January) and 1.92 mg/l (June) at station IV. The range of copper particulate varied from 0.19 mg/l (January) to 0.88 mg/l (August) at station V, from 0.34 mg/l (January) to 1.42 mg/l (March) at station VI and from 0.17 mg/l (April) to 0.92 mg/l (August) at station VII.

In the present investigation, the spatial distribution indicates almost uniform pattern with a slight downward trend from the mouth (station I) to the head of the estuary (station II). The concentration of particulate copper showed almost a negative correlation with salinity in the riverine zone (stations III to VII).

The highest value of 4 mg/l was recorded at station III during November and the lowest value of 0.11 mg/l was recorded at stations II and III during May.

In the present study, the values of particulate copper in the suspended sediment were maximum in the postmonsoon period followed by monsoon period. The minimum values were recorded in the premonsoon period.
Table 5b. Longitudinal variation of particulate copper (mg/l)

<table>
<thead>
<tr>
<th>Station</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
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<td>3.46</td>
<td>0.13</td>
<td>0.53</td>
<td>0.67</td>
<td>0.51</td>
<td>0.28</td>
<td>0.43</td>
<td>0.10</td>
<td>0.14</td>
<td>2.98</td>
<td>0.923</td>
</tr>
<tr>
<td>II</td>
<td>2.09</td>
<td>0.22</td>
<td>1.60</td>
<td>1.17</td>
<td>0.28</td>
<td>1.60</td>
<td>0.11</td>
<td>0.18</td>
<td>0.09</td>
<td>0.15</td>
<td>0.749</td>
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<td>0.88</td>
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<td>0.82</td>
<td>0.11</td>
<td>0.23</td>
<td>0.17</td>
<td>0.76</td>
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</tr>
<tr>
<td>IV</td>
<td>1.29</td>
<td>0.90</td>
<td>0.28</td>
<td>0.37</td>
<td>0.37</td>
<td>0.35</td>
<td>0.40</td>
<td>1.92</td>
<td>0.97</td>
<td>0.52</td>
<td>0.737</td>
</tr>
<tr>
<td>V</td>
<td>0.64</td>
<td>0.58</td>
<td>0.19</td>
<td>0.68</td>
<td>0.70</td>
<td>0.33</td>
<td>0.41</td>
<td>0.58</td>
<td>0.63</td>
<td>0.88</td>
<td>0.562</td>
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<tr>
<td>VI</td>
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<td>0.76</td>
<td>0.34</td>
<td>0.54</td>
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<td>0.48</td>
<td>0.36</td>
<td>0.35</td>
<td>0.63</td>
<td>0.65</td>
<td>0.645</td>
</tr>
<tr>
<td>VII</td>
<td>0.55</td>
<td>0.18</td>
<td>0.43</td>
<td>0.21</td>
<td>0.46</td>
<td>0.17</td>
<td>0.32</td>
<td>0.29</td>
<td>0.58</td>
<td>0.92</td>
<td>0.411</td>
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<tr>
<td>Mean</td>
<td>1.85</td>
<td>0.457</td>
<td>0.607</td>
<td>0.55</td>
<td>0.625</td>
<td>0.575</td>
<td>0.306</td>
<td>0.521</td>
<td>0.459</td>
<td>0.98</td>
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</tbody>
</table>
Fig. 5.2 Concentration of particulate copper

- November
- December
- January

- February
- March
- April
- May

- June
- July
- August

Copper (mg/l)

Stations
5.4.3 Particulate iron

The results obtained for particulate iron in the surface suspended sediment at station I to VII are presented in Table 5c and are graphically represented in Fig. 5.3.

The concentration of iron particulate ranged from 2.38 mg/l (August) to 19.14 mg/l (January) at station I, from 2.39 mg/l (June) to 39.9 mg/l (January) at station II, from 3.44 mg/l (June) to 24.03 mg/l (January) at station III and from 2.63 mg/l (August) to 30.0 mg/l (December) at station IV. The range of iron particulate was between 2.8 mg/l (February) and 18.81 mg/l (January) at station V, between 2.25 mg/l (May) and 26.53 mg/l (November) at station VI and between 3.10 mg/l (November) and 26.07 mg/l (January) at station VII.

In the present study, the spatial longitudinal distribution of iron particulate showed only slight variations. All the stations, recorded higher values of particulate iron content compared with other metals in particulate form. Maximum value of 39.90 mg/l was recorded at station II and a minimum value of 2.25 mg/l was recorded at station VII. The annual average particulate content was higher at station IV and lower at station I.

The particulate iron content was found higher in the postmonsoon season and lower in the premonsoon and monsoon seasons.
Table 5c. Longitudinal variation of particulate iron (mg/l)

<table>
<thead>
<tr>
<th>Station</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
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<td>19.14</td>
<td>4.66</td>
<td>4.86</td>
<td>5.30</td>
<td>4.91</td>
<td>2.94</td>
<td>2.931</td>
<td>2.38</td>
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<td>4.85</td>
<td>39.90</td>
<td>4.82</td>
<td>4.96</td>
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<td>2.39</td>
<td>3.23</td>
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<td>5.40</td>
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<td>4.08</td>
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</tr>
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<td>3.20</td>
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<td>4.90</td>
<td>10.00</td>
<td>2.85</td>
<td>2.63</td>
<td>9.468</td>
</tr>
<tr>
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<td>8.97</td>
<td>9.34</td>
<td>18.81</td>
<td>2.80</td>
<td>12.80</td>
<td>12.00</td>
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<td>3.01</td>
<td>2.95</td>
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<td>4.85</td>
<td>4.32</td>
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<td>3.92</td>
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<td>4.30</td>
<td>4.63</td>
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<td>4.86</td>
<td>5.85</td>
<td>5.76</td>
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<td>5.771</td>
<td>5.564</td>
<td>4.777</td>
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</table>
Fig. 5.3 Concentration of particulate iron

---

**November**

Stations

**December**

**January**

**February**

**March**

**April**

**May**

**June**

**July**

**August**

---

Iron (mg/l)

Stations

1  2  3  4  5  6  7
5.4.4 Particulate zinc

The results obtained for longitudinal distribution of particulate zinc is the suspended sediment at stations I to VII are presented in Table 5d and graphically represented in Fig. 5.4.

The particulate zinc content ranged from 0.05 mg/l (December) to 5.07 mg/l (August) at station I, from 0.13 mg/l (December) to 4.81 mg/l (March) at station II, from 0.09 mg/l (July) to 5.7 mg/l (May) at station III, from 0.17 mg/l (July) to 3.63 mg/l (May) at station IV. The range of particulate zinc varied from 0.05 mg/l (December) to 2.41 mg/l (March) at station V, from 0.27 mg/l (December) to 2.98 mg/l (March) at station VI and from 0.31 mg/l (December) to 3.6 mg/l (May) at station VII.

In the present investigation, the highest value of 5.7 mg/l was observed during May at station III and the lowest value of 0.05 mg/l was recorded at stations I and V during December. Station I recorded maximum value of particulate zinc followed by stations III and II.

In the present study, higher values of particulate zinc content were recorded in the premonsoon and monsoon seasons and low values in the postmonsoon season.
Table 5d. Longitudinal variation of particulate zinc (mg/l)

<table>
<thead>
<tr>
<th>Station</th>
<th>Nov</th>
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<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Mean</th>
</tr>
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<td>0.95</td>
<td>3.00</td>
<td>3.11</td>
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<td>1.92</td>
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<td>0.22</td>
<td>0.17</td>
<td>0.98</td>
<td>1.359</td>
</tr>
<tr>
<td>V</td>
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<td>0.05</td>
<td>1.04</td>
<td>1.03</td>
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<td>1.80</td>
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</tr>
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<td>2.06</td>
<td>2.98</td>
<td>2.89</td>
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<td>0.19</td>
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<td>1.05</td>
<td>1.345</td>
</tr>
<tr>
<td>VII</td>
<td>2.16</td>
<td>0.31</td>
<td>1.28</td>
<td>2.15</td>
<td>2.88</td>
<td>2.48</td>
<td>3.60</td>
<td>1.70</td>
<td>0.39</td>
<td>0.89</td>
<td>1.784</td>
</tr>
<tr>
<td>Mean</td>
<td>1.495</td>
<td>0.18</td>
<td>1.013</td>
<td>2.131</td>
<td>3.014</td>
<td>2.948</td>
<td>2.991</td>
<td>0.822</td>
<td>0.837</td>
<td>1.512</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 5.4 Concentration of particulate zinc

- November
- December
- January

- February
- March
- April
- May

- June
- July
- August
5.4.5 Particulate manganese

The results obtained for longitudinal distribution of particulate manganese in suspended sediments at stations I to VII are presented in Table 5e and graphically represented in Fig. 5.5.

The concentration of particulate manganese ranged from 0 mg/l (May) to 1.91 mg/l (February) at station I, from 0.05 mg/l (May) to 2.66 mg/l (January) at station II, from 0.23 mg/l (December and August) to 2.65 mg/l at station III, and from 0.16 mg/l (December) to 5.71 mg/l (March) at station IV. The concentration varied from 0.15 mg/l (July) to 2.91 mg/l (March) at station V, from 0.22 mg/l (December) to 5.19 mg/l (March) at station VI and from 0.14 mg/l (May) to 2.15 mg/l (March) at station VII.

In the present investigation the spatial distribution showed almost uniform pattern. Station IV recorded the highest concentration of particulate manganese. This was attributed to the untreated sewage disposal. This was in agreement with the observations made by Kanwar and Randhawa (1974) in Darbhanga rivers.

In the present study, the seasonal variations were not well pronounced. However particulate manganese recorded maximum values at all the stations in the premonsoon season. During premonsoon season the freshwater discharge through the river was minimum and hence heavily polluted.
### Table 5e. Longitudinal variation of particulate manganese (mg/l)

<table>
<thead>
<tr>
<th>Station</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.13</td>
<td>0.25</td>
<td>1.32</td>
<td>1.91</td>
<td>0.73</td>
<td>0.32</td>
<td>0.00</td>
<td>0.27</td>
<td>0.67</td>
<td>0.55</td>
<td>0.715</td>
</tr>
<tr>
<td>II</td>
<td>2.17</td>
<td>0.32</td>
<td>2.66</td>
<td>1.66</td>
<td>1.36</td>
<td>1.72</td>
<td>0.05</td>
<td>0.34</td>
<td>0.40</td>
<td>0.41</td>
<td>1.109</td>
</tr>
<tr>
<td>III</td>
<td>1.20</td>
<td>0.23</td>
<td>1.73</td>
<td>1.54</td>
<td>2.65</td>
<td>2.29</td>
<td>0.25</td>
<td>0.62</td>
<td>0.80</td>
<td>0.23</td>
<td>1.163</td>
</tr>
<tr>
<td>IV</td>
<td>1.81</td>
<td>0.16</td>
<td>0.90</td>
<td>1.61</td>
<td>5.71</td>
<td>3.30</td>
<td>0.16</td>
<td>1.38</td>
<td>0.38</td>
<td>0.55</td>
<td>1.596</td>
</tr>
<tr>
<td>V</td>
<td>0.95</td>
<td>0.24</td>
<td>0.50</td>
<td>0.55</td>
<td>2.91</td>
<td>0.78</td>
<td>0.21</td>
<td>2.85</td>
<td>0.15</td>
<td>2.82</td>
<td>1.196</td>
</tr>
<tr>
<td>VI</td>
<td>0.85</td>
<td>0.22</td>
<td>0.85</td>
<td>1.42</td>
<td>5.19</td>
<td>1.55</td>
<td>0.24</td>
<td>1.23</td>
<td>0.50</td>
<td>0.68</td>
<td>1.273</td>
</tr>
<tr>
<td>VII</td>
<td>1.58</td>
<td>0.20</td>
<td>1.28</td>
<td>0.55</td>
<td>2.15</td>
<td>1.25</td>
<td>0.14</td>
<td>1.16</td>
<td>0.42</td>
<td>1.32</td>
<td>1.005</td>
</tr>
<tr>
<td>Mean</td>
<td>1.384</td>
<td>0.2314</td>
<td>1.32</td>
<td>1.32</td>
<td>2.957</td>
<td>1.6014</td>
<td>0.15</td>
<td>1.121</td>
<td>0.487</td>
<td>0.937</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 5.5 Concentration of particulate manganese

- November
- December
- January

- February
- March
- April
- May

- June
- July
- August

<table>
<thead>
<tr>
<th>Stations</th>
<th>Stations</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.5 Discussion

Many toxic substances are rapidly adsorbed by the sediments during river discharge and the transport of such substances from the land surface to rivers is frequently in association with particulate materials. Klemas et al. (1977) stated that suspended sediments could be used as a natural tracer to determine the surface circulation in estuarine and coastal regions.

In the present study, the amount of suspended sediment was higher during monsoon and postmonsoon seasons and lower during premonsoon season. Higher values of suspended sediment during monsoon and postmonsoon may be due to heavy influx of monsoonal flood with heavy load of eroded materials. During July and August high suspended sediment was noticed at all the seven stations. The observations carried out by Azis and Nair et al. (1987) in Ashtamudi estuary revealed that only during monsoon months, higher concentration of suspended sediments were observed both in estuary and in river. This was in conformity with the present investigation during monsoon season. In Muvattupuzha river, Balachand (1983) noted an increase in suspended sediment load in rainy season and he predicted that high amount of suspended sediment was probably brought in by land drainage. However, during postmonsoon season, the contribution by the rivers receded and a comparatively low amount of suspended sediment was noticed. Similarly, a comparatively low suspended sediment concentration was noticed during postmonsoon season in the present investigation also.
In the present study, the seasonal average values showed that the suspended sediment load was found to be low during premonsoon season. This was attributed to the low river discharge during this period compared to the monsoon period. But the spatial distribution showed that during premonsoon period, relatively higher concentration of suspended sediment load was observed at stations I and II. This was because stations I and II are situated near the sea, where intrusion of sea water enhances the suspended sediment load. The resuspension of bottom mud also increased the suspended sediment load. This findings was in conformity with observations in Beypore estuary during premonsoon period by Nair (1995).

The annual average suspended sediment load of station II (14.535 mg/l) was higher than that of station I (6.39 mg/l). This was because station II was situated towards the mouth of the river where addition of more and more freshwater enhanced suspended sediment load. Meade (1969) reported that estuaries with large upstream drainage basins, such as Chesapeake Bay, receives sediment mainly from river runoff. Substantial contribution by rivers to the estuarine suspended sediment was also reported by Biggs (1970) and Schubel et al. (1976). The higher concentration of suspended sediment observed at station II (estuary) may also be due to the entrainment from the deeper layers owing to one or several physical factors such as waves and currents operative in this area. The shallowness of the estuary, the texture of the bottom sediments and its rheological behaviour also decide the nature of resuspension process in estuaries. Postma (1967) observed a temporal increase in suspended sediment concentration due to increased wave action and
shallowness of the estuary. Dyer (1978) has pointed out that hysteresis between maximum current velocity and the suspended sediment is an important factor in determining turbidity maxima. The influx of water having high sediment load creates zone of turbidity (Allen, et al. 1976). At station II, turbulence owing to boating activities also causes resuspension of surficial sediment which may enhanced the suspended sediment load.

In the present investigation, the amount of suspended sediment recorded during March ranged between 2.4 mg/l (station IV) and 12.8 mg/l (station V). The value recorded in the estuary was found to be 10 mg/l. Similar type of monthly distribution was observed by Sankaranarayanan and Stephen (1978) in Vembanad lake. They observed the range between 0 mg/l to 25 mg/l during March with 10 mg/l concentration for station near coastal region.

In the present study, the higher concentration of suspended sediment in other stations may be due to resuspension of bottom mud by the disturbance caused by fishing, washing activities, industrial effluents and agricultural land wash off. This was in conformity with the observations made by Balachand (1983) in Muvattupuzha river.

Copper often occurs in high concentration in rivers than in sea water. Although the suspended particles contain a large fraction of the total copper transported by the rivers (Troup and Bricker, 1975), the significance of the
particulate fraction with respect to copper cycling in small since much of copper remains fixed in a crystalline form.

In the present investigation, the spatial distribution of particulate copper did not show any noticeable trend. The concentration of particulate copper was higher at station I. This was because, station I was situated near the sea. The high value was attributed to the desorption of river borne particulate matter, flux of copper from digentic remobilisation from bottom sediments or due to anthropogenic input. This was in conformity with the observations of Garvin et al. (1977). Sholkovitz (1976) reported that 40 per cent of total dissolved copper is transferred to its particulate form during mixing. Rajendran et al. (1982) reported that when river water mixes with saline water the trace metals in the suspended sediment are replaced by major cations.

In the present study, the concentration of particulate copper showed high values in the postmonsoon and monsoon seasons. The highest values were recorded when the river was flooded with freshwater. The higher particulate copper content was mainly due to the contribution of river run off. Similar type of observation was made by Valenta et al. (1983). They recorded low concentration of particulate trace metals in summer due to high biological activity.

The estuarine and river basins are rich in the metal iron content when compared with other metal concentration. Gibbs (1977) carried out extensive studies to elucidate transport mechanisms of Cr, Mn, Fe, Co, Ni and Cu in the Amazon and
Yukon river waters. He reported that the main transport phases of Cr, Mn, Co, Fe, Ni and Cu are crystalline particles and hydroxide coatings over suspended material and together these two mechanism contribute 65-92 per cent of metal transport.

In the present investigation, a high concentration of iron was recorded in the particulate form than in the dissolved form at all the stations. This was in agreement with the observations conducted in Ashtamudi estuary (Rema Devi, 1994).

In the present study, iron content in the surface sediment-particulate during different seasons showed pronounced variations. In the present study the concentration of particulate iron was maximum in the postmonsoon and minimum in the monsoon and premonsoon seasons. The higher concentration during postmonsoon was mainly caused by river run off after heavy rainfall. The postmonsoonal increase of particulate iron in the present study was in confirmation with similar type of observation by Valenta et al. (1983). They observed distinctly higher levels of trace metals during winter.

In the present study, the concentration of particulate iron exhibited a clear upward trend from the bar mouth (station I) to the head of the estuary (station II). The particulate iron content decreased with increase in salinity. The relation between minimal particulate trace metal and salinity was observed by Groot et al. (1971) in Rhine river. They noticed a steady decrease in the distribution of particulate trace metals of highly polluted Rhine river with increase in salinity.
In the present investigation, the longitudinal distribution of particulate zinc content at all the stations showed pronounced variation. The annual average zinc content at station I was found to be higher. This was because this station was situated near the sea. Zinc can exist in sea water in dissolved state, as solid precipitate or adsorbed to particle surface. (Rema Devi, 1994). The elevated level of zinc at this coastal station may be due to a mixture of effluents reaches this area.

The concentration of particulate zinc was higher in the premonsoon and monsoon seasons. The highest values were recorded when the river was flooded with freshwater. The highest value in the premonsoon was due to the evaporation which caused minimum flow of water and heavy pollution.

Rust and Waslenchuk (1974) found that Fe, Mn and Hg were more associated with the fine grained phase of the sediments of Ottawa river water. Laboratory studies carried out by Hunt (1981) has shown that manganese can be rapidly transferred to the particulate phase following a skeletonia costatum bloom. Flocculant organic particulate matter derived from the bloom implicated in the transfer phase. He suggested that the removal of manganese from the water column of the near shore and open ocean was due to adsorption by the flocculant organic matter derived from phytoplankton. This implies that in the coastal zone as well as in other regions, particulate organic floc can incorporate trace metals like manganese.
In the present study, almost uniform pattern was noticed in the spatial distribution of particulate manganese. Station II (estuary) recorded higher value of particulate manganese when compared with station I (barmouth). This may be due to increased land drainage and river discharges. This was in agreement with the observations made in Visakhapatnam harbour by Bhavanarayana and Subramaniam (1986). Station IV recorded maximum value of particulate manganese content (1.596 mg/l), the minimum value of (0.715 mg/l) was recorded at station I.

In the present investigation, higher values of particulate manganese content were recorded in the premonsoon season and lower values in the monsoon and postmonsoon seasons. During premonsoon season, freshwater discharge through the river was minimum which attributed to more pollution.

From the above discussion, it is clear that in the present investigation higher concentration of particulate iron and particulate zinc were recorded when compared with the particulate copper and manganese. This may be due to the river water which flows through the lateritic bed, boat activity and sewage disposal during the period when freshwater discharge was low. This is in agreement with the observations made by George et al. (1984). They noticed a decline in the metal content during monsoon season mainly due to increased load of suspended matter causing desorption of metals. In the present study also, particulate iron, zinc and manganese recorded minimum values in the monsoon period.
The observations made by Sankaranarayanan and Stephen (1978) in Cochin backwater recorded higher levels of some of the metals in particulate form which were attributed to the activity in the harbour area and to industrial effluents. Similarly in Beypore estuary Nair (1995) observed and recorded higher values of metals in particulate form due to industrial and domestic pollution. In the present investigation also the comparatively higher concentration of iron and zinc in particulate form was in confirmation with the observations of Sankaranaryanan and Stephen (1978) and Nair (1997).