INTRODUCTION

In an aquatic ecosystem, sediment acts as sink and source of materials. The studies on the chemical characteristics of the backwater sediments are useful in assessing the water quality and management of ecosystem. Studies on the role of sediments in a natural water body in element cycles, transportation of nutrients and contaminants and preservation of the water quality are important for the understanding of an aquatic ecosystem. The sediments mainly govern the nutrient economy of an aquatic ecosystem and knowledge on the role of sediment - nutrients is especially useful in determining the sediment water interactions, which eventually affect the productivity (Nair et al., 1984). Sediment analysis of aquatic environment has drawn greater attention in the world’s scientific scenario due to growing awareness of environmental pollution and its impact on ecosystem. The most important raw materials for plant productivity in aquatic systems are organic and inorganic forms of carbon, nitrogen phosphate, light and micronutrients. Textural characteristics of sediments play a significant role in the distribution and concentration of carbon, nitrogen and phosphorous, both in the sediment and in the overlying water column.


MATERIALS AND METHODS

The sediment samples were collected every month from the six stations from February 2001 to January 2002. A part of air-dry samples is used for the textural analysis by the pipette method suggested by Krumblon and Pettijohn (1938). Some portion of sediment samples were taken and dried in oven at 100-105°C over night, for analysis of organic carbon, total phosphorous,
total nitrogen, and other elements. The organic carbon content of the sediment samples was analysed by an oxidation method as adopted by EI Wakeel and Riley (1957). Total phosphorous content of sediment sample was measured by the modified method of Murphy and Riley (1962) and total nitrogen by Kjeldahl method described by Barnes (1959). The major ions like Na, K, Li and Ca were determined using flame photometer based on the procedure described in APHA (1995).

RESULTS

Analysis reveals that the sandy material (coarse sand) dominated all through the year, other fraction showed some regular fluctuations in all the stations. The seasonal data on sand, silt and clay fractions of each the station along with their textural classification (Shepard, 1954) is presented in Table 1. Maximum value coarse sand was observed during monsoon season and minimum during premonsoon season at all the stations. Maximum sandy materials (94.69%) were noticed at station I and a minimum (63 %) at station IV. The season wise percentage of clay was maximum during premonsoon and was minimum during monsoon at all stations. Over all, station II, IV and V showed minimum during post monsoon season. Only the station VI showed minimum organic content during monsoon. Maximum mean seasonal values of organic carbon were recorded during monsoon period except in stations I and VI, where the content were high during premonsoon. Annual mean value of organic carbon content recorded a low value at station II and high value at station IV. Analysis of variance of organic carbon revealed that only the variations between the six stations were significant at 1 % level (Table 3).

Total nitrogen content of the sediment varied from 0.08mg/g to 3.88 mg/g (Table 2). The seasonal mean values of total nitrogen were minimum during premonsoon at the stations II, IV and VI, during monsoon at station III and V, and during post monsoon at station I. The maximum value of total nitrogen was recorded during monsoon at stations II, IV and VI, during premonsoon at station I and III, during post monsoon at station V. Minimum annual mean was recorded at station II and maximum at station V. Statistical analysis showed that there is no significant variation between season and months. However, the difference between station was significance.

Table 1: Seasonal variation of soil texture (%) at six stations of Paravur - Kappil backwaters

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Stations</th>
<th>Seasonal Mean</th>
<th>Premonsoon</th>
<th>Monsoon</th>
<th>Post monsoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand I</td>
<td>92.45</td>
<td>94.69</td>
<td>93.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>89</td>
<td>90.5</td>
<td>89.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>86.5</td>
<td>88.86</td>
<td>88.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>63</td>
<td>64.94</td>
<td>64.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>71.31</td>
<td>72.77</td>
<td>71.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>73.11</td>
<td>75.32</td>
<td>74.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay I</td>
<td>6</td>
<td>4.01</td>
<td>6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>8.85</td>
<td>7.98</td>
<td>8.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>9.21</td>
<td>8.96</td>
<td>8.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>21.1</td>
<td>20</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>16.82</td>
<td>16.07</td>
<td>16.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>23.4</td>
<td>20.5</td>
<td>22.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silt I</td>
<td>1.51</td>
<td>1.3</td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>2.12</td>
<td>1.5</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>4.26</td>
<td>2</td>
<td>2.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>15.89</td>
<td>14.56</td>
<td>14.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>11.94</td>
<td>11</td>
<td>11.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>3.62</td>
<td>3.58</td>
<td>2.43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

maximum values were noted (22.4 %) at station VI and minimum values (4.01 %) at station I. The silt content was maximum during premonsoon and a minimum during post monsoon season at all the stations. The silt content was high (15.89 %) at station IV and low at station I. Mean seasonal values of organic carbon did not show a general pattern (Table 2). Stations II and III showed minimum values during premonsoon, while station I, IV and V showed minimum during post monsoon season. Only the station VI showed minimum organic content during monsoon. Maximum mean seasonal values of organic carbon were recorded during monsoon period except in stations I and VI, where the content were high during premonsoon. Annual mean value of organic carbon content recorded a low value at station II and high value at station IV. Analysis of variance of organic carbon revealed that only the variations between the six stations were significant at 1 % level (Table 3).

Mean seasonal values of sodium showed that a minimum value was observed during monsoon at all the stations and the maximum was observed during post monsoon except at station I and V, where the maximum
IV (Table 2). Statistical analysis revealed that only the variations between the six stations were significant at 1 % level. The mean seasonal values of calcium showed a low during post monsoon season at station II and III, while at station I, V and VI, it was minimum during monsoon. In the stations IV, it was minimum during premonsoon season (Table 2). High values of calcium concentrations were observed during premonsoon season at stations I, II, III and VI. While at the stations IV and V it was during monsoon and post monsoon seasons respectively. Minimum annual mean was recorded at station VI and maximum at station IV. Analysis of variance revealed that there was no significant variation between stations, season and months between seasons.

The general distribution of lithium for surficial sediment varied between 0.034 mg/g and 0.19 mg/g (Table 2). The mean seasonal value of lithium was low during the monsoon season except in stations IV and V, where it was low during monsoon and post monsoon seasons respectively. Minimum annual mean was recorded at station VI and maximums at station I. Analysis of variance of calcium revealed that there was no significant variation between stations, season and months between seasons. The mean seasonal values of calcium showed a low during post monsoon season at station II and III, while at station I, V and VI, it was minimum during monsoon. In the stations IV, it was minimum during premonsoon season (Table 2). High values of calcium concentrations were observed during premonsoon season at stations I, II, III and VI. While at the stations IV and V it was during monsoon and post monsoon seasons respectively. Minimum annual mean was recorded at station VI and maximums at station I. Analysis of variance of calcium revealed that there was no significant variation between stations, season and months between seasons.
Table 4: Correlation coefficient between the various geo-chemical parameters at six stations of Paravur- Kappil backwaters

<table>
<thead>
<tr>
<th></th>
<th>Station I</th>
<th>Station II</th>
<th>Station III</th>
<th>Station IV</th>
<th>Station V</th>
<th>Station VI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O.C</td>
<td>T.N</td>
<td>T.PO</td>
<td>K</td>
<td>Na</td>
<td>Li</td>
</tr>
<tr>
<td>O.C</td>
<td>-</td>
<td>-0.205</td>
<td>-0.089</td>
<td>0.214</td>
<td>0.095</td>
<td>0.030</td>
</tr>
<tr>
<td>T.N</td>
<td>-0.118</td>
<td>-0.217</td>
<td>0.312</td>
<td>-0.229</td>
<td>0.126</td>
<td>-0.336 T.N.</td>
</tr>
<tr>
<td>T.PO</td>
<td>0.263</td>
<td>-0.117</td>
<td>-0.032</td>
<td>-0.243</td>
<td>-0.058</td>
<td>-0.503 T.PO.</td>
</tr>
<tr>
<td>K</td>
<td>0.303</td>
<td>0.023</td>
<td>0.128</td>
<td>-0.164</td>
<td>0.151</td>
<td>-0.454 K</td>
</tr>
<tr>
<td>Na</td>
<td>0.351</td>
<td>-0.008</td>
<td>0.221</td>
<td>0.972**</td>
<td>-0.7388**</td>
<td>-0.491 Na</td>
</tr>
<tr>
<td>Li</td>
<td>0.170</td>
<td>-0.415</td>
<td>0.348</td>
<td>0.043</td>
<td>0.142</td>
<td>-0.290 Li</td>
</tr>
<tr>
<td>Ca</td>
<td>0.407</td>
<td>-0.133</td>
<td>0.188</td>
<td>0.940</td>
<td>0.966**</td>
<td>0.257 Ca</td>
</tr>
</tbody>
</table>

Station - I O.C T.N T.PO K Na Li Ca
-0.360 -0.06 0.868** 0.543 0.233 0.079 O.C
0.18 0.672* 0.185 -0.005 -0.483 T.N.
-0.497 -0.239 -0.047 -0.392 -0.533 -0.570 T.PO.
0.164 -0.394 0.529 -0.537 0.101 -0.180 K
0.081 0.019 -0.192 0.429 -0.184 0.307 Na
0.145 0.524 0.156 0.319 0.563 -0.490 Li
0.021 0.618* 0.146 -0.274 0.145 0.538 - Ca

Station - II O.C T.N T.PO K Na Li Ca
0.365 0.513 0.704* 0.549 0.843** 0.647* O.C
0.377 0.202 0.075 -0.056 -0.023 T.N.
0.118 0.253 -0.116 0.111 0.670* 0.490 T.PO.
0.940* 0.124 0.106 -0.626* 0.728** 0.472 K
0.327 -0.113 -0.361 0.436 -0.618* 0.793** Na
-0.125 -0.088 0.245 -0.010 0.010 - 0.802** Li
-0.324 0.146 -0.306 -0.300 0.288 -0.203 - Ca

Station - III O.C T.N T.PO K Na Li Ca
0.085 0.531 0.704* 0.549 0.843** 0.647* O.C
0.377 0.202 0.075 -0.056 -0.023 T.N.
0.118 0.253 -0.116 0.111 0.670* 0.490 T.PO.
0.940* 0.124 0.106 -0.626* 0.728** 0.472 K
0.327 -0.113 -0.361 0.436 -0.618* 0.793** Na
-0.125 -0.088 0.245 -0.010 0.010 - 0.802** Li
-0.324 0.146 -0.306 -0.300 0.288 -0.203 - Ca

DISCUSSION

Grain size is one of the basic attributes of sediments and its determination is essential to delineate the sedimentary environments. In general, the study of grain size distribution reveals the physical effects of the environments on deposition and the hydrodynamic conditions existing at the time of deposition. Textural characteristics of sediments play a significant role in the distribution and concentration of carbon, nitrogen and phosphorous, both in the sediment and in the overlying water column. The season wise data of textural characteristics showed moderate variation in the Paravur-Kappil backwater system. The entire area of Paravur backwater, except station IV was composed of sandy sediments, where vast quantity of sand was noted, when compared with the other stations. The sandy nature of the entire area may be due to the excess deposition of sand from the sea by tidal cycle through the artificial canal (spillway shutter). Shaji (2002) also reported a huge deposition of sand in the Paravur backwater system.

In the present study, the sediment organic carbon contents did not show a general pattern. The sediment organic carbon varied from station to station depending on the nature of soil texture as well as hydrological conditions. The higher concentration of organic carbon was observed at station IV, while the lower concentration was exhibited at stations II. It is well known that the sediment behaves as the storehouse of essential elements / molecules of productivity of over lying water and pollutants. Organic carbon is important as an energy source for organisms in aquatic systems. Estuarine/backwater sediments are richer in organic matter than those of the adjacent seas (Nixon and Lee, 1982). The high organic carbon content observed at stations IV, V and VI may be due to the deposition of terrestrial organic matter from the excessive land run off, settling of detritus matter and decay of vegetation (Prasanthan, 1999 and Rashid and Reinson, 1979). The higher organic carbon content in station IV may be due to the retting of coconut husk: the practice of dumping coconut pith into the adjacent water after processing is prevalent (Nair et al., 1983). The seasonal mean of organic carbon content showed a maximum during monsoon season and a minimum during premonsoon and postmonsoon in almost all stations. But station VI showed a minimum value during monsoon season. The high content organic carbon at station I and VI during premonsoon may be due to death and decay of vegetation, disposal of poultry wastes and more or less stagnant nature of water. Observations made by Retmanai and Nayar (1996), Prasanthan (1999) and Santhosh (1999)
also concluded with this statement. But the low organic content in station III, which is adjacent to the estuary, may be due to the high deposition of sand particles from the sea through tidal cycle. This finding is in agreement with the result of Nair et al., (1983). The sediment in the drowned river channel near the mouth has the highest organic content in the entire estuary, because a complex series of depositional mechanisms are operative in this region during each tidal cycle (Kranck, 1974). This argument is satisfied with the increased organic carbon content in the riverine zone of Paravur-Kappil backwater.

Shanmughappa (1981) recorded a maximum concentration of organic carbon during monsoon and a minimum during summer. This is in agreement with present study. He also pointed out that high concentration of organic carbon in an aquatic medium is due to the bulk of organic matter derived from fresh water run off or through seepage from land. The comparatively decreased concentration of organic carbon in stations I, II and III may be due the nature of sediment. Because sediment's nature influences abundance of organic matter. The above pointed stations were always containing more than 85% sand was encountered. Hence, low values were observed at this station throughout the period of study. This also is in agreement with the finding of Shanmughappa (1987) in Vellar estuary.

In general, sediment organic carbon was more abundant and more widely distributed in the Paravur backwater system. Alagarswamy (1991) opined that if the sediment organic carbon is less than 5% the estuary or lake could be considered as unpolluted. From the investigation of the present study, all the stations exhibited organic carbon content of less than 5%. This clearly indicated that the station was unpolluted with organic carbon. A comparison of the concentration of organic carbon reported at the various aquatic systems with present system showed that only a moderate concentration of organic carbon was present in the sediment samples of station IV and V. The higher concentration observed in various stations may be due to the significant load of vegetative matter brought in by freshwater from the discharge of the Ithikkara river, retting of coconut and land run off into the Paravur-Kappil backwater. The shallow ness of water, retting operation near the station IV and minimum flushing leads to higher setting of organic matter to the sediments.

Maximum values of total nitrogen (3.88 mg/g) were found in the month of May at station I, while minimum value (0.08 mg/g) was noticed during the months of March and June at station II and III. Higher value of total nitrogen at station I may be due to dumping of poultry waste and decay of vegetation. Like wise the low concentration of total nitrogen at stations II and III may be due to the accumulation high load of sand deposition from the sea though tidal cycle. This is agreement with findings of Prasanthan (1999) at Parvathyputhen Ar and Nair et al., (1987) at Ashtamudi estuary. The dissolved oxygen content in the water system is less (more or less anoxic), where high amount of nitrogen is released. The high amount to nitrogen in the water gets adsorbed onto sediments. Sivakumar et al., (1983) recorded higher values during premonsoon season, which agrees with the value obtained at stations III and VI of the present study. Nair et al., (1983) observed high seasonal values of total nitrogen in the Ashtamudi estuaries during monsoon, which they attributed to the heavy disposal of effluent from Punalur paper mills. In the present investigation stations II, III, IV and V exhibited high seasonal average values during monsoon. This may be due to anthropogenic influence, coir retting and river discharge. More over monsoon plays an important role for the high concentration of total nitrogen in sediment due to the land run off into the lake (Santhosh, 1999).

The total phosphorous content varied between a high value of 1.136 mg/g (Apr.) at station V and low value of 0.161 mg/g (Apr.) at station IV. Sivakumar et al., (1983) observed higher value of total phosphorous content in sediment of Vellar estuary during monsoon and a lower value during summer, which is in agreement with the present investigation where maximum values were obtained during monsoon at station II, III, IV and V. At station VI maximum seasonal average values were observed during premonsoon. This may be due to pollution by anthropogenic activities, disposal of waste and decay of vegetation. Nair et al., (1983) and Nair et al., (1984) also observed similar increase in phosphorous level in the polluted zone. A lower concentration of phosphorous was registered at all stations along the Paravur - Kappil backwater when compared with the values reported by Rethnamani and Nayar (1996). It may be due to the sandy nature of the sediment with negligible amount of silt and clay. However, the present study revealed that the total phosphorus content of Paravur backwater showed a decrease, when compared with the earlier works.

Qasim and Sankaranarayanan (1972) reported a total phosphorus variation in the detritus of the Cochin backwater between 1.3 and 1.9 mg g\(^{-1}\). The higher concentration of sediment phosphorous was due to the effect of domestic wastes and land run-off. In the present study, the higher concentration was noticed during monsoon season almost in all stations. This may be due to variability of the texture. Santhosh (1999) also observed high concentration of phosphorous during monsoon and premonsoon at Paravur canal. Murty and Veerayya (1972) have also reported the phosphorus concentration (0.04 mg g\(^{-1}\) to 1.68 mg g\(^{-1}\)) of mud collected from the Vembanad Lake during northeast monsoon. This finding agrees with the maximum values obtained at station I during post monsoon.
monsoon season in the present study. Thus variability has been explained due to the variability in the texture of the sediments, which is an agreement with the present investigation.

Monthly variation in potassium content in the sediment ranged between 0.44 mg/g (Mar.) at station II to 6.54 mg/g at station I. In general, the distribution of potassium concentration fluctuated without any order. The present investigation revealed that low potassium content was noticed almost at all the stations, when compared with the observations made by various investigators (Sajan, 1988; Mohan, 1990). Samin et al., (1992) reported that the sediments of Goksu River have a mean concentration of 5.5 mg/g to 21.7 mg/g. Mohan (1990) also reported a concentration of 4.795 mg/g in the sediments of Vellar estuary and Sajan (1988) estimated 3.707 mg/g potassium from the sediments of Ashtamudi Lake. In the present study, the concentration of potassium in the sediments collected from different stations of Paravur and Kappil backwater was found to be very low as compared to other backwaters. Seasonal average values recorded a maximum during monsoon at all stations, except in stations I, II and VI, where a high concentration was observed during premonsoon and post monsoon season respectively. Similar types of observations were made by Nair et al., (1987) and Santhosh (1999). In general, almost all stations showed a low concentration of potassium concentration. This is agreement with the findings of Prasanthan (1999) at Parvathyputhan Ar. The concentration of potassium was higher at station I than in the other stations, which may be due to the disposal of sewage water, poultry waste and decay of vegetation. Concentration of the potassium may increase due to the disposal of waste (Prasanthan, 1999). The low concentration of potassium in almost all stations may be due to presence heavy sand deposition and diminishing of organic detritus. Nair et al., (1983) suggested that the organic detritus associated with potassium entered the system mainly by leaching. At station VI the maximum concentration of potassium was during post monsoon season. This may be due to after effects of monsoon. Nair et al., (1984) also observed a high concentration of potassium during Post monsoon at riverine zone.

The highest value of sodium content noticed was 8.4 mg/g (Dec.) at station IV and the lowest value of 0.4 mg/g (JUL., JUN.) was at stations IV and VI. Slightly increased value was noticed at stations I and V, when compared with the values of other stations. Over all, the concentration of sodium value observed in this study was lower than the normal concentration of sodium in the soil except in station I, IV and V. The mean season wise observation showed a minimum concentration during monsoon at all the stations. This may be due to the heavy sand deposition from the sea through artificial canal by tidal cycle and heavy fresh water discharge from the Ithikkara River. Maximum concentration of sodium was observed during post monsoon except in stations I and V, where the maximum was noted during premonsoon season. This finding is agreement with the observation of Hoq et al., 2002. Some earlier investigators reported the level of sodium concentration in the sediments of various systems. Mohan (1990) reported a maximum concentration of sodium (8.20 mg/g) in Vellar estuary. Sajan (1988) reported a value of 7.663 mg/g of sodium concentration from Ashtamudi Lake. Samin et al., (1992) estimated 3.630 mg/g to 4.8 mg/g from the sediments of Goksu River. Samin et al., (1992) also reported the sodium concentration, which ranged from 11.1 mg/g to 12.7 mg/g in the sediments of Mediterranean Sea. The higher concentration of sodium observed in the present study at station IV may be due to the mineralogical composition of the sediment. The parameters that generally modify the sodium, potassium contents in the sediments are the grain size of the sediment, the clayey sediment presents a better adsorption of sodium (Weaver, 1967), the salinity distribution and the pore water composition. Many industrial wastes and domestic sewage are rich in sodium and increase its concentration in natural water after disposal (Trivedi and Goel, 1986). Thus we can conclude that the first and fourth stations were highly polluted than other stations during the period of study, as the concentrations of sodium were highest in these stations.

Monthly variation of calcium content in the sediments of Paravur-Kappil backwater showed that the highest concentration was at stations I and the lowest concentration was at station VI. The maximum levels of calcium observed during the month of April at station I and it also increases at stations II, III and V. This may be due to the presence of increased carbonate content, which was confirmed by the shell fragments found on the sediments of these stations. Sajan (1988) reported the mean concentration of 14.233-mg/g calcium in the sediments at Ashtamudi Lake and pointed out that the calcium carbonate variation in the Ashtamudi lake sediments may be due to the presence of large amount of shell fragments in the sediments. Season wise analysis showed a maximum concentration of calcium during premonsoon season except in stations VI and V, where maximum was observed during monsoon and post monsoon season respectively. Prasanthan (1999) also pointed out the same seasonal changes in the concentration of calcium in Parvathyputhanar. Hoq et al., (2002) also noticed the same seasonal changes in the concentration of calcium. Some investigations have been done on the estimation of calcium content in earlier times. Mohan (1990) have estimated 5.070 mg/g calcium content from the sediments of Vellar estuary. Sajan (1988) observed a value of 14.223 mg/g in the sediments of Ashtamudi. In
general, low concentration of calcium was found at all stations located along Paravur-Kappil backwater which may be due to the substratum and the high sandy nature of the sediments.

Paravur - Kappil backwaters showed a minimum concentration of lithium at all stations throughout the year. Monthly variation of lithium in the sediment of Paravur-Kappil backwater ranged from 0.034 mg/g to 0.19 mg/g. The highest value was noticed at station IV during May and minimum concentration of lithium was noticed at station II during September. The season wise average value of lithium concentration showed a maximum during monsoon and post monsoon and comparatively low during monsoon except station IV and V, where minimum was recorded during post monsoon season. Higher concentration of lithium at station IV may be due the leaching of sediment. Information available on the distribution of the major element lithium is very little. Leivuori et al., (1993) studied the distribution of lithium and other trace metals in the sediments of the Gulf of Bothnia, which is comparatively lower than that of the present study. Prasanthan (1999) also pointed out a least concentration of lithium during monsoon and high during Premonsoon and post monsoon season. Sheela (1996) recorded maximum concentration of lithium in Kayamkulam Lake and it ranged from 0.01 mg/g to 250 mg/g. This concentration is higher than that of the present study. The lithium concentration in the present investigation showed a more or less negligible quantity in all the stations.

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