

# Short Communications

## Sediments of Cochin Backwaters in Relation to Pollution

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Organic carbon, nitrogen, C/N-ratio and nature of sediments at 4 stations, viz. upstream of industrial complex (st 1), effluent discharge area (st 2), barmouth (st 4) and point about midway between sts 2 and 4 (st 3), on the northern limb of Cochin backwaters are reported. Effluents discharged into the river Periyar at Udyogamandal (Eloor), prior to its joining the backwaters cause high local fluctuations in the parameters studied. Seasonal variations are most pronounced at st 2 and least at st 3. Fine grained sediments and organic matter show a direct relationship only at st 4. Organic carbon and nitrogen though positively correlated at all stations is significant only at st 1. Nature and extent of fluctuations in the composition and nature of sediments at st 2 indicate a high stress environment.

Relative dominance of coarse fractions over fine grained material in the sediments of estuaries depends on the shape of the estuary, nature of river flow, tidal currents and availability of fine grained material<sup>1</sup>. Human influences on estuaries have assumed significant proportions<sup>2</sup>. The state of preservation of organic matter in the sediment depends partly on its texture. The main sources of organic matter, measured in terms of organic carbon or nitrogen in the sediments are autochthonous contribution, bottom flora and fauna. Terrigenous sources are of considerable importance in nearshore and estuarine environs. The measure of organic nitrogen is a good index of the productivity of the water body<sup>3</sup>. Its relative amount with respect to carbon (C/N ratio) is helpful in assessing the nutritional value of the sediments.

The components and composition of the sediments have received much attention<sup>4-6</sup>. Most of the work in India relates to the texture and organic content of marine sediments<sup>7-10</sup> and some work has been done on estuarine material<sup>11-15</sup> also. Biochemical and geochemical studies on Arabian Sea sediments have been reported<sup>16,17</sup>. This paper presents data on sediments collected over an year (1976-77) from 4 stations on the northern limb of the Cochin backwaters. The river Periyar which joins this part of the estuary passes through an industrial belt where a variety of effluents are discharged into it.

The 4 stations sampled were located upstream of the industrial belt (st 1), the main effluent discharge area (st 2), barmouth (st 4) and a point about half-way between sts 2 and 4 (st 3). Detailed description of the environment is previously reported<sup>18</sup>. The principal pollutant load at st 4 was organic while st 2 experienced sporadic intense organic loads<sup>18</sup>.

Sediment samples were collected with a van Veen grab<sup>19</sup> (0.048 m<sup>2</sup>). Samples were dried in a hot air oven at 95°C. The sample was analysed for grain size and percentages of sand, silt and clay, determined by sieving (62  $\mu$ ) and pipette methods<sup>20</sup>. Samples for chemical analysis were washed repeatedly with distilled water prior to drying to remove the salts. Organic carbon was estimated by wet oxidation method<sup>21</sup>, and nitrogen by Kjeldahl method<sup>19</sup>. Percentage organic matter<sup>22</sup> was calculated from the organic carbon values using a factor of 1.724.

Colour and texture of sediments varied with stations and seasons, the seasonal changes being less evident at st 3. Variations in the grain size (Table 1) as well as changes in the input and state of oxidation of organic matter were largely responsible for this. St 1 had reddish brown sediment indicating oxidised condition. The sediment at st 3 had light black shade and showed least variations. At the effluent discharge area (st 2) the colour of the sediment was not constant and occasionally contained sulphur particles. This station had no fine grained material in June, July (Table 1) when the strong monsoonal floods flushed away all accumulated material exposing the gravel underneath. During the rest of the monsoon season light grey sediment was present. The predominance of terrigenous matter is reported to impart light colour to the sediments<sup>23</sup>. At st 4 the sample contained an abundance of organic debris and was black in colour. Settlement and decay of domestic and industrial wastes might have influenced the sediments here.

In terms of texture the sediments at the 4 stations fall under different categories, sandy clay, clayey sand, clayey silt and sandy silt. During the monsoon season sand predominated at all the stations, presumably due to the flushing of finer particles by monsoonal floods. Sandy silt was present at st 2 throughout the year except in the monsoon season.

*Organic carbon*—The average values of organic matter (3.14, 3.36 and 3.5% at sts 1, 2 and 4 respectively) are higher compared to the reported value<sup>13</sup> of 2.55%.

Table 1—Organic Carbon, Nitrogen, Nature of Sediments and C/N Ratios at Different Stations

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
St 1													
A	0.54	1.66	0.78	1.64	2.42	3.16	0.29	2.17	2.52	2.26	2.07	2.36	1.82
B	1.87	1.87	0.93	0.70	0.93	2.80	0.93	1.87	2.33	1.87	1.40	2.33	1.65
C	49.42	67.51	51.53	62.73	53.08	61.48	94.92	54.46	48.19	47.62	37.34	36.87	55.43
D	26.58	13.99	22.97	11.27	16.92	6.52	1.21	21.04	25.31	26.68	23.16	25.63	18.44
E	24.00	18.50	25.50	26.00	30.00	32.00	3.81	24.50	26.50	25.50	39.50	37.50	26.10
F	2.87	8.87	8.32	23.41	25.88	11.28	3.14	11.64	10.79	12.10	14.79	10.12	11.90
St 2													
A	0.38	2.80	0.52	0.41	0.31	G	G	2.26	9.25	1.00	0.80	0.67	1.96
B	0.46	1.40	2.80	0.47	2.33	R	R	3.73	2.10	1.40	0.86	0.60	1.70
C	20.43	80.36	40.97	26.47	25.72	A	A	47.48	69.69	57.06	53.80	54.20	47.61
D	70.07	4.64	2.96	31.53	56.28	V	V	29.02	8.81	18.94	38.20	38.40	29.89
E	9.50	15.00	56.25	42.00	18.00	E	E	23.50	21.50	24.00	8.69	7.40	22.56
F	8.10	19.96	1.85	8.87	1.33	L	L	6.05	44.03	7.15	9.30	11.16	12.00
St 3													
A	0.86	1.55	1.59	1.03	2.04	1.40	2.69	1.92	1.21	1.00	0.01	1.55	1.40
B	1.87	1.87	1.87	0.93	1.67	1.67	1.40	1.40	0.93	2.34	1.40	1.87	1.60
C	65.11	52.64	68.04	74.38	54.69	69.19	85.24	67.57	82.57	41.60	80.17	66.30	67.29
D	12.39	20.86	2.76	5.12	9.31	11.31	5.57	13.93	5.43	32.90	1.30	9.20	10.84
E	22.50	26.50	29.20	20.50	36.00	19.50	9.19	18.50	12.00	25.50	18.53	24.50	21.86
F	4.62	8.32	8.50	11.09	17.44	11.97	19.22	13.68	12.94	4.29	7.19	8.32	10.60
St 4													
A	—	1.69	2.17	2.12	1.31	1.48	1.64	1.55	3.12	2.19	2.67	2.40	2.03
B	—	1.87	1.87	0.47	1.63	0.67	0.47	1.87	1.87	1.87	1.87	1.92	1.45
C	—	27.64	25.33	24.80	40.98	30.90	69.03	42.39	37.91	39.22	48.74	38.02	35.41
D	—	41.36	30.17	31.28	26.02	37.60	8.12	24.41	20.59	30.48	8.51	33.48	24.34
E	—	31.00	44.50	43.90	33.00	31.50	22.57	33.20	41.50	30.31	42.75	28.50	31.89
F	—	9.06	11.64	45.44	8.02	21.19	35.10	8.32	16.72	16.72	14.32	12.50	18.20

A = Organic carbon, %; B = Organic nitrogen, mg/g; C = sand, %; D = silt, %; E = clay, %; and F = C/N ratio

except at st 3 (2.53%). Comparison of average organic matter values at sts 1 and 2, which have fresh water regime through the year, shows only marginal enrichment at st 2. Studies on water quality have shown that st 2 experiences intermittent high organic loads<sup>18</sup>. Organic matter content at st 4 is appreciably higher compared to the values reported<sup>8-12,15</sup>. The annual organic carbon value for the areas adjacent to the Cochin harbour<sup>15</sup> (0.74-3.84%) agrees well with the present value (Table 1). Murthy *et al.*<sup>7</sup> have reported a value of 3.8 at 13 fm off Cochin and noted a decrease up to 20 fm followed by a slight increase in organic content. They have attributed the higher organic content in the shallower area to the contribution of terrigenous sources and this reasoning seems to hold good for st 4 also. Sarala Devi *et al.*<sup>18</sup> have reported high organic loads at st 4, based on water quality studies. Patel *et al.*<sup>24</sup> have reported 3-3.2% organic carbon for the sediments from Bombay harbour - a tidal estuary.

Range in percentage organic carbon was higher at all stations in the monsoon season due to the contribution

from land runoff. Seasonal variations were well pronounced at st 2 (Table 1). Blooms of filamentous alga *Oscillatoria* sp. were reported from this area during monsoon season<sup>25</sup>. The termination of the blooms along with an increase in organic load of the effluents<sup>18</sup> may be the contributing factor for the very high value at st 2.

Association of organic matter with fine grained material is well established<sup>23-28</sup>. While st 4 largely followed this trend no clear relationship could be seen between fine sediments and organic matter at sts 1-3. High oxygen content, high temperature and shallow nature of these stations<sup>18</sup> seem to encourage oxidation of organic matter in the sediments. Murthy and Veerayya<sup>13</sup> have also attributed these reasons to this apparent discrepancy in the sediments at the southern end of the Vembanad lake, a predominantly fresh water zone.

**Organic nitrogen**—Seasonal variations in organic nitrogen (Table 1) were not very pronounced at sts 3 and 4. Sts 1 and 2, however, showed a larger variation, with st 2 recording maximum variations. The highest

value of organic nitrogen (3.73 mg/g) was recorded at st 2 in August (Table 1). The nitrogenous wastes from the fertilizer factory and other effluents discharged at this area may be responsible for this high value. Coefficients of correlation calculated for organic carbon and nitrogen though positive at all stations was significant only at st 1 ( $P < 0.01$ ).

**C/N ratio**—This varies with sediment type, depth of burial and analytical procedure. Bhosle *et al.*<sup>16</sup> have reported C/N values ranging from 2.48-37.5 (av. 14) in Arabian Sea sediments. Qasim and Sankaranarayanan<sup>29</sup> have found C/N ratios of detritus to vary from 5-10.5. Sankaranarayanan and Panampunnayil<sup>15</sup> have reported a range of 2.5-16.9 for sediments of the Cochin harbour and adjacent areas. They have also indicated from N/P ratios that a major portion of the phosphorus is of abiogenic origin. The consistently high organic carbon values and C/N ratios at st 4 (Table 1) in the present data also indicate the influence of wastes discharged into this area. Sts 1 and 3 show comparatively lesser variations during the year, with st 3 showing the least variations (Table 1). The highest value of C/N ratio was found at st 4 (45.44) in April. The peak in C/N ratio (44.03; September) at st 2 was caused by a sudden increase in organic carbon content while high values in April and July at st 4 coincided with low nitrogen values (Table 1). The relatively high organic carbon content and the tendency of nitrogen to be lost at a faster rate may be responsible for this high C/N ratios<sup>30</sup>.

Sts 2 and 4 represent areas subject to different types of pollutant loads. While the major pollutant load at st 4 is organic, st 2 experienced only sporadic high organic loads. This pattern observed in a concurrent study of water quality of the area of investigation<sup>18</sup>, is reflected on the sediment characteristics also (Table 1). The shallow nature, higher temperatures and oxygen tension at st 2 (ref. 18) seem to encourage oxidation of organic matter, while at st 4 the rates of oxidation seem to be slower. The large surplus of basic food available in the estuary<sup>31</sup> and the contribution of humic material from river discharge along with the municipal wastes discharged into this area probably account for the higher levels of organic matter in the sediments at st 4.

Reports on the inter-relationship between C/N ratios and organic content of soils, sediments and clays are available<sup>28</sup>. No clear pattern of inter-relationship is evident except at st 4. The comparatively faster rate of oxidation of organic matter that can be expected at sts 1-3 (ref. 13, 14, 16-18), perhaps accounts for this lack of inter-relationship. Eisma *et al.*<sup>28</sup> comparing data on C/N ratio and organic matter relationships from different environments observed that the relation between these 2 parameters is different for different soils and is related to the original amount and

composition of organic matter as well as the structure of the soil. They further suggested that the relationship can be expected to become less evident when different soils or sediments are compared which contain mixtures of organic matter in varying stages of decomposition. The present data also suggest that the state of break down of organic matter, which depends on the environmental factors and textural characteristics of the sediment, rather than its absolute quantity, influence the C/N ratios.

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## Organic Carbon Content of Tropical Zooplankton

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In the Zuari and Mandovi estuaries variations in organic carbon of zooplankton are 26.4-38.8 and 24-39.9% of dry weight respectively. Maximum carbon content of estuarine zooplankton is observed in November. Organic carbon in nearshore and oceanic zooplankton is 34.5 and 41% of dry weight respectively. Variation in the carbon content of zooplankton is attributed to its composition. Diversity of zooplankton increases from estuarine to oceanic realm with a concomitant rise in the value of organic carbon. The average dry weight for 1 ml of nearshore and oceanic zooplankton is 61.9 and 81.7 mg respectively.

To estimate secondary production in an ecosystem the zooplankton biomass needs to be converted into a more general unit like weight of organic carbon. Some information<sup>1-6</sup> on the organic content of zooplankton dealing mainly with temperate waters is available. Organic carbon content of tropical zooplankton is lower than that from higher latitudes<sup>4,6</sup>. In the present study carbon contents of estuarine and nearshore zooplankton from Goa waters and oceanic zooplankton from the southwest coast of India are estimated. Seasonal variations in the carbon content of zooplankton in the Mandovi-Zuari estuarine system of Goa also form part of this communication.

From the estuaries and nearshore waters of Goa vertical zooplankton samples, 5 m to the surface, were collected (Fig. 1) using a HT net (mouth area 0.25 m<sup>2</sup>; mesh size 0.3 mm). A few vertical collections from the Arabian Sea were taken with an IOS net (0.33 mm mesh size)<sup>7</sup>. As the mesh size of both the nets are almost same zooplankton organisms caught in the 2 sets of collections are comparable. The samples were frozen and 20% of each sample was preserved in 5% formalin for analysing the different taxa and the rest was used for carbon estimation. Samples were washed thoroughly with distilled water and dried in an oven at 60°C until a constant weight was attained. Organic carbon in a 10 mg sample was estimated by the wet oxidation

method<sup>8</sup>. For each sample triple estimates were done and the mean value was considered.

Data from 3 sets of samples were used for the present study. (1) Fortnightly or monthly collections from the mouths of Mandovi (st 1) and Zuari (st 2) were taken from January to December 1978. During September and October, which represent monsoon and postmonsoon periods respectively, sampling could not be done. Data are, however, available for 3 remaining months of respective monsoon periods and hence a general trend in organic carbon can be surmised. (2) Fortnightly samples were taken from the nearshore waters of Goa at 20 m (st 3) during January to May 1978. The period and area of collection coincided with the *Trichodesmium* bloom<sup>9</sup>. Due to navigational difficulties sampling could not be done from June to December. (3) During the 31st cruise (March 1978) of *RV Gaveshani* 12 vertical zooplankton samples from 60-200 m to surface were taken. Stations were located between 9° 16'N-12° 40'N and 72°-75° 44'E in the Arabian Sea.

*Estuarine zooplankton*—Variations in the carbon content of zooplankton in the Zuari and Mandovi estuaries are given in Table 1. Maximum values of organic carbon was obtained at the beginning of the postmonsoon period. At both the estuaries biomass and percentage of organic carbon did not show any correlation. Often low biomass was associated with relatively higher carbon values or vice versa.

*Nearshore zooplankton*—The organic carbon content indicated an increasing trend from January to May (Table 1). In 1979, *Trichodesmium* bloom was observed from January to April<sup>9</sup> and maximum carbon value was recorded in May. The lowest value observed in March corresponds to similar values

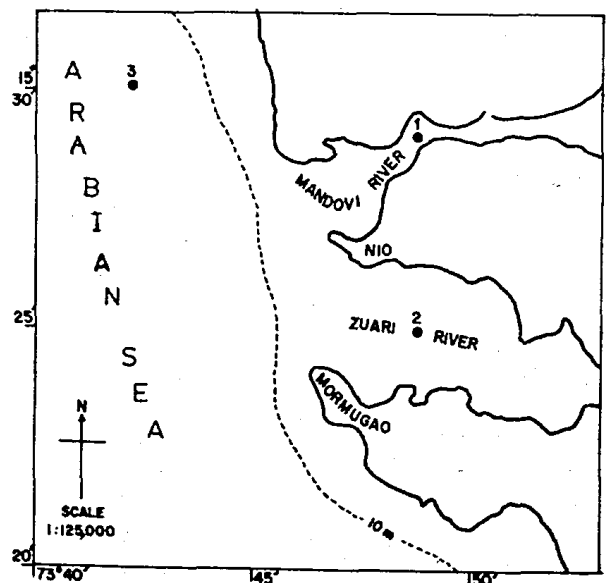


Fig. 1—Locations of stations in the Mandovi, Zuari and nearshore waters of Goa