Jour. Indian Association of Sedimentologists Vol. 13(1994), pp. 69-79

SEDIMENTS DISTRIBUTION AND ITS RELATION WITH ORGANIC CARBON WITHIN THE MAYEM LAKE; GOA, INDIA

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Abstract

Mayem is a small lake in Bicholim Taluka of Goa, surface sediment samples collected during the per-monsoon and the monsoon seasons are used to understand their size distribution in the lake. The major part of the sediment falls in a very fine grained category (silt and clay). Seasonal variation occur in the sediment characters and there is a definite relation between the sediment distribution and the organic carbon.

Introduction

Major factors which control the water dynamics within the lake include :

(i) Climate—which in turn controls water chemistry, shoreline fluctuations, organic productivity and water temperature.
(ii) Water depth—which similarly controls lake stratification and current effectiveness.
(iii) Nature and amount of sediment input from the drainage basin of the lake.

Study Area

The Mayem Lake lies between 73° 56′ 21″ E and 73° 56′ 34″ E and 15° 34′ 19″N and 15° 34′ 35″ N at an elevation of 15 m above MSL. It is a closed lake with a surface area of about 55,000 sq m and catchment area of about 2 sq km. Within the lake, the water depth is 3-4 m during the pre-monsoon season (Feb.-May) which rises to about 7-7.5 m during the monsoon (June-Sept.). It is the only lake in Goa containing freshwater of potable quality, which is being used mainly for agricultural and drinking purpose during all seasons. An artificial outlet has been constructed to channelise the water.

Catchment Area

The lake is situated between hill ranges which attain a maximum elevation of about 120 m above MSL. The hills show gentle to moderate slopes with intermediate vegetation mainly along southern and southeastern parts of the lake; northern and northeastern portions are relatively barren. Rainwater received by the catchment area flows in the form of surface run-off into the lake basin during the monsoon through four seasonal streams along the eastern margin of the lake (Fig. 1). During the fair weather seasons, springs are the main source of water, they occur at the base of the streams.

The catchment area of the lake, geologically, is covered by altered BHQ's, ferrugenous and limonitic quartzites at lower levels, capped by hard, compact and at places vescicular laterite at higher elevations. Though there are no mines within the catchment area of the lake, mining rejects which are being dumped there seems to have increased the rate of siltation within the lake basin.

The present study is the preliminary part of the detailed three-year research project entitled "Impact of mining and physico-chemical changes within Mayem lake due to siltation and other

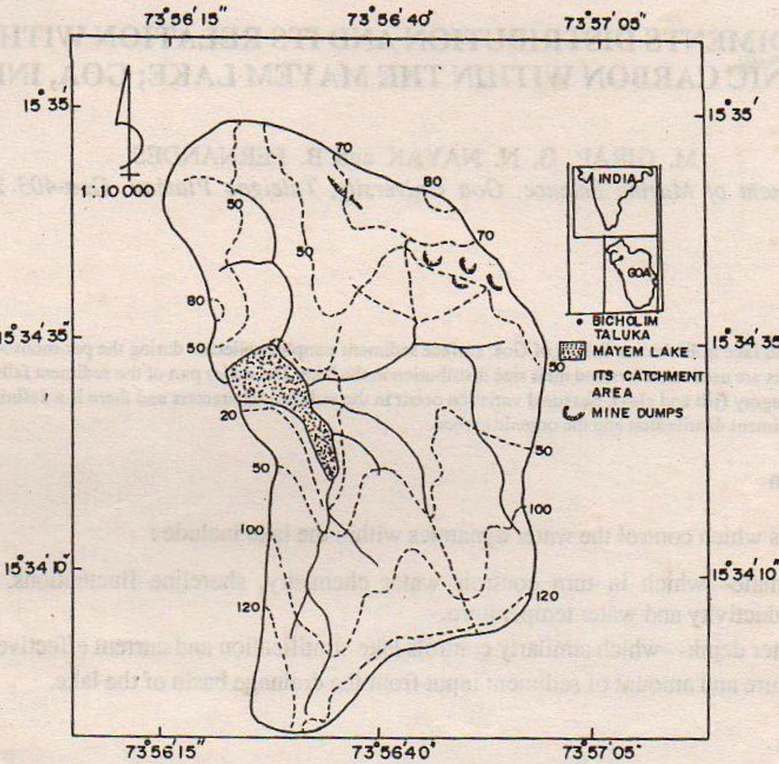

Fig. 1. Mayem Lake with its Catchment Area

water bodies of Bicholim taluka, Goa" funded by Department of Environment and Forests, Government of India under the guidance of one of the authors (GNN).

Methods of Study

Field Study

For the present study, two sets of surface sediment samples (pre-monsoon and monsoon) from 15 sampling stations (Fig. 2), collected using Van-Veen grab were considered. Four samples were also collected in the month of February during reconnaissance survey. Samples collected were kept in plastic bags and stored in a refrigerator awaiting analysis. Water depth at all the sampling stations was noted.

Laboratory Analysis

A representative part of the sample was taken for analysis by wet sieving and pipette method. Sodium hexametaphosphate (10 percent) was used as deflocculating agent. The results obtained were used to calculate sand, silt and clay percentages and grain size parameters. The total organic carbon was determined by wet oxidation method (Elwakeel and Riley, 1957). Concentration of organic matter was calculated by multiplying the value of organic carbon by a factor of 1.724.

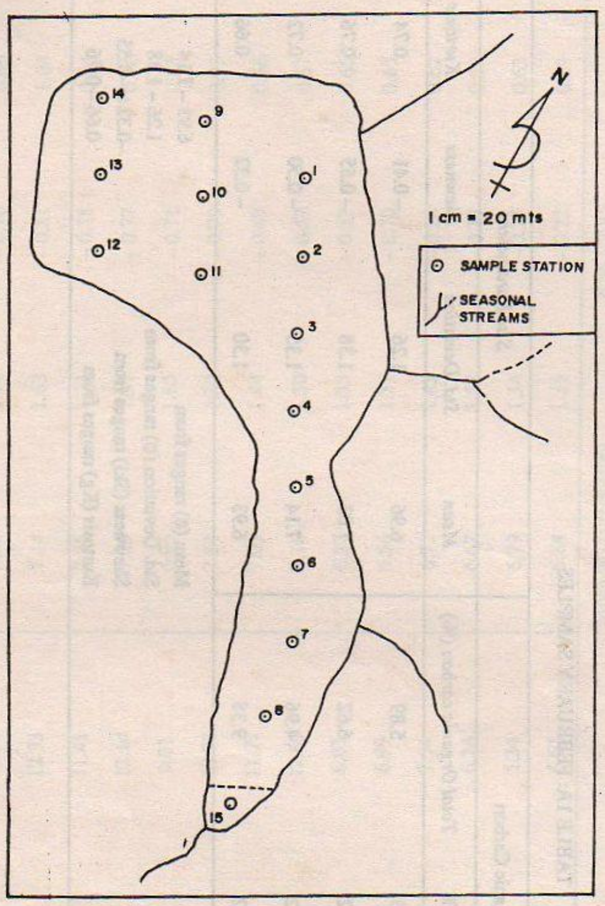

Fig. 2. Sampling Locations within Mayem Lake

Results

Variation with the Season

Data obtained is presented in Table 1A-1C. The range of sand, silt and clay during the pre-monsoon season is 2.03 to 16.87; 35.14 to 75.40 and 21.60 to 59.57 percent respectively, and that during the monsoon is 1.09 to 8.36; 46.76 to 57.45 and 36.12 to 51.24 percent.

The study reveals that the Mayem Lake sediments fall in the very fine-grained category of the size grade scale (Fig. 3). They may be classified as mud or better as clayey silt. As the sediments of the Mayem Lake contain a very meager amount of sand it is ignored and only silt and clay fractions are considered. From Table 1A, it is clear that the silt to clay ratio is greater in the monsoon than in the pre-monsoon season. In-addition, the range of silt and clay during the monsoon is relatively less. In general, the Mayem Lake sediments contain relatively higher percentage of organic carbon. During the pre-monsoon, average organic carbon content is 9.46 percent while during the monsoon the average organic carbon content is 8.12 percent. Also, the amount of organic carbon in all the sediment samples is lower during the monsoon than in the pre-monsoon. It is clear from the variations in the size parameters (Table 1B) that as the mean size decreases. sediments become better sorted as well as more negatively skewed (Fig. 4). Thus

TABLE 1A: FEBRUARY SAMPLES

Sample Location	Sand, Silt, Clay and Organic Carbon				Size Parameters			
	+ 230 fraction (%)	*Silt %*	*Clay %*	*Total Organic carbon (%)*	*Mean*	*Std. Deviation*	*Skewness*	*Kurtosis*
1	3.41	64.34	32.23	5.89	6.96	1.26	−0.41	0.74
2	2.40	51.90	45.62	6.62	7.03	1.38	−0.55	0.76
3	3.18	48.70	48.12	4.96	7.14	1.35	−0.50	0.72
4	2.00	55.14	42.82	9.38	6.93	1.30	−0.32	0.66

+ 230 fraction (%) ranges from 2% to 3.41%
Silt % ranges from 48.70 % to 64.34 %
Clay % ranges from 32.23 % to 48.12 %
Total Organic carbon % ranges from 4.96 % to 9.38%

Mean (ϕ) ranges from 6.93 – 7.14
Std. Deviation (σ) ranges from 1.26 – 1.38
Skewness (Ski) ranges from −0.32 to −0.55
Kurtosis (Kg) ranges from 0.66 – 0.76

TABLE 1B : PRE-MONSOON SAMPLES

Sample Location	Sand, Silt, Clay and Organic Carbon				Size Parameters			
	+ 230 fraction %	*Silt %*	*Clay %*	*Total Organic carbon (%)*	*Mean*	*Std. Deviation*	*Skewness*	*Kurtosis*
1	3.98	64.40	31.78	10.30	6.66	1.38	−0.10	0.66
2	7.84	40.35	51.75	12.33	7.14	1.63	−0.81	1.04
3	5.28	35.14	59.57	11.41	7.35	1.23	−0.78	0.84
4	2.03	46.50	51.46	12.14	7.29	1.27	−0.77	0.76
5	5.01	49.91	45.04	9.01	6.95	1.65	−0.71	0.87
6	5.98	38.21	55.80	13.98	7.31	1.32	−0.79	0.93
7	6.04	50.81	42.36	11.77	7.03	1.44	−0.69	0.66
8	13.95	45.85	40.20	12.69	7.16	1.30	−0.67	0.67
9	2.90	57.73	39.73	6.07	6.87	1.35	−0.37	0.65
10	2.85	75.40	21.60	6.99	6.56	1.37	−0.70	0.65
11	7.55	57.00	35.40	7.54	6.72	1.43	−0.24	0.62
12	16.87	51.60	31.53	6.26	6.62	1.57	−0.37	0.52
13	2.84	59.69	37.43	5.34	6.79	1.34	−0.23	0.63
14	3.17	58.65	38.17	6.62	6.84	1.35	−0.22	0.69

+ 230 fraction (%) ranges from 2.03 to 16.87 %
Silt % ranges from 35.14 to 75.40 %
Clay % ranges from 21.60 to 59.57%
Total Organic carbon % ranges from 5.34 to 13.98%

Mean (ϕ) ranges from 6.56 – 7.35
Std. Deviation (σ) ranges from 1.23 – 1.65
Skewness (Ski) ranges from −0.1 to −0.81
Kurtosis (Kg) ranges from 0.52 to 1.04

TABLE 1C: MONSOON SAMPLES

Sample Location	Sand, Silt, Clay and Organic Carbon				Size Parameters			
	+ 230 *fraction* %	*Silt* %	*Clay* %	*Total Organic carbon* (%)	*Mean*	*Std. Deviation*	*Skewness*	*Kurtosis*
1	8.36	55.43	36.12	4.78	6.99	1.28	–0.40	0.69
2	4.41	55.52	40.00	11.41	6.96	1.44	–0.56	0.68
3	1.19	55.80	43.00	10.30	6.89	1.44	–0.52	0.66
4	1.09	57.45	41.45	10.86	7.09	1.28	–0.54	0.74
5	4.85	51.23	43.88	9.94	7.23	1.19	–0.64	0.67
6	1.98	46.76	51.25	7.54	7.29	1.25	–0.76	0.80
7	1.29	53.82	44.88	11.23	7.16	1.25	–0.62	0.65
8	1.65	54.64	43.46	9.94	7.09	1.29	–0.56	0.69
9	2.82	53.52	44.35	6.99	7.14	1.25	–0.56	0.69
10	2.12	51.99	45.87	5.15	7.20	1.25	–0.69	0.69
11	2.54	55.28	42.17	4.23	6.86	1.34	– 0.40	0.66
12	7.93	49.65	42.41	5.70	6.99	1.42	–0.66	0.63
13	2.04	56.51	41.44	2.76	6.99	1.39	–0.54	0.75
14	3.48	56.28	40.23	5.52	7.03	1.28	–0.51	0.73
15	11.16	51.35	37.43	15.46	7.00	1.28	–0.46	0.68

+ 230 fraction (%) ranges from 1.09 to 11.16%
Silt % ranges from 46. 76 to 57.45%
Clay % ranges from 36.12 to 51.25%
Total Organic carbon % ranges from 2.76 to 15.46%

Mean (ϕ) ranges from 6.86 – 7.29
Std. Deviation (σ) ranges from 1.19 – 1.44
Skewness (Ski) ranges from – 0.4 – 0.76
Kurtosis (Kg) ranges from 0.63 – 0.80

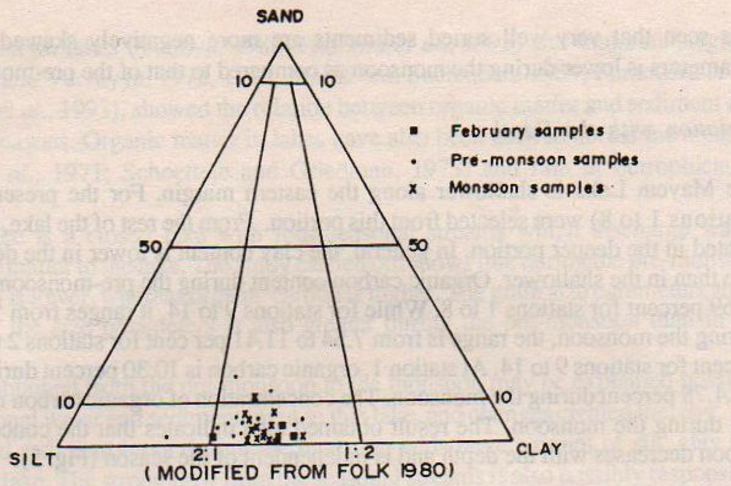

Fig. 3. Triangular Diagram Showing Distribution of Mayem Lake Sediments

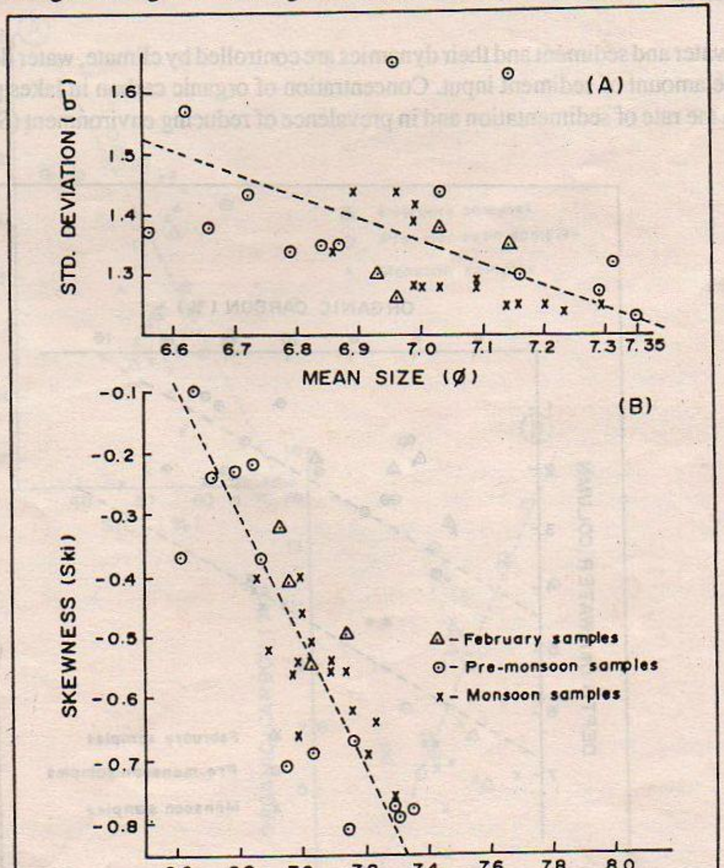

Fig. 4. Bivariant Plot between Mean Size and Standard Deviation (A) and Mean Size and Skewness (B).

it is seen that very-well sorted sediments are more negatively skewed. The range of size parameters is lower during the monsoon as compared to that of the pre-monsoon.

Variation with the Depth

The Mayem Lake is shallower along the eastern margin. For the present study 8 locations (stations 1 to 8) were selected from this portion. From the rest of the lake, stations 9 to 14 were located in the deeper portion. In general, the clay content is lower in the deeper portions of the lake than in the shallower. Organic carbon content during the pre-monsoon ranges from 9.01 to 12.69 percent for stations 1 to 8. While for stations 9 to 14, it ranges from 5.34 to 7.54 percent. During the monsoon, the range is from 7.54 to 11.41 per cent for stations 2 to 8 and 2.76 to 6.95 percent for stations 9 to 14. At station 1, organic carbon is 10.30 percent during the pre-monsoon and 4.78 percent during the monsoon. The concentration of organic carbon recorded here is very low during the monsoon. The result obtained also indicates that the concentration of organic carbon decreases with the depth and is independent of the season (Fig. 5).

Discussion

Lake water and sediment and their dynamics are controlled by climate, water depth and the nature and the amount of sediment input. Concentration of organic carbon in lakes plays an important role in the rate of sedimentation and in prevalence of reducing environment (Syriac *et al.*, 1990).

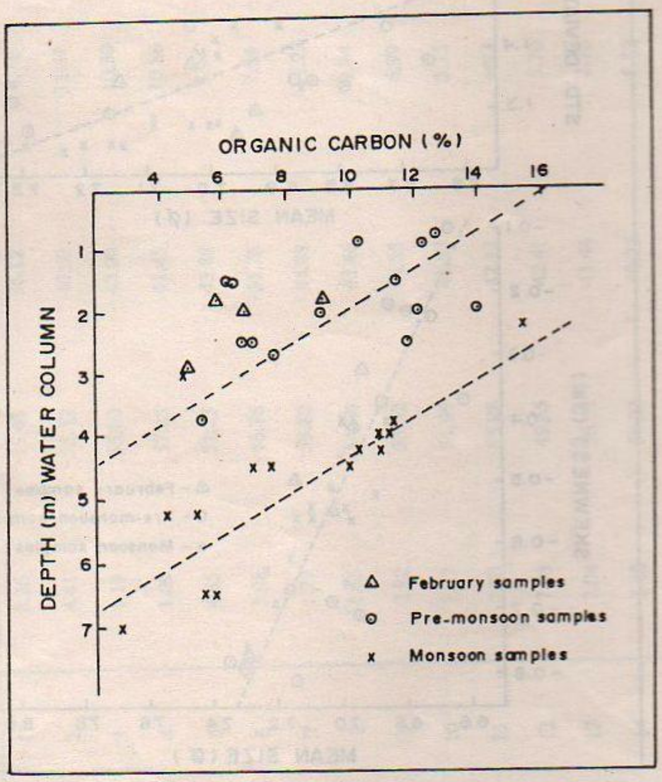

Fig. 5. Relationship between Organic Carbon with the Depth of Water Column in Mayem Lake

Earlier studies in India on lakes (Valdiya, 1988; Hashimi *et al.*, 1993) and estuarine stagnant water bodies (Murty and Veerayya, 1972, 1974; Mallik and Suchindan, 1984; Purandara *et al.*, 1993; Chandrasekar *et al.*, 1993), showed the relation between organic matter and sediment and their variation with seasons. Organic matter in lakes have also been used to define the areas of pollution (Shimp *et al.*, 1971; Schoettele and Griedman, 1973) and rate of eutrophication (Mackereth, 1965).

The Mayem Lake is a closed lake with four seasonal streams which discharge water, sediment and organic matter to the lake. The study carried out shows that during the pre-monsoon the ratio of silt to clay is lower, whereas organic carbon is higher. The grain size parameters show that the range of all the size parameters is also greater during the pre-monsoon than in the monsoon seasons.

The variations obtained from the pre-monsoon to the monsoon may be explained possibly with the help of seasonal water and sediment input to this lake, and changes created thereby. The continuous water and sediment input during the monsoon adds large amount of silt, clay and organic matter to the lake. The strong flow from the seasonal streams is also possibly responsible

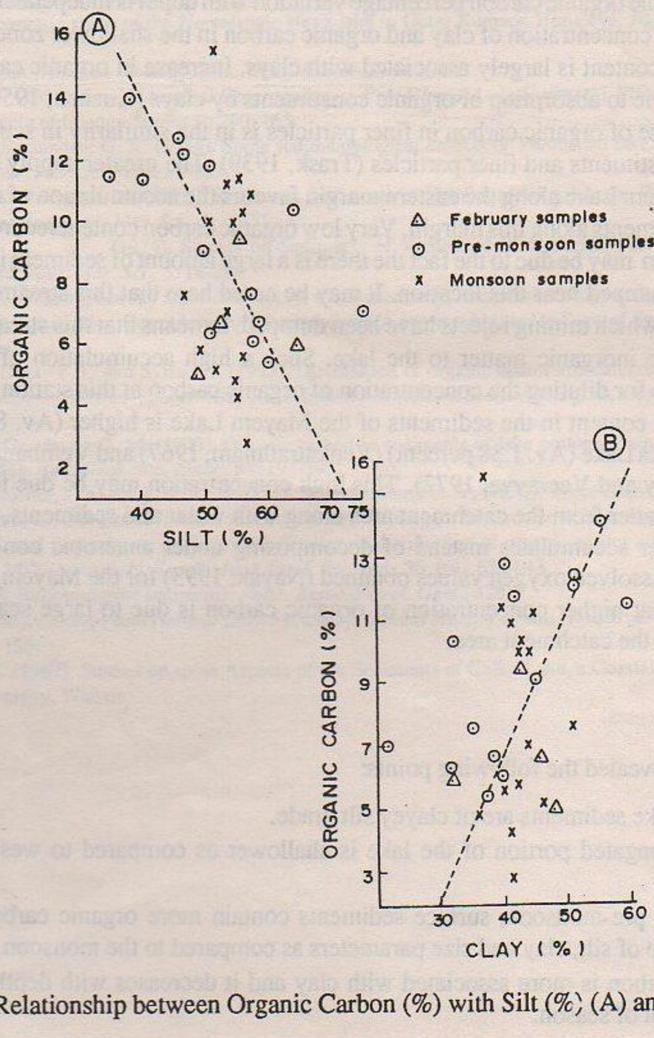

Fig. 6. Relationship between Organic Carbon (%) with Silt (%) (A) and Clay (%) (B)

for resuspension of the settled finer constituents within the lake. As a result of this, major finer fraction (clay) of the sediments and lighter organic matter remains in suspension during the monsoon. This process is responsible for obtaining the higher ratio of silt to clay and lower organic carbon percentage in the sediments during the monsoon. During the pre-monsoon, however the supply of water and sediment is negligible and also the long calm period is available for sedimentation. Therefore, the material which was in suspension during the monsoon slowly settles down and results in increased percentage of organic carbon and decrease in the ratio of silt to caly. This also produces larger range in grain size parameters during this season.

In the present study, variation of silt, clay and organic carbon with depth within the Mayem Lake is also considered. The results obtained clearly shows that the percentage of organic carbon and clay decreases with depth (Fig. 5 and 6B) and that of silt increases with depth (Fig. 6A). It may be noted here that the Mayem Lake is shallower along the eastern margin along which the four streams join the lake. It is also clear from the results that the organic carbon content is the lowest at the sample location No. 13, which is the deepest part of the lake. The values obtained for this location are 5.34 percent (pre- monsoon) and 2.76 percent (monsoon). The results (Fig. 5) also indicate that the organic carbon percentage variation with depth is independent of seasons.

The increase of concentration of clay and organic carbon in the shallower zones means that the organic carbon content is largely associated with clays. Increase in organic carbon in finer sediments may be due to absorption of organic constituents by clays (Kuenen, 1950). The main cause for the increase of organic carbon in finer particles is in the similarity in settling velocity of both organic constituents and finer particles (Trask, 1939). The greater supply of water and sediment to the Mayem Lake along the eastern margin favours the accumulation of more organic matter and finer sediments along this margin. Very low organic carbon content recorded at station 1 during the monsoon may be due to the fact the there is a large amount of sediment input brought by the stream and dumped near this location. It may be noted here that this stream flows along the hillslopes along which mining rejects have been dumped. It means that this stream during the monsoon adds more inorganic matter to the lake. Such a high accumulation of sediment is possibly responsible for diluting the concentration of organic carbon at this station.

Organic carbon content in the sediments of the Mayem Lake is higher (Av. 8.79 percent) than that of the Chilka Lake (Av. 1.38 percent) (Venkatrathnam, 1967) and Vembanad Lake (Av. 2.55 percent) (Murty and Veerayya, 1972). This high concentration may be due to large scale supply of organic matter from the catchment area along with water and sediments. In shallower lakes, organic matter accumulates instead of decomposing under anaerobic condition (Foth, 1984). The higher dissolved oxygen values obtained (Nayak, 1993) for the Mayem Lake waters strongly supports that higher concentration of organic carbon is due to large scale supply of organic matter from the catchment area.

Conclusions

The present study revealed the following points:

(1) Mayem Lake sediments are of clayey silt grade.

(2) Eastern elongated portion of the lake is shallower as compared to western broader portion.

(3) During the pre-monsoon, surface sediments contain more organic carbon and have larger range of silt, clay and size parameters as compared to the monsoon.

(4) Organic carbon is more associated with clay and it decreases with depth and is also independent of season.

(5) Organic carbon content is relatively high and is due to supply of organic matter from the catchment area.

Acknowledgements

Two of the authors (MG and BF) are grateful to the Department of Environment and Forests, Government of India for financial assistance. The authors are thankful to the Head, Department of Marine Science for providing the necessary laboratory facilities to carry out the analysis.

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