Spatial Variability of Lake Sediments : A Case Study

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ABSTRACT

Spatial variability of sediment properties in Vembanad Lake, southwest coast of India is studied. Vembanad lake is a major estuary connected to sea at Kochi (Kerala). The parameters observed are particle size distribution, biogeochemical properties such as calcium carbonate and organic matter distribution. The results showed that, there are considerable variation in particle size, $CaCO_3$ and Organic matter concentration. It is found that the textural variations depends mainly on hydrological parameters such as, river discharge, slope of the river bed, depth of water column, morphology of the lake basin and wind-induced currents. The chemical parameters such as calcium carbonate and organic matter content is closely related with the grain-size. It is observed that the coarse textured soils are rich in $CaCO_3$ whereas, fine-grained sediments are enriched in organic matter content.

INTRODUCTION

The role of lake and estuary in a coastal ecosystem is very important for the supply of dissolved and solid material to the ocean. It is reported that about 250 $*10^{14}$ g /year material is transported via rivers and estuaries. Almost 85% of all soluble and particulate weathering products pass through the estuarine environment before entering coastal waters. Therefore, the estuaries and lagoons which form the transition zones between fluvial and marine environment constitute an important stage in the transport of sediments from continents to oceans. Further, they also serve as traps for a portion of the solid continental weathering products. They represent a situation in which sedimentary detritus during its transport to oceans can undergo modifications through several processes operating in these systems resulting in enrichment or impoverishment of various trace elements in the bottom sediments (Murthy and Veerayya, 1981). Due to the rapid accumulation of sediments and the need to maintain navigable channels, periodic dredging of estuaries is often necessary. These dredging operations have the potential to remobilize buried materials and to affect the local biota and the chemical composition of the estuary. Vembanad lake is the largest estuarine system in central Kerala and a major fishery ground for hundreds of fishermen in and around the lake.

Along the study area there are four major rivers which debauches into the Vembanad lake and then to the sea. The sediments brought by the rivers first settle in the lake and then it filters out to the sea through the estuary. The estuarine region presents a different

situation with a stable marine condition prevailing for major part of the year. During the monsoon period fresh to brackish water condition exists at the surface, and marine condition continues to prevail at the bottom. The estuarine region is highly productive and the underlying sediments are correspondingly rich in organic matter content. Therefore, in the present study a detailed investigation is made to understand the sediment characteristics with chemical constituents such as organic matter and calcium carbonate.

STUDY AREA

Vembanad lake extends between, Azhikode in the north and Alleppey in the south (9° 28' N to 10 °16' N latitude and 76° 13' E to 76° 30' E longitude). The estuary is one of the important nursery grounds for commercially important penaeid prawns and support a rich fin fish and shell fish growth. The Kochi harbour is situated within the estuarine part of the lake by cutting a number of channels which enable to land ships safely. This is one of the major coastal lagoon bordered on its west by the Arabian sea and separated from it by a barrier beach (fig. 1).

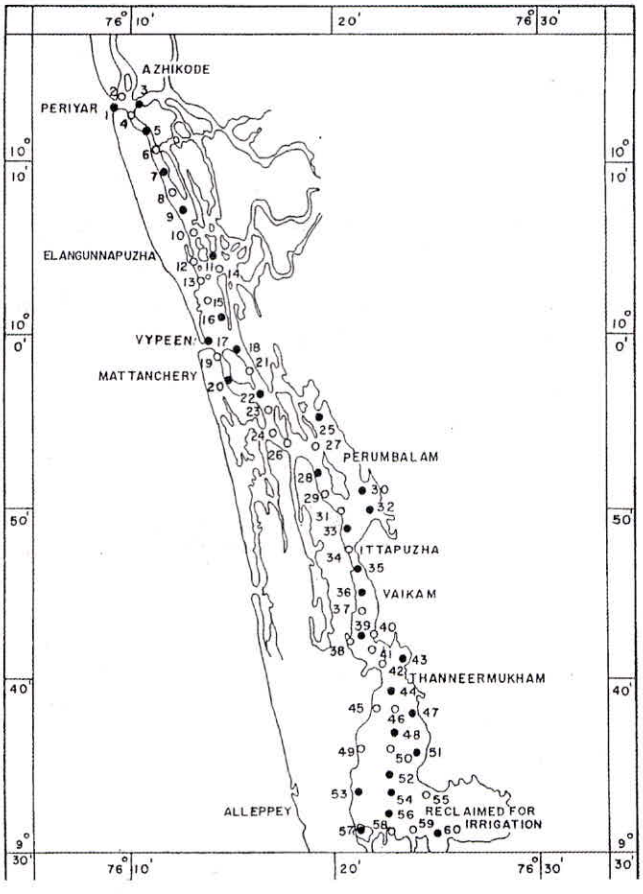

Fig. 1 : Study Area

METHODOLOGY

Sixty samples were collected using van Veen grab from the lake bed. Sediment samples were subjected to combined sieving and pipette analysis given by Krumbein and Pettijohn(1938). From the grain size analyses the various grain size parameters were determined by employing the formulae of Folk and Ward (1957). The CM diagram were drawn for both pre-monsoon and post-monsoon sediments to draw a relationship between the transportation and sedimentation pattern of the lake sediments.

Total calcium carbonate is determined by Herrin's et al (1958) method which involves the treatment of the sediment sample with sulphuric acid and the excess acid was found out by titrating with standard sodium hydroxide. The percentage is obtained by multiplying the difference in titre values of the sample and the blank solution by 5.

The samples for chemical analysis were dried, pulverized and the content of organic carbon was determined by the wet oxidation method of El Wakeel and Riley (1957) and the organic matter content was calculated by multiplying the value with 1.723.

RESULTS

Textural analysis of the bed sediments showed that the phi mean size of the lake sediments vary between 2.5 and 10.55 during the study period. The average value is 8.21 in the pre-monsoon and 6.4 during the post-monsoon season. The Phi median ranges from 2.6 to 10.1 during pre-monsoon, and in the post-monsoon, the phi value ranges between 2.05 and 9.05. Majority of the sediments are very poorly sorted both during the pre-monsoon and post-monsoon seasons. The standard deviation varies between 1.39 phi and 4.54 phi (pre-monsoon) and 1.95 phi and 3.85 phi (post-monsoon). The value of skewness varies between -0.38 to 0.48. It is also noted that large portion of the lake sediments are platykurtic in nature. The kurtosis value ranges from 0.55 to 0.98 phi during pr-monsoon and 0.31 to 0.98 phi during post-monsoon months. From the above results it is found that the sediments are coarser during post-monsoon and finer during pre-monsoon season. The kurtosis value shows a decrease from pre-monsoon to post-monsoon season.

CALCIUM CARBONATE AND ORGANIC MATTER DISTRIBUTION

Distribution of calcium carbonate in the Vembanad lake is shown in Table 1. In the northern part of the estuarine mouth, the percentage of calcium carbonate is found to be high when compared to southern part of the lake. The distribution of calcium carbonate in the river mouths is very low. The average percentage of calcium carbonate in the estuarine sediments is 3.06%. Very high percentage of calcium carbonate is reported from the Alleppey area (9%).

In the Vembanad lake, the organic matter percentage varies between 1.7 and 11.73. based on organic matter percentage, three zones can be distinguished in the lakes : i)

northern part of the lake extending from Azhikode to Vypeen with moderate quantity of organic matter 3 – 5%, ii) Vypeen to Thannermukham with high organic matter content (more than 5%) and iii) Thanneermukham to Alleppey region with relatively low per cent (less than 3). Relatively very low percentage of calcium carbonate is recorded near the river mouths. Estuarine region show high organic matter content.

Table 1 : Per cent of $CaCO_3$ in Vembanad lake sediments

Sample numbers	$CaCO_3$ %	Sample numbers	$CaCO_3$ %
Zone I		31	3.00
		32	1.25
1	6.25	33	0.75
2	1.25	34	0.75
3	1.50	35	5.00
4	0.50	36	1.75
5	0.50	37	1.25
6	1.50	38	1.25
7	2.00	39	0.13
8	3.50	40	5.60
9	2.75	41	4.90
10	3.50	42	1.25
11	2.75	43	2.75
12	3.75		
13	3.00	**Zone IV**	
14	3.25		
15	4.25	44	1.50
		45	2.03
Zone II		46	1.50
		47	0.90
16	3.00	48	1.00
17	1.75	49	1.25
18	6.50	50	1.15
19	5.00	51	0.50
20	6.25	52	2.50
21	4.50	53	4.25
22	8.00	54	1.25
23	9.00	55	3.25
24	7.00	56	1.00
25	6.25	57	3.40
26	4.50	58	5.25
27	3.25	59	1.50
		60	6.25
Zone III			
28	1.75		
29	1.25		
30	5.25		

DISCUSSION

From the grain-size analysis of the Vembanad lake sediments, it is observed that the sediments are predominated by silty clays and clayey silts. However, certain patches, particularly near the river mouths, coarser sediments, i.e. medium to coarse sands were observed. Textural characteristics of pre-monsoon and post-monsoon sediments reveal that the pre-monsoon sediments are relatively finer than the post-monsoon sediments. Spatial variations of textural parameters are very significant. Based on the grain size distribution pattern, the lake environment can be divided into four zones.

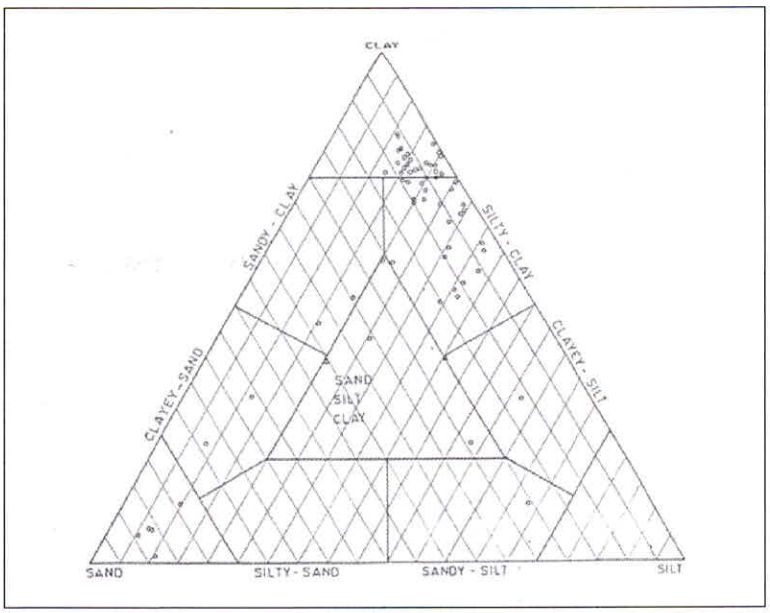

Fig. 2 : Textural Classification of Lake Sediments

Zone I : Starts from the north of the estuarine mouth to the northernmost part of the Vembanad lake where river Periyar, joins the sea. In this zone, the phi mean size of the sediments varies between 6.8 and 9.8 with an average phi mean size of 8.77. Here, both during pre-monsoon and post-monsoon season, there is no marked variation in grain-size parameters. This is attributed to the continuous influx of sediments from the adjoining sea and from the river Periyar which supplies large quantities of sediments from the northern part of the estuary.

Zone II: This extends from the estuarine mouth to the Perumbalam area, where the phi mean size of the sediments varies between 6.15 and 10.55 phi. This is mainly a clayey zone with clayey silts and clayey silts. The existence of very fine sediments may be due to the incursion of sediments from the sea during tidal actions and estuarine circulation process. Further, the dredging operations taking place in the area also give rise to the accumulation of finer sediments.

Zone III: The central part of the lake extending from Perumbalam to Thanneermukkam. This is a region of coarser sediments where the phi mean size varies between 2 and 9.9, however, the percentage of finer particles are significantly less in comparison to zone I and zone II. The average phi mean size is 6.

Zone IV: Southern part of the lake is chiefly composed of finer sediments of silty clays/clayey silts extending from the southern part of the Thanneermukkam in the north to Alleppey in the south region with a grain-size 5.1- 7.8 phi. The average phi mean size of the sediment is 6.8. The accumulation of fine sediments in this region is mainly due to the deposition of sediments that are transported and deposited by major rivers like Muvattupuzha, Minachil and Pamba.

Comparison of pre-monsoon and post-monsoon sediments of Vembanad lake, shows that the pre-monsoon sediments are relatively better sorted than post monsoon sediments. The very poorly sorted nature of the post-monsoon sediments may be due to the inter mixing of river-borne finer sediments brought in suspension towards the monsoonal season. The sorting of the sediments varies widely both during pre-monsoon and post-monsoon seasons. More than 70% of the sediments are very poorly sorted and the rest (30%) are either poorly sorted or extremely poorly sorted. The very poor sorting of the sediments show the unstable energy conditions and multiple source of the sediments.

Lake sediments are predominantly of positive skewness. According to Duane (1964), the positive skewness of the lake sediments could be attributed to the deeper waters where the bottom sediments are not disturbed by bottom currents or wave base surge. In areas of intermittent winnowing actions or fluctuating energy conditions, the bottom currents show local variation in the sign of skewness. Though there is a general tendency of decreasing skewness with the increase of phi mean, it changes due to the various factors which controls the estuarine sedimentation. Usually, it is suggested that unimodal sediments normally have a symmetrical distribution. Pure medium to fine sand mode samples are mostly unskewed in nature. However, the presence of secondary coarser sand or gravel mode makes the distribution negative, whereas secondary silt or clay mode makes it positive.

The Vembanad lake sediments are mainly platykurtic in nature. As explained by Folk and Ward (1957), it can be stated that the addition of very minor proportion of another mode to a unimodal sediment, worsens the sorting in the tails. The sorting in the central part remains good and thus make the deposit leptokutic in some parts of the lake.

The CM pattern drawn for the pre-monsoon and post-monsoon sediments indicated that the sediments are transported mostly by uniform suspension and graded suspension. The maximum size of the grains transported is 650 micron in size during pre-monsoon and it is 420 micron during post monsoon season.

CALCIUM CARBONATE AND ORGANIC MATTER DISTRIBUTION

The geological problems relating to the conditions of formation of limestones have greatly stimulated the study of calcium carbonate in the marine sediments. This is mainly because, most of the limestones were formed under marine environmental conditions.

Three broad sources for the calcium carbonate in the fluvial and deltaic deposits:

1. Calcareous mineral and sediments derived from continental rocks;
2. Shell fragments and tests of calcareous organisms, and;
3. Inorganic and organic precipitation from the overlying waters of the depositional environment.

Variations of calcium carbonate in the estuary i.e. higher percentage in the southern part and lesser in the northern part may be attributed to:

1. Excessive discharge of river sediments in the northern part. Low values of calcium carbonate in the river mouths sediments may be related to high rate of sedimentation and the nature of the substratum.
2. Various Physico-chemical processes taking place in the mixing zone of the estuary;
3. Continuous dredging operations may affect the biogenic activity in the region

The important factors controlling the organic matter accumulation in sediments are (i) the supply of organic matter to the environment of deposition; (ii) rate of deposition of organic and inorganic constituents; (iii) texture of the sediments. Trask (1939) stated that the main cause of the increase of the organic matter is associated with the grain size. This is due to the similarity in settling velocity of both organic constituents and fine particles. It could also be due to the enhanced surface adsorption of organic matter because of the greater surface area of fine sediment grains. Suess (1973) demonstrated that the increase in organic carbon and nitrogen with decreasing grain-size is linearly related to the surface area of mineral grains.

The very high content of organic matter and its variation in the Vembanad lake sediments are attributed to the following causes. In this ecosystem, the organic production is favoured by:

1. Vegetation around the Vembanad lake especially, mangrove swamps;
2. Texture of the sediments, brought by number of west flowing rivers, which are fine in nature; and
3. Degree of oxidation- due to oxygen deficient ecosystem prevailing in different part of the lake, the degradation of organic matter is less in this area and hence the high amount is encountered here. In Cochin harbour area in addition to the above factors, disposal of waste from the city may also contribute to the enrichment of organic matter.

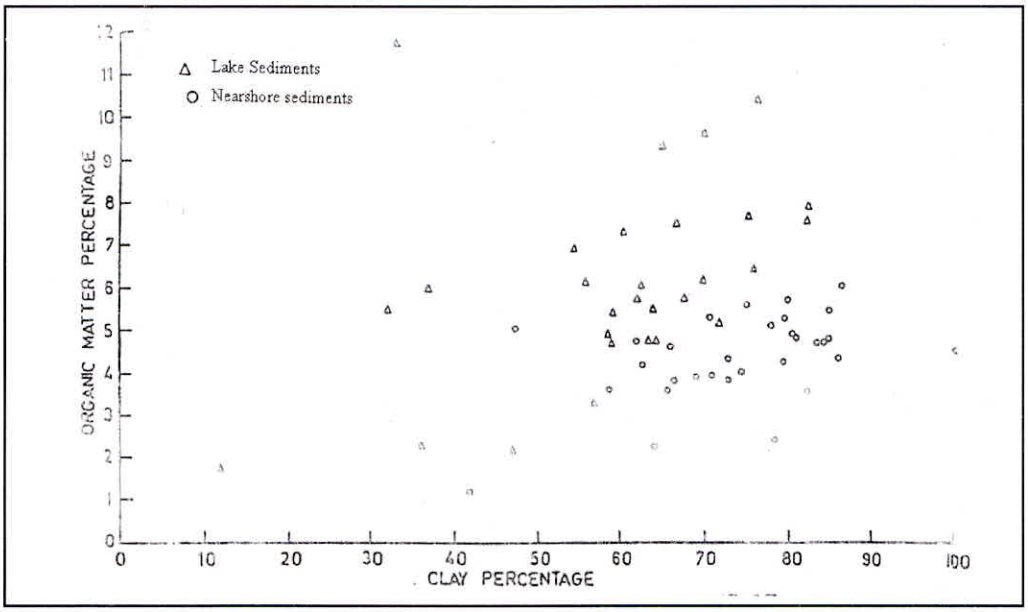

Figure 3 : Clay percentage versus Organic matter Concentration in Vembanad lake and adjoining shelf sediments

The relatively higher percentage of organic matter in the northern part of the estuary may be due to the denser planktonic and benthic population, salinity differences and the thicker vegetation around the area. In the southern part of the estuary, the fresh water conditions and coarse bottom sediments could be responsible for depletion in the organic matter content compared to the northern part. Besides this, circulation and depth of occurrence also play an important role in the accumulation of organic matter.

CONCLUSIONS

Dominance of silty clays and clayey silts are observed in the distribution pattern of the Vembanad lake sediments. A comparison of the pre-monsoon and post-monsoon sediment distribution shows that pre-monsoon sediments are finer with an improved sorting over the post-monsoon sediments. This is an index of mixing of sediments in the lake environment. The principal contribution of sediment is through the rivers during the monsoonal months. The dispersal of the coarser sediments in the lake during the monsoon results in the comparative coarseness of the post-monsoon sediments over the pre-monsoon sediments. The CM pattern showed that during post-monsoon the sediments are mostly transported by uniform and graded suspension.

The chemical constituents like calcium carbonate and organic matter bears a relationship with the texture of the sediments. The coarser the size, higher the calcium carbonate concentration. It is also found that, organic matter is higher in finer sediments. Organic matter is very important parameter because it paves way for the concentration

of other harmful metals. Therefore, it is suggested to undertake systematic monitoring of chemical parameters in the Vemaband lake and adjoining areas.

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