Sediment characteristics in relation to changing hydrography of Cochin estuary

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Sediments of Cochin estuary were studied in relation to changing hydrographical conditions. Seasonal spatial grading of particles as sand, silt and clay was observed. Contents of organic carbon, phosphorus and iron in sediments were closely studied in relation to hydrographical changes and attempts were made to describe the textural distribution on the above basis. The northern and southern arms of the upper estuary were mainly composed of sand particles. The lower estuarine regions indicated seasonal abundance of sand during monsoons pointing out to bedload movement. Otherwise, this area was predominantly covered by clay, silt size fractions. Surficial sediments also indicated variations in texture resulting from detritus settlement influenced by mixing conditions in the estuary.

In the highly dynamic environment of an estuary, hydrodynamical, chemical and biological factors vary greatly with different time scales and it is quite likely that these variations may influence sedimentary processes and also physical and chemical characteristics of sediments. However the studies on this aspect are quite few, and this paper discusses variations recorded in some of the characteristics of sediments, collected at monthly intervals for 1 y from December 1988 to November 1989, from Cochin estuary, a typical tropical positive estuary situated on the southwest coast of India.

Materials and Methods
The Cochin estuary is the largest of the estuaries on the Kerala coast. The hydrography of the estuary is controlled mainly by discharges from Periyar and Muvattupuzha rivers and also by tidal action through the Cochin barmouth1 - 4. Saline water intrusion to the southern parts of the estuary is regulated by the Thanneermukkam bund (marked as BUND in Fig. 1), a salt water barrier commissioned in 1975. Four more rivers, namely, Achancol, Meenachil, Manimala and Pamba discharge water into the estuary on opening of the Thanneermukkam bund during the rainy season.

Samples were collected from 10 stations (Fig. 1). Selection of the stations was based on specific geographical features, water flow regimes and anthropogenic activities. For a critical appraisal, stations may be subgrouped into 3 segments as:

Segment I, (sts 1-4) the southern arm of the estuary extends up to the southern limit of salt water intrusion and to the point where Muvattupuzha river debouches into the estuary. Segment II (sts 5-7) extends from the barmouth up to 10 km on the northern arm of the estuary and contains that part of the estuary that is saline throughout the year. Segment III (sts 8-10) extends beyond segment II on the northern arm of the estuary. For most of the time these stations contain only freshwater; saline water

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Fig. 1—Cochin estuary showing location of sampling sites [sts 1-4 (segment I), 5-7 (segment II) and 8-10 (segment III)]
intrusion can be recorded only during the periods of very low river discharge.

Sampling was made at monthly intervals during November 1988 to December 1989. Surface water samples were collected using a clean plastic bucket. Bottom water samples were collected using a Hytech sampler. A van Veen grab was used to collect the sediments. At each location 5 to 6 grab-full of sediments were sampled and the top 5 cm layer was carefully skimmed to eliminate shells and grit from all grabs using a polyethylene spatula. The sediment portion so obtained was homogenised and used for analyses.

Analyses of water quality parameters such as salinity, pH (Elico pH meter) and suspended solids were performed. Sediments were analysed for moisture, organic carbon and texture. Iron and phosphorus of sediments were extracted by nitric-perchloric acid mixture; iron was determined by AAS (Perkin Elmer 2380) and phosphorus was determined spectrophotometrically.

Results and Discussion

Since the hydrography of the estuary changes with the monsoonal climate, the influence of hydrography on sediment parameters was discussed by recognising 4 seasons namely, winter (December-February), premonsoon (March-May), monsoon (June-August) and postmonsoon (September-November). The seasonal mean values (Fig. 2) bring out seasonal and spatial variation observed at each station in sediment characteristics.

The moisture percentage in sediments indicated lower values in segment III and higher values in segment II. Seasonally, monsoonal values were lower except for sts 1 and 2 in segment I (Fig. 2). The variations in water content could be attributed to variations in organic matter and clay content.

In the Cochin estuary, the bulk of the sedimentary material is being supplied by Periyar on the north and Muvattupuzha on the south, mainly during rainy months (June-September). Percentage distributions of different size fractions of sediments broadly indicated the existence of a partition between coarser and finer components of the sediments. Seasonal variations of various grain-size groups in the surficial sediments are presented in Fig. 2. The sediments of segment III were mainly composed of sand particles. Cobbles and gravel also constituted a major fraction of sediments, especially in samples collected during monsoon period. In the sediments of segment I also sand particles constituted the bulk of the sediment, but the size of particles varied from fine sand to medium sized (63 to 1000 \( \mu \text{m} \)) grains. Sediments of segment II, however, had the lowest contribution from this size class. A slightly higher sand percentage, nevertheless, was recorded during monsoon. Recently, Sundaresan also reported similar features in the seasonal distribution of sediment particles in the Cochin harbour area. Sediments of st 7 (segment II) showed a clear cut seasonal variation in sand content, indicating significant bedload movements during monsoon and postmonsoon periods. The distribution of clay-size particles showed the opposite trend. In addition to the above 3 size classes, the size group < 16 \( \mu \text{m} \) fractions, was determined, since this fraction was considered to be of importance in metal transport in estuaries. Distribution pattern of < 16 \( \mu \text{m} \) size fraction followed the same trends as shown by clay size particles.

Veerayya & Murty opined that in Cochin estuary the sediments may be transported as bedload as well as suspended load. It was noted that major part of segment II was underlain with sediments of fine size. Further, it was observed that in the above segment, settling of finer fractions of sediments took place preferentially during winter and premonsoon season. Likewise, the increase noted in the case of finer fractions during winter and premonsoon period could be attributed to low fluvial discharge and a better mixing of saline and freshwater that facilitated flocculation and settling of suspended particles. The decreased percentage of silt and other finer particles during the monsoon period could be attributed to flushing of finer materials from the estuarine region to the sea.

Distribution pattern of organic carbon content also exhibited distinct spatial and seasonal trends (Fig. 2). Relatively higher values were recorded for sediments of segment II. The coarse sandy sediments of segment III were associated with minimum organic carbon. A comparison of data on grain size distribution and organic carbon distribution revealed that the organic carbon distribution in estuarine sediments followed broadly the sediment distribution pattern, in that, finer the sediment, higher was the organic carbon content. Both were high in sediments of mid-estuarine reaches in the north. Seasonal maximum was recorded during premonsoon period and minimum during monsoon period. From this relation it could be inferred that the adsorption of organic compounds onto clay minerals was promoted under saline conditions; organic coating on clay minerals affected the size distribution and settling rates of inorganic particles and thus contributed to the increase in both clay-size particles and organic matter.
Phosphorus content (Fig. 2) in the sediments also exhibited significant seasonal and spatial variations. Highest value was recorded in sediments of segment II and spatial distribution pattern followed the texture in the sense that higher the percentage of finer particles, higher was the phosphorus content. This dependency of phosphorus content on particle size is in agreement with an earlier report by Murty & Veerayya\textsuperscript{13} from the southern parts of the estuary. Postmonsoonal values were high except at st 1, 2, 6 and 7 where maximum was recorded during the monsoon. Seasonal fluctuations and range of values recorded during the current investigations were in unison with the observations of Sankaranarayanan & Punampunnayil\textsuperscript{16}.

Iron values in the estuarine sediments varied from 2811 to 20183 mg kg\textsuperscript{-1}. Highest value was observed at st 6 (segment II) during postmonsoon season (Fig. 2) and st 2 to 4 of segment I, st 5 of segment II and st 8 to 10 of segment III recorded minimum iron concentration during monsoon season. Winter/ premonsoonal values were generally higher at these
stations. For the remaining stations (st 1 of segment I, st 6 and 7 of segment II) the minimum value for total iron was recorded during winter with values increasing slightly through monsoon and postmonsoon. Variation in seasonal distribution followed the trends observed in the case of total phosphorus and a close association of these 2 elements was indicated. It was concluded from the above relation that the abundance of iron largely depended on changes in pattern of land drainage and erosion of agricultural soils of this tropical region, where iron phosphate formation was the rule rather than a mere probability as judged from chemistry of tropical soils.

Correlation coefficients indicating the relationship between various parameters studied are presented in Table 1. While sediment moisture content was significantly and positively related to organic carbon content and clay content, it was negatively but significantly related to sand content. Organic carbon, iron and phosphorus contents were significantly and positively related to clay content. Both iron and phosphorus contents were related to each other and also to organic carbon content, but relationship of phosphorus was stronger than that of iron. The data (Table 1) indicate a significant and positive relationship (except sand vs moisture) for all parameters studied and this suggests that the increasing salinities promote the coagulation, and estuarine hydrodynamics lead to setting of organic matter and fine clay, which in turn are responsible for a corresponding increase in moisture, iron and phosphorus content.

The present study was confined to 0-5 cm layer of surface sediments, which was usually influenced by varying inputs into the estuary. Qasim and Sankaranarayanan studied seasonal variations in the quantity and composition of detritus which settled to the bottom and reported that the bottom sediment was chemically similar to detritus. They also noted that the quantity of settled detritus was minimum during monsoon and postmonsoon periods when the turbidity in the estuary was maximum; they attributed it to the stratification which developed in the estuary from June to October as a result of discontinuity in the vertical profiles of temperature and salinity, which probably reduced substantially the settling rates of detritus. The rate of detritus settlement showed a sharp increase as the estuary returned to a well-mixed condition. Seasonal variations observed in fine particle composition and organic carbon content, during the present study, also indicated that surficial sediments were quite sensitive to the periodic addition of detritus, mainly composed of inorganic matter (fine silt and sand) to which organic matter adhered and formed aggregates.

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References