Distribution of nutrients in the Periyar river estuary

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Levels of phosphate, nitrate, nitrite and ammonia from 9 stations in the Cochin backwaters in an area extending from barmouth to 21 km upstream, up to an industrial belt at Elloor (Alwaye) were estimated. Inorganic phosphate showed an increasing trend towards upstream from st 1-8 and decreased at st 9 in all months. Nitrate indicated irregular pattern of spatial and temporal variations. Interface water exhibited maximum fluctuations. Partial distribution of nitrite in the surface and bottom waters revealed a gradual reduction in the nitrite content from st 5 to st 9. High values were recorded only for interface water in most of the months at st's 5 and 6. Nitrite content at the effluent discharge point (st 8) varied from 0.8-2.67 μmol l⁻¹. Levels of ammonia increased towards upstream with low values at st's 1-4 and 9 and high values for surface water (844 μmol l⁻¹) at the effluent discharge point (st 8). Temporal variations were highly irregular. Interface water showed higher values compared to the surface and bottom water. Irregular pattern of distribution of ammonia was recorded at all stations. Early monsoon season showed uniform conditions in this section. Subsequently a build up of nutrients in the mid-reaches was suggested. The fluctuations noticed in the nutrient levels may be the after effect of intermittent discharges of effluents and variations in river flow.

Estuaries apart from being the interface between rivers and oceans have been mediating man's predominantly land based activities and interacting with oceans. The latter has been on the increase over the years. The study of estuarine regions is all the more important as they are highly productive and play an important role as nursery grounds for many commercially important fishes especially shrimps. Many studies have been undertaken from this region on the physical, chemical and biological aspects. But a comprehensive study on nutrient sources and sinks is lacking. An attempt has been made to study the various nutrients, and probable pathways in this estuary.

Materials and Methods
Monthly sampling was done at 9 stations during 1981 (Fig. 1) from the river mouth towards upstream, a distance of about 21 km. Surface samples were collected using a clean bucket and for the bottom water a Meyer type of sampler was used. The water close to bottom was also collected. In the effluent discharge area (st 8) samples were collected close to discharge point for analyses. Inorganic phosphate⁹, ammonia¹⁰, nitrite¹¹ and nitrate¹² were estimated.

Periyar river, one of the largest perennial rivers of the area divides into 2 branches and one of the

Fig. 1—Station locations
branches opens into the sea at Cochin. The lower reaches is known as the Periyar estuary, a part of Cochin backwater system. The system is shallow with < 5 m depth. The bottom is characterised by easily resuspended sediment over 70% of its bottom from sts 1 to 3. Sts 4 to 6 are shallower with sandy bottom (60-90% sand), while sts 7 and 8 are dominated by silt (45-70%) and st 9 is with varying mixture of sand, silt and clay. Mean tidal range in the region is around 1 m.

Results and Discussion

Ammonia—In general the ammonia concentration (Fig. 2) at all levels increased from the mouth towards upstream (from 2 to > 500 μmol.1⁻¹) and there was a drop beyond st 8. Higher ammonia content was observed beyond st 4. As expected the water collected close to the bottom showed higher concentration of ammonia at all stations throughout the year except during January. Low (< 10 μmol.1⁻¹) values were observed at sts 1 and 2. St 9, situated upstream of the effluent discharge area, had relatively low values (< 10 μmol.1⁻¹) during all months except March and April. In general, ammonia values were low at the surface and bottom at all stations during June to October. However the interface values were higher during these months. High ammonia concentrations observed has been attributed to the ammonia discharged along with the effluent from a fertiliser factory. Higher levels of ammonia observed during March and April at st 9 may be due to the transport of the effluent upstream by the tidal flux.

Nitrite—Nitrite concentrations increased from sts 1 to 4 during January to June and there was a decrease further upstream (Fig. 3). In April, September and November high levels of nitrite were observed at sts 5 to 7 both at the surface and bottom. Highest concentration of nitrite (27.8 μmol.l⁻¹), in the interface water at st 4 was noticed in December.

Nitrate—Nitrate content was quite high. Unlike nitrite, nitrate levels increased upstream with highest concentration between sts 4 and 8 (Fig. 4) except in

Fig. 2—Distribution of ammonia at various locations during different months of the year.
January and May. At st 9 the concentration was relatively low in all months. From June to October the nitrate concentrations showed a regular increase upstream both at surface and bottom. Concentrations at the interface water however were lower than those at the surface and bottom at most of the stations from June to November. High values (68 and 140.4 μmol l⁻¹) were observed in the interface water in March at sts 3 and 4 respectively.

Inorganic phosphate—Surface and bottom waters in general showed a steady increase of inorganic phosphate from sts 1 to 8 and a sharp decrease at st 9 (Figs 5 and 6). Phosphate levels were minimum at st 9 throughout the period of observation. Lower values in surface and bottom waters were observed from July to October. Interface water showed very high values during March to May and July to October. During November to January the interface concentrations were lower than the overlying water. However in November and January the concentrations were higher at sts 5 to 8.

pH—Variations in pH over space in the water column by and large showed a reduction from the river mouth towards upstream (Fig. 7). These variations seemed to be associated more with the effluent discharge. They were significant between sts 4 and 8. The rivering end and sts 1 to 3 near the mouth showed a fairly steady picture, the variations being seasonal. Changes in the degree of tidal forcing seem to decide the points at which changes are noticed within this stretch.

Various nutrients in the estuarine system show high values throughout the year. The data indicate that the contribution from the river is negligible as it is clear from the lower values at st 9 which is situated upstream of industrial discharge area. The inputs are: (i) mainly through the effluent discharge from the fertiliser factory, (ii) from the sea and (iii) from non point sources in the system itself. Ammonia and inorganic phosphate from the fertiliser factory effluents get accumulated in the system prior to getting diluted and emptied into the sea. It is well established that benthic regeneration in estuarine and shallow coastal environments is potentially important to the underlying waters. Organic rich debris associated with high productivity in the estuarine nearshore areas is deposited in a labile state. In the estuarine and coastal environments where the sedimentary inputs are large, microbially mediated benthic remineralisation of debris is the major
recycling pathway and it can supply a significant fraction of the nutrients to the overlying water. This is indicated by high inorganic phosphate concentration in the interface water during all months except during November to January, showing high regenerative action and desorption to the overlying water.

Sankaranarayanan et al. observed during the southwest monsoon season a very weak lateral salinity gradient with phosphate concentration accumulating in the region of 4 to 12 km upstream. This, they attributed to poor seawater-dilution and flushing. The same feature is observed here also. Ammonia and phosphate levels showed a tendency to accumulate during June to September between sts 2 to 4.

Various nutrients discharged through the effluent indicate that the concentration is getting diluted most during the southwest monsoon season when the fresh water discharge through the river is maximum. During the other 2 seasons the levels of nutrients are
higher in the overlying water and this can be due to the low fresh water flow through the river. The interface water data show higher nutrient concentration during post and premonsoon seasons. During monsoon season, along with the fresh water discharge a large amount of suspended sediment is also brought in. Mechanisms of removal of phosphate from the overlying water are formation of phosphate complexes and sorption. Adsorption can also be important when suspended loads are high as in the monsoon seasons. Montgomery et al.\textsuperscript{16} has observed the removal rate of phosphorus by undisturbed sediments as of 70 mg m\textsuperscript{-2} day\textsuperscript{-1} and this rate of uptake can be increased by animals and wave action.

The present data suggest that the nutrient supply from the upper reaches of the estuary is far in excess of the requirements of producers. The discharged amounts are flushed out of the system, however the frequency of renewal through tidal mixing and exchange is not precisely known. The present results also indicate that part of nitrogen and phosphorus present in the system is getting adsorbed to the sediment particles and settled to the bottom. The sources of phosphorus and nitrogen which may increase this availability are the sediments and recycling of plant nutrients. From the data it is clear that these sources are smaller than the other sources. The contribution of sediments buried and the removal of nitrogen by denitrification are the other sources. The sediments collected always had the smell of hydrogen sulphide indicating the prevalence of anoxic conditions within the sediment and desorption of phosphate from the sediments.

Human influences are pronounced in the area among which the proliferation of industries on the riverine end and retting and sewer discharge at the lower reaches are prominent. The system is shallow, and the extensive network of canals modify the general pattern of circulation. Nonetheless it is clear that there is a build up of pollutants in the middle reaches of the estuary when flushing is not effective.
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References
