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# DISTRIBUTION OF INORGANIC NUTRIENTS IN THE GOSTHANI ESTUARY, EAST COAST OF INDIA

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Abstract

The horizontal and vertical distribution of ammonia, nitrite, nitrate, phosphate and silicate were studied from September 1987 to February 1989, in relation to depth, distance and time. The levels of concentration were exceptionally high. Their contribution through land drainage, untreated domestic sewage and sluggish circulation in this semi-enclosed bar-built shallow estuary were considered responsible for the high nutrient levels. Regeneration of inorganic nitrogenous and phosphate salts from macrovegetation in the estuary is significant.

## Introduction

The Gosthani Estuary is a semi-enclosed bar-built estuary opening into the Bay of Bengal arising in the eastern ghats at an altitude of 1275 m about 2 km northeast of Konada (18° 19′ N and 82°57′ E). The formation of a bar, an annual feature totally occluding the mouth owing to the massive coastal drift of water, takes place during May-June period. The river mouth experiences extensive geomorphological changes during the southwest monsoon season. During the period of total occlusion of river mouth the estuarine water level swells consequent on the unimpeded flow of water from the head of the estuary and land drainage. The sand bar either erodes out under the gravity impelled flow of estuarine water or may be manually cut, thus making a vent for the estuarine water to erode its way through the sand bar into the sea (Dhanalakshmi *et al.*, 1978).

Considerable work was done on the hydrography, plankton and benthos in the Hooghly-Maltah system of Ganges River, Chilka and Pulicat Lakes. Various aspects of hydrography, systematics and ecology of plankton and of benthos were studied in some detail in the Godavari and Krishna estuarine system. The Vellar and Edaiyar-Sadras system received considerable attention. On the west coast, various aspects of hydrobiology of the estuaries of the Malabar Coast in general and Cochin Backwater in particular, and the twin estuarine system of Mandovi and Zuari were studied fairly intensively.

To understand the distribution of nutrients in the Gosthani Estuary and to fill up the gap in this aspect from this estuary, a detailed investigation was undertaken and the results are discussed and presented in this paper.

The financial support of the UGC for the project entitled 'Studies on Hydrography and meiobenthos of Gosthani Estuary' is greatly acknowledged. Thanks are due to Mr. K. Parthasarathi for the help in the collection of samples and the authorities of Andhra University for the facilities provided.

## Materials and Methods

### *Area of study*

The area investigated includes a stretch of about 3.5 km, the navigable portion of Gosthani Estuary extending between the confluence at Bhimunipatnam and Chirpada towards the head of the estuary (Fig. 1). Beyond Chirpada the water is ankle to knee deep. Four stations (I to IV) were fixed opposite permanent landmarks for water sampling.

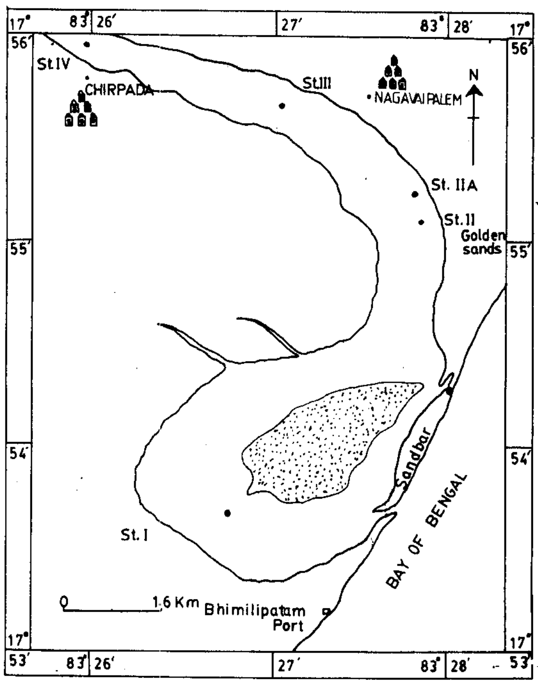


Fig. 1. Study area in Gosthani Estuary.

The ranges given relate to the four seasons namely, the northeast monsoon season (December-February), Summer (March-May), southwest monsoon season (June-August) and post-southwest monsoon season (September - November).

Water samples were collected at fortnightly intervals at the surface and subsurface levels during the period September 1987 to February 1989. The surface water was collected with a clean bucket and the subsurface samples with a shallow water sampler. The depth of the water column at Stn I to IV during high tide was nearly 1.5 m, 2.4 m, 2.4 m and 1.0 m respectively.

Inorganic nutrients were estimated colorimetrically with a spectrophotometer. Nitrite was estimated following Bendschreider and Robinson (1952), nitrates following Morris and Riley (1963), ammonia following Koreleff (1969), reactive phosphate following Murphy and Riley (1962) and reactive silicate following Koreloff (1971).

## Results and Discussion

### *Northeast monsoon season*

During this period the inflow of freshwater from the head of the estuary had considerably diminished. Consequently, brackishwater conditions became established from December.

*Nitrite :* The surface and bottom concentrations ranged from 0-1.78 $\mu$g at.l$^{-1}$ and from 0-6.92 $\mu$g at.l$^{-1}$ respectively. In general the bottom concentrations were higher than those at the surface level. Fairly high concentrations were noticed at the intermediate stations (Stn II and III). The surface-bottom differences were equally high and they ranged from 0.05 to 4.62 $\mu$g at.l$^{-1}$.

*Nitrate :* The surface and bottom concentrations ranged from 0.5 to 13.86 $\mu$g at.l$^{-1}$ and from 0.53 to 21.0 $\mu$g at.l$^{-1}$ respectively. Stn II and III maintained steadily a high level of concentration in December and January while in February the magnitude was comparatively less. The surface-bottom differences ranged from 0 to 15.54 $\mu$g at.l$^{-1}$.

*Ammonia* : The magnitudes of the ranges of variation in ammonia concentration were nearly identical at the surface and bottom levels. They varied from 0 to 10.90 and 0 to 17.85 μg at.$l^{-1}$

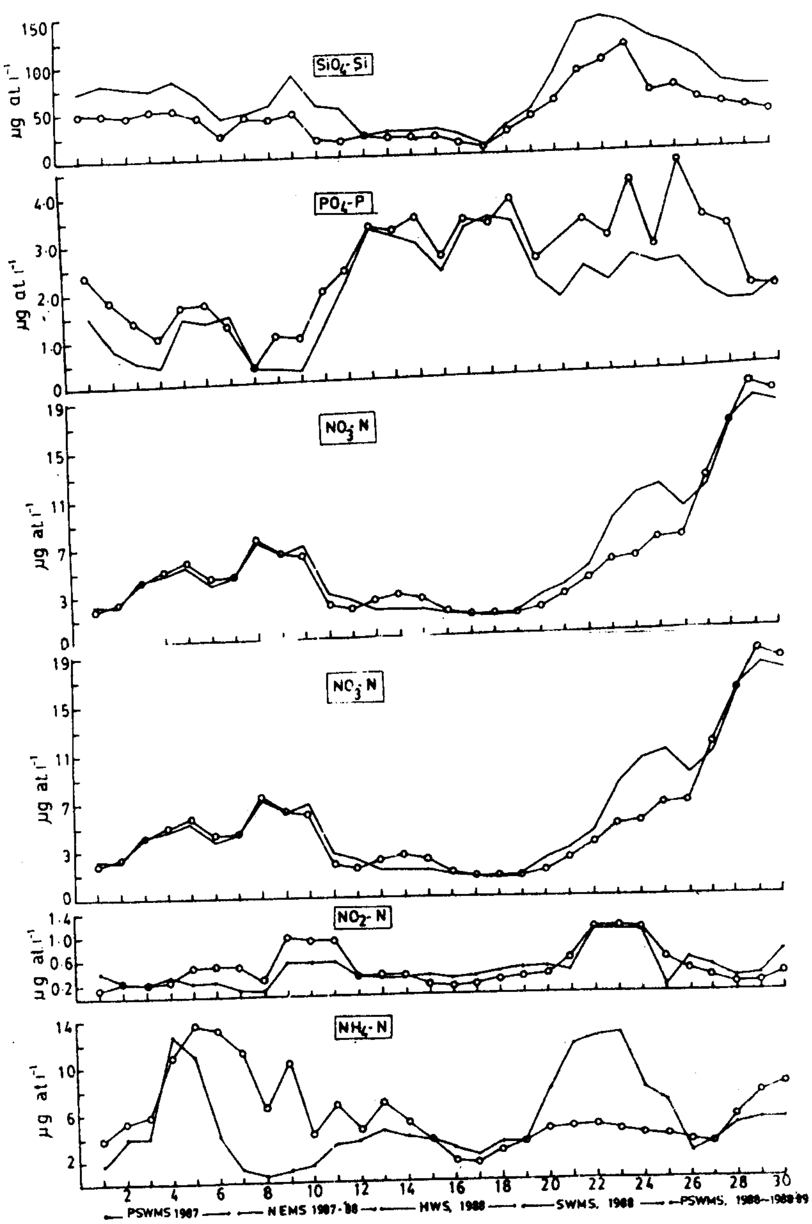


FIG. 2. Seasonal variations in ammonia, nitrite, nitrate, phosphate and silicate contents (averages) during the period September 1986 to February 1989 at Station I.
PSWMS : Post-southwest monsoon season; NEMS : Northeast monsoon season, HWS : Hot weather season (Summer) and SWMS : Southwest monsoon season.

at the surface and bottom respectively. There was a steady increase in ammonia soon after system started recovering from heavy freshwater spates. The water at Stn I and IV held a higher content of ammonia. There was a perceptible decline during the later half of February. The surface-bottom differences ranged from 0-17.36 μg at.$l^{-1}$.

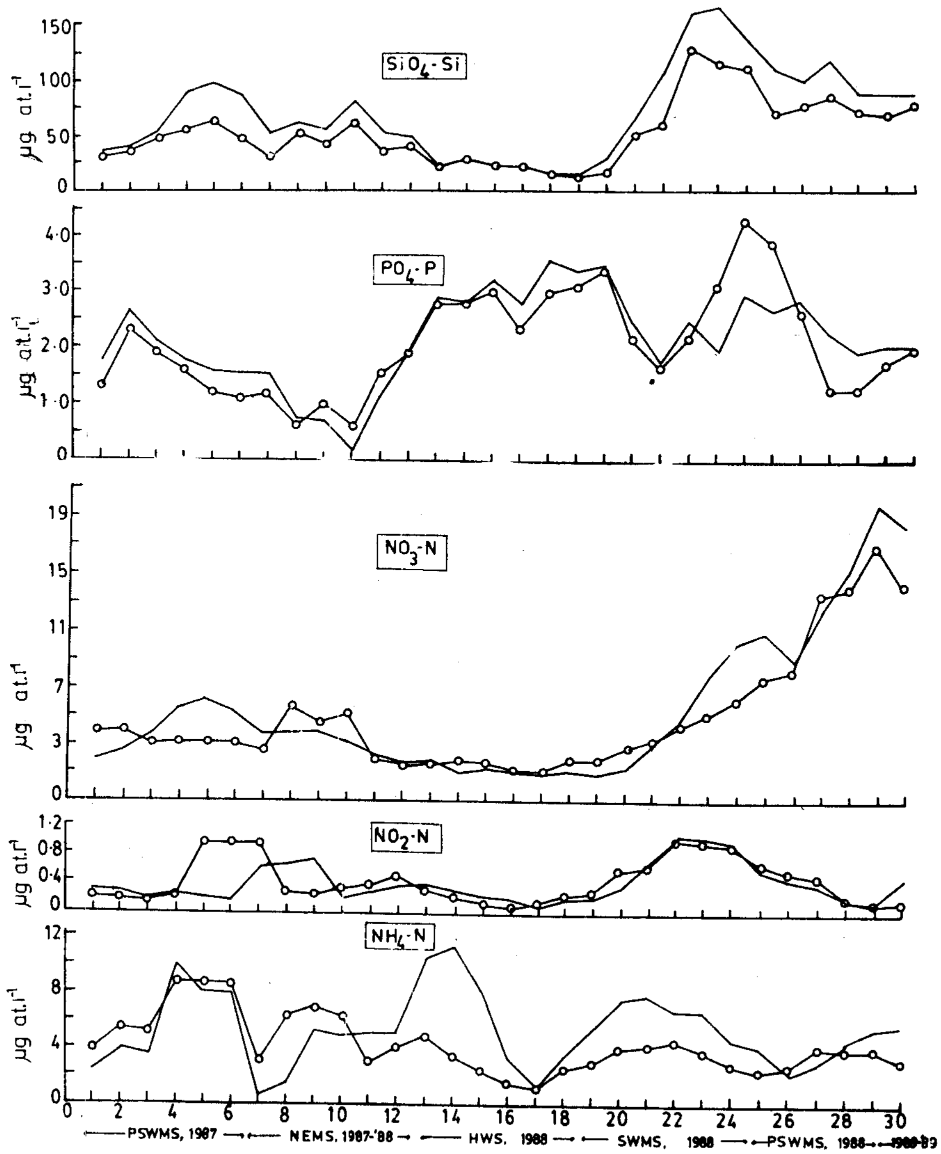


FIG. 3. Seasonal variations in ammonia, nitrite, nitrate, phosphate and silicate contents (averages) at Station II.

*Phosphate* : The phosphate concentration ranged from 0 to 4.8 μg at.$l^{-1}$ both at the surface and bottom levels. The general level was high during early December following the system's recovery from freshwater floods. There was an increase during January and the levels of concentration were optimal during the rest of the season. The surface-bottom differences ranged from 0 - 2.04 µg $at.l^{-1}$.

*Silicate* : The general level of silicate concentration was high both at the surface and bottom levels. An inverse relationship between salinity and silicates was noticed conspicuously in December. An increase in silicate with increasing salinity was noticed and markedly so during the end of February. The surface

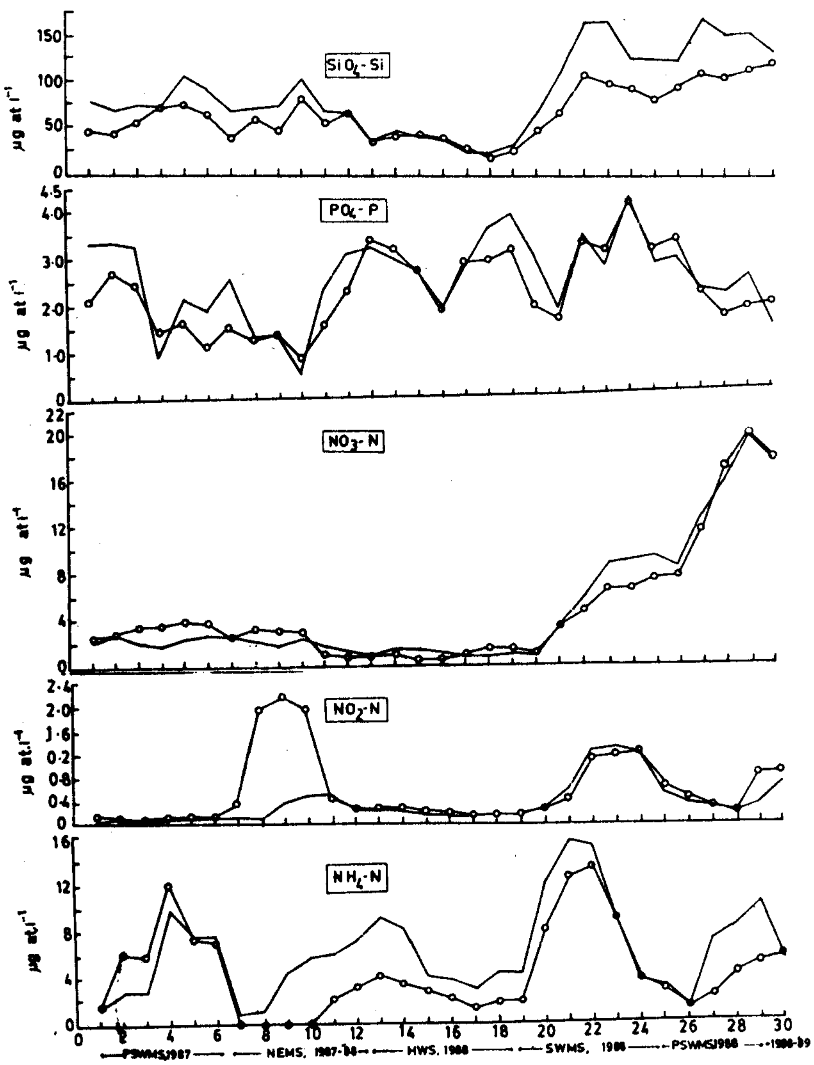


FIG. 4. Seasonal variations in ammonia, nitrite, nitrate, phosphate and silicate contents (averages) at Station III.

and bottom concentrations ranged from 13 to 160 µg at.$l^{-1}$ and from 13.5 to 120.0 µg at.$l^{-1}$ respectively. The surface-bottom differences were quite conspicuous and they ranged from 0 to 83.5 µg at.$l^{-1}$ the magnitudes of which were relatively higher at Stn I and II than at Stn III and IV.

*Summer*

*Nitrite :* The nitrite concentration varied from 0.27 to 0.52 and 0 to 0.41 µg at.$l^{-1}$ at surface

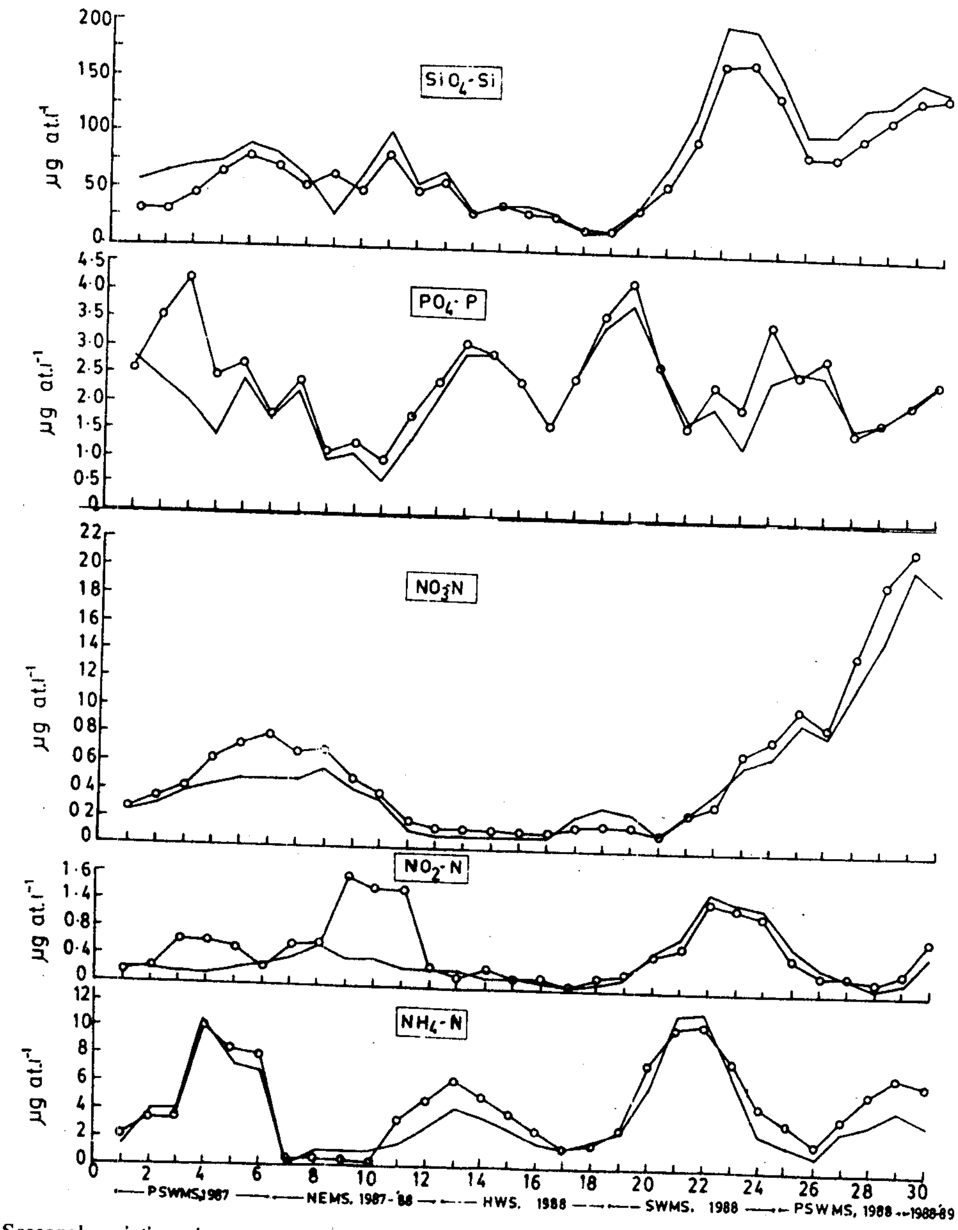


FIG. 5. Seasonal variations in ammonia, nitrite, nitrate, phosphate and silicate contents (averages) at Station IV.

and bottom levels respectively. The distribution of nitrite did not indicate variations in any significant measure, but the level of concentration was high in March and April. The surface-bottom differences arising out of surface excess over bottom or *vice-versa* were inconsistent.

*Nitrate :* Nitrate concentration varied from 0.15 to 2.55 µg at.$l^{-1}$ and from 0 to 4.48 µg at.$l^{-1}$ at the surface and bottom levels respectively. A clear decline in nitrate was noticed more conspicuously during May. The general low concentration may be attributed to the utilization by the benthic algae and phytoplankton.

*Ammonia :* A general increase in the concentration of ammonia was noticed. The surface and bottom concentrations of $NH_4$-N ranged from 0.87 to 16.40 µg at.$l^{-1}$ and from 1.25 to 9.07 µg at.$l^{-1}$ respectively. Surface-bottom differences were not consistent throughout the season.

*Phosphate :* As observed in the distribution of ammonia, there was a slight increase in the phosphate concentration during the early summer season. At the end of this season there was a perceptible decline as in other nutrients. The surface and bottom concentrations ranged from 0.54 to 5.88 µg at.$l^{-1}$ and from 0.54 to 3.78 µg at.$l^{-1}$ respectively. The surface-bottom differences varied between 0 and 2.2 µg at.$l^{-1}$.

*Silicate :* There was a perceptible decline in the silicate concentration due obviously, to its utilization by the bottom macro algae and loss to the bottom. The surface and bottom concentrations ranged from 7.3 to 50.0 µg at.$l^{-1}$ and 0 to 50.0 µg at.$l^{-1}$ respectively. A general tendency to increase from the confluence towards the head of the estuary was evident. Surface-bottom differences ranging from 0 to 24.0 µg at.$l^{-1}$ prevailed.

*Southwest monsoon season*

*Nitrite :* The pattern of nitrite distribution showed an increasing trend at the surface and bottom levels. The values ranged from 0.05 to 2.47 µg at.$l^{-1}$ of $NO_2$ - N at both surface and bottom levels. In general an increase in nitrite was evident considering with freshwater incursion. Surface - bottom difference that prevailed ranged from 0 to 0.64 µg at.$l^{-1}$.

*Nitrate :* Unlike nitrite the general levels of nitrate concentration showed a declining trend. The concentrations ranged from 0.55 to 8.50 µg at.$l^{-1}$ and 0.55 to 9.35 µg at.$l^{-1}$ at the surface and bottom levels respectively. Relatively higher concentrations were encountered at Stn IV in June and near the confluence at Stn I in July. The concentrations were high throughout the estuary as observed during August. The surface-bottom differences ranged from 0 to 3.27 µg at.$l^{-1}$.

*Ammonia :* The concentrations ranged from 1.35 to 25.47 µg at.$l^{-1}$ and 0.86 to 19.30 µg at.$l^{-1}$ at the surface and bottom levels respectively. Relatively high concentrations were encountered during July and August. Stn III and IV appeared to hold higher concentration of ammonia at Stn I and II. The surface-bottom differences ranged from 0 to 11.01 µg at.$l^{-1}$.

*Phosphate :* As in the case of other nutrients there was an increase in the general level of phosphate also in the estuary, but the levels were moderately high and nearly uniform. Fairly high concentrations were encountered during the end of August when estuary was filled with freshwater from surface to bottom at all stations. The $PO_4$-P values ranged from 1.08 to 6.60 µg at.$l^{-1}$ and 1.08 to 6.96 µg at.$l^{-1}$ at the surface and bottom levels respectively. The surface-bottom differences ranged from 0 to 3.84 µg at.$l^{-1}$.

*Silicate :* Silicate concentrations reached high levels during this period. Surface concentrations were consistently higher than bottom values. The values ranged from 1.13 to 3.30 $\mu g$ at.$1^{-1}$ and 1.12 to 2.80 $\mu g$ at.$1^{-1}$ at the surface and bottom levels respectively. An inverse relationship prevailed between salinity and silicate concentrations throughout this season.

*Post-Southwest monsoon season*

*Nitrite :* There was a decline in the nitrite levels which ranged from 0 to 0.88 $\mu g$ at.$1^{-1}$ and from 0 to 0.99 $\mu g$ at.$1^{-1}$ at surface and bottom levels respectively. The surface-bottom differences ranged from 0 to 0.47 $\mu g$ at.$1^{-1}$.

*Nitrate :* There was a remarkable increase in the nitrate concentration. The values ranged from 4.13 to 23.17 $\mu g$ at.$1^{-1}$ and from 4.84 to 25 $\mu g$ at.$1^{-1}$ at the surface and bottom levels respectively. Highest values for the season were encountered during November. Surface-bottom differences arising out of surface excess over bottom values were more frequent which ranged from 0 to 0.47 $\mu g$ at.$1^{-1}$.

*Ammonia :* Ammonia also occurred in high concentrations during this season. The increase was gradual to reach moderately high values by November. The surface values ranged from 0.19 to 18.33 $\mu g$ at.$1^{-1}$ and the bottom values from 0.77 to 7.43 $\mu g$ at.$1^{-1}$. The surface-bottom differences ranged from 0 to 13.7 $\mu g$ at.$1^{-1}$ considering the entire season.

*Phosphate :* The general level of phosphate was slightly lower compared to that of the previous season. The $PO_4$-P concentration ranged from 0.42 to 5.40 $\mu g$ at.$1^{-1}$ and 0.36 to 5.76 $\mu g$ at.$1^{-1}$ at the surface-bottom levels respectively. The surface-bottom differences varied from 0 to 4.50 $\mu g$ at.$1^{-1}$.

*Silicate :* The general level of silicate concentration was high at the surface and bottom levels despite increase in salinity. This was manifestedly clear during the preceding season. The $SiO_4$-Si concentration ranged from 60 to 190 $\mu g$ at.$1^{-1}$ and from 27.5 to 135.0 $\mu g$ at.$1^{-1}$ at the surface and bottom levels respectively. The surface-bottom differences varying from 0 to 90 $\mu g$ at.$1^{-1}$ were encountered considering the entire season.

A knowledge of nutrients relating to their contributory sources, utilization levels and their availability will be of great value to assess the productivity potential of an estuary. Drainage from farm lands, mangroves and some of the sewage effluents are known to enrich estuaries.

The Gosthani Estuary is free from industrial pollution. The only extraneous source is the untreated domestic sewage drained into the proximal broad limb near the confluence from only a segment of the town. Considering the entire stretch of study area (Fig. 2 to 5) the trends of changes in ammonia indicate a general rise during the post-southwest monsoon season in 1987 and again during the northeast monsoon season. The high values encountered during early summer season perceptibly declined during the remainder of the season. The southwest monsoon season witnessed a rise again consistently at all the stations. In general ammonia varied inversely with nitrite during a major part of study period at different stations. Occurrence of relatively high concentrations, encountered during southwest monsoon season, coinciding with rainfall and land drainage, indicates nutrient contribution in a significant measure from the freshwater end, whereas the increase during the post-southwest monsoon season may be attributed to regeneration from the detritus and extraneous inputs such as land drainage.

Changes in nitrite indicate (i) an increase during the northeast monsoon season

(Dec.-Feb.), (ii) a decline during the summer followed by a rise during southwest monsoon season and (iii) wherever peak values were observed there was an increase at the bottom level. The trends further indicate an inverse relationship between $NO_3$ and $NO_2$ during the post-southwest monsoon season (Sep.-Nov.) in the entire study area. Seasonal changes in nitrite indicate that wide fluctuations occurred at closer intervals of time as indicated by the observed near zero values at different stations on many occasions.

Maximum concentration of nitrite occurred during the period of study at Stn I and II during the southwest monsoon season. This indicates its contribution (i) from the neritic end, (ii) regeneration within the estuary and obviously (iii) addition through untreated sewage. The occurrence of ammonia and nitrite in high quantities lends support to the inference that effect of untreated domestics sewage into the estuary could be high. Similar was the trend of changes in nitrite concentration. It could be inferred that during the end of November and early December, coinciding with onset of northeast monsoon, the effect of addition of untreated sewage and conversion of ammonia and nitrite to nitrate could be high. In general an inverse relationship with nitrite, with slight departure, could be made out except during the summer, when a direct relationship was observed.

Seasonal changes in the phosphate concentration indicate that it occurred in fairly high concentrations in the broad proximal limb of the estuary. Similar trends noticed in respect of nitrite and nitrate. As in the case of nitrite, changes in the phosphate concentrations also occurred frequently.

Broadly an inverse relationship was observed between nitrate and phosphate considering the whole study period except during the early part of southwest and northeast monsoon seasons at Stn I, II and III. Phosphate occurred in high quantity during early post-southwest monsoon season at Stn III and in lesser magnitude at the bottom during southwest monsoon season.

There are diverse views as to the nature of the soil and its nutrient contribution (Seshappa, 1953; Suryanarayana Rao, 1957). Studies on Godavari Estuary also revealed that contribution from the river was insignificant and that the mangroves played a major role (Rama Sarma, 1965). The estuarine mud of Vellar Estuary was reported to be rich in phosphate (Balasubrahmanyan, 1961).

In the coastal waters, the nutrients regenerated from benthic sediments are a major source influencing primary production suggests that meiofauna and macrofauna are responsible for about 20% of regenerated nutrients (Mann, 1981).

The role of rooted vegetation inhabiting Gosthani Estuary (*Enteromorpha compressa, Gracillaria filifera* and angiosperms, adapted for estuarine flats, namely *Halophila ovalis* and *H. becari)* in the overall phosphorus budget may be considered significant. It is felt that these weeds play a role similar to that of *Spartina* (Poneroy, 1970) and *Zostera* (Mc Roy *et al.,* 1972).

The availability of nutrients by resuspension, at times of active mixing of waters appears to be considerable. The high nutrient, content arising from suspended and embedded organic matter, outwelling from the estuary into the adjoining neritic zone may be considered high. The possible contribution from Gosthani Estuary by way of organic matter and nutrients to the adjoining coastal waters, needs special mention. A similar observation was made on the role of Edaiyar-Sadras system in the environment of the coastal waters (Satpathy *et al.,* 1987).

It is necessary to mention in this context, the role of meiofauna in recycling nutrients (Mc Intyre, 1969) while considering at length, the role of meiofauna in the context of sustaining the predatory component belonging to higher trophic levels in the benthic ecosystem, suggested that the meiofauna plays an important role in the recycling of nutrients and in some areas, they may even complete with large sized predators for food. But the meiofaunal abundance in the area of study may not be considered high enough to conclude that the high nutrient levels observed in the estuary have, resulted from recycling of nutrients through the meiobenthic component in such a high measure (Sunitha Rao and Rama Sarma, 1990).

While the occurrence of nutrients in high concentration in the Gosthani Estuary can be reasonably attributed to the inputs of untreated sewage as well as recycling from decay of detritus, the contribution of nutrients through meiofaunal component could possibly be limited. Rich nutrient supplies arising from natural and domestic sources coupled with sluggish circulation, because of low sill depth at the mouth obviously keep estuarine environments, as the Gosthani under study, support a high order of oraganic production.

In the present study high values were observed principally during the southwest monsoon season at all stations when spates of freshwater passed down the estuary. A well defined increase from the marine end in the direction of the head of the estuary was evident, more conspicuously during the recovery phase of the estuarine system ultimately back to the prolonged phase of marine domination characteristic of summer.

The temporal variations showed that the concentration declined to minimal values during the summer. While the increased concentrations during the southwest monsoon and post-southwest monsoon seasons could be attributed to the freshwater inflow from the head of the estuary which are the main source of silicon. The decline in silicate level during the summer can be reasonably attributed to its utilization by phytoplankton and bottom algae. Part of the silicate content may have been lost to the bottom on mixing witl sea water.

Fairly high values were reported in a number of estuaries and coastal bodies of water around India, such as Gautami (Rama Sarma, 1965) and Vasishta (Sai Sastry, 1987) of the Godavari estuarine system, Cochin Backwater (Joseph, 1974) and Korapuzha Estuary (Rao and George, 1959). More or less a similar pattern of seasonal changes was observed (Nair and Ganapathy, 1983) in Edaiyar-Sadras estuarine system of Kalpakkam near Madras.

The seasonal changes bring to light the fact that there exists an inverse relationship between salinity and silicate concentrations as observed in the Godavari estuarine system (Rama Sarma, 1965; Sai Sastry, 1987) and in the Edaiyar-Sadras system at Kalpakkam (Nair and Ganapathy, 1983). Periods of vertical stratification in salinity coincided with stratification in silicates (Sunitha Rao and Rama Sarma, 1991). This was greatly in evidence during the recovery phase. During the summer the silicate levels declined considerably and no surface-bottom differences, either in salinity or in silcate prevailed.

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