

Physico-Chemical Characteristics of the Mahanadi Estuarine Ecosystem, East Coast of India

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Seasonal pattern of temperature, salinity, pH, dissolved oxygen, phosphate, nitrate and silicate profiles of the Mahanadi estuary have been studied. On the basis of physical characteristics, Mahanadi estuarine system can be classified as a partially mixed coastal plain estuary. The oxygen concentration in this estuarine system is closely related to biological activity and hence to seasonal changes in pH and it bears an inverse relationship with salinity structure. Dissolved nutrients are mostly non-conservative in this estuary. Land runoff coupled with biological and abiological processes appear to have a considerable bearing on the distribution pattern of these micronutrients in this estuarine waters.

The Mahanadi river is one of the largest river systems in the east coast of India draining into the Bay of Bengal near Paradip. Dissolved uranium, silicon and some of the major cations in the Mahanadi estuary have been reported^{1,2}. The present study deals with the spatial and temporal changes in various physico-chemical parameters during all the seasons of the year along approximately the whole estuarine system of the Mahanadi river. The investigation concentrates more on chemical factors along the confluence region of fresh water with seawater (brackish water regime) with respect to the impact of marine and land areas.

Materials and Methods

The river runs a total stretch of about 857 km having a drainage basin of 141,600 km² with a large catchment area. From environmental features and topography, the estuarine system of river Mahanadi (Fig. 1) can be classified as tide-dominated coastal plain estuary but geomorphologically this is a drowned river valley estuary. The tides in this region are of semi-diurnal nature with a maximum range of about 2.85 m (Indian Tide Tables, 1983 and 1984). The average annual rainfall in this area during the southwest monsoon is 1300 mm. The average annual runoff³ in this river is $66,640 \times 10^6$ m³. The depth range of the water column, from the mean sea level or chart datum in the Mahanadi estuary varies from 2-12 m.

Monthly water samples were collected from surface and near bottom at all stations (Fig. 1) during spring tide using Niskin water sampler. Temperature was measured using ordinary thermometer, pH with a portable pH meter (Philips make) onboard

the boat and salinity by Mohr-Knudsen chlorinity titration method. Dissolved oxygen (DO) and nutrients (PO_4^{3-} -P, NO_3^- -N and SiO_4^{4-} -Si) were analysed applying standard methods⁴⁻⁶. Seven sets of such observations were carried out from Dec. 1983-Aug. 1984.

Results and Discussion

The characteristic features of the estuarine system which closely follow the pattern of river runoff

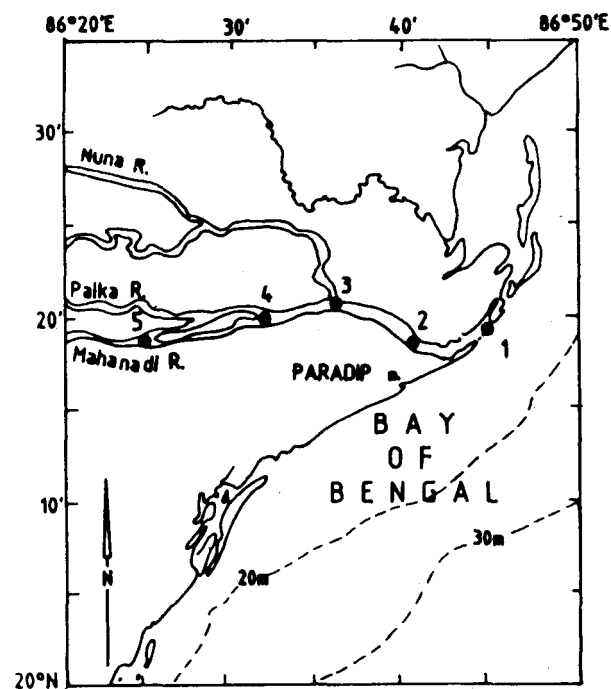


Fig. 1—Mahanadi estuarine system showing location of stations

and tidal variations were mostly controlled by the seasonal regimes, viz. premonsoon (Feb.-May), monsoon (June-Sept.) and postmonsoon (Oct.-Jan.).

Salinity—Sharp seasonal variations in salinity (Fig. 2) are observed at sts 1-4 except at st 5. The salinity structure reveals the increasing trend of salinity both during postmonsoon and premonsoon, recording highest of about 32×10^{-3} at the mouth (st 1) in May and a sharp decline during monsoon with the minimum in July. On many occasions the difference in salinity of surface and bottom layers is quite significant but the bottom water is more saline

than the surface water always. The salinity of the upper and bottom layers increases downstream so that there is a steady lateral salinity gradient over most of the estuary.

Salinity varies from 8×10^{-3} (monsoon) to 32×10^{-3} (premonsoon) at st 1, which shows the zone to be euryhaline. The salinity at st 5 (about 25 km from the mouth) is $< 0.5 \times 10^{-3}$ throughout the year signifying the fresh-water region (limnetic zone).

Adopting the index of salt water penetration as 1×10^{-3} salinity, it is evident from Fig. 2 that the intrusion is effective up to a maximum of 23 km in summer season and a minimum of 13 km in monsoon along the bottom. The surface intrusions of both are, however, less. The tidal reach in Mahanadi river is far beyond the estuarine region. The length of the tidal reach exceeds > 60 km upstream whereas the estuarine region extends up to 23 km only.

Temperature—Time series curves for the temperature of surface and bottom waters are almost uniform or even sometimes they are identical (Fig. 3A). The magnitude of apparent variation of temperature in the water column is insignificant. There has been a gradual rise in temperature from the mouth (st 1) upstreams along the estuarine system reaching the riverine system (st 5) in both premonsoon and monsoon seasons but during winter (December-January) a reverse trend showing colder waters along upstream regions of the estuary has been observed. These findings are in general agreement with that of Day⁷, that rivers are usually cooler than the coastal waters in winter and warmer in summer.

pH—A wide range of pH changes was encountered in the Mahanadi estuary (Fig. 3B). During postmonsoon pH was very high reaching 8.48 in mid-winter (December) due to the influence of seawater penetration and biological activity⁷ followed by low pH in premonsoon (7 to 8), which may be due to lower primary productivity⁷. During floods in peak monsoon, pH was quite low (7.5-6.28) which is due to the influence of freshwater influx and decomposition of organic matter^{7,8} carried by flood waters into the riverine system.

Dissolved oxygen—The concentration of DO showed a wide range of variation throughout the year (Fig. 3C). During December the concentration was very high ($6.05 \text{ cm}^3.\text{dm}^{-3}$) at st 1 whereas it was low during monsoon ($3.65 \text{ cm}^3.\text{dm}^{-3}$). The premonsoon however maintained the range of variation which was higher than that during the monsoon but lower than postmonsoon values. The DO values of surface waters were usually higher than the bottom waters. In general the DO concentration increased

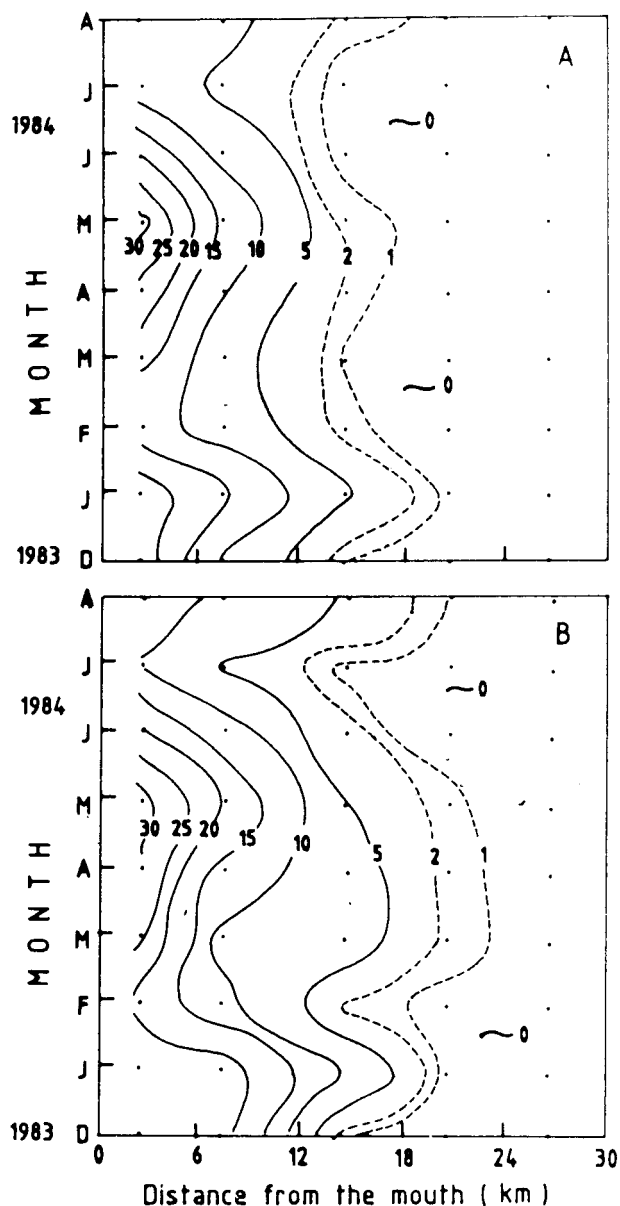


Fig. 2—Extent of salt water penetration along (A) surface and (B) bottom from the mouth of the Mahanadi river upstream in different months of the year [Continuous isohalines give the salinity of 5×10^{-3} intervals, broken lines indicate salinities of 2×10^{-3} and 1×10^{-3}]

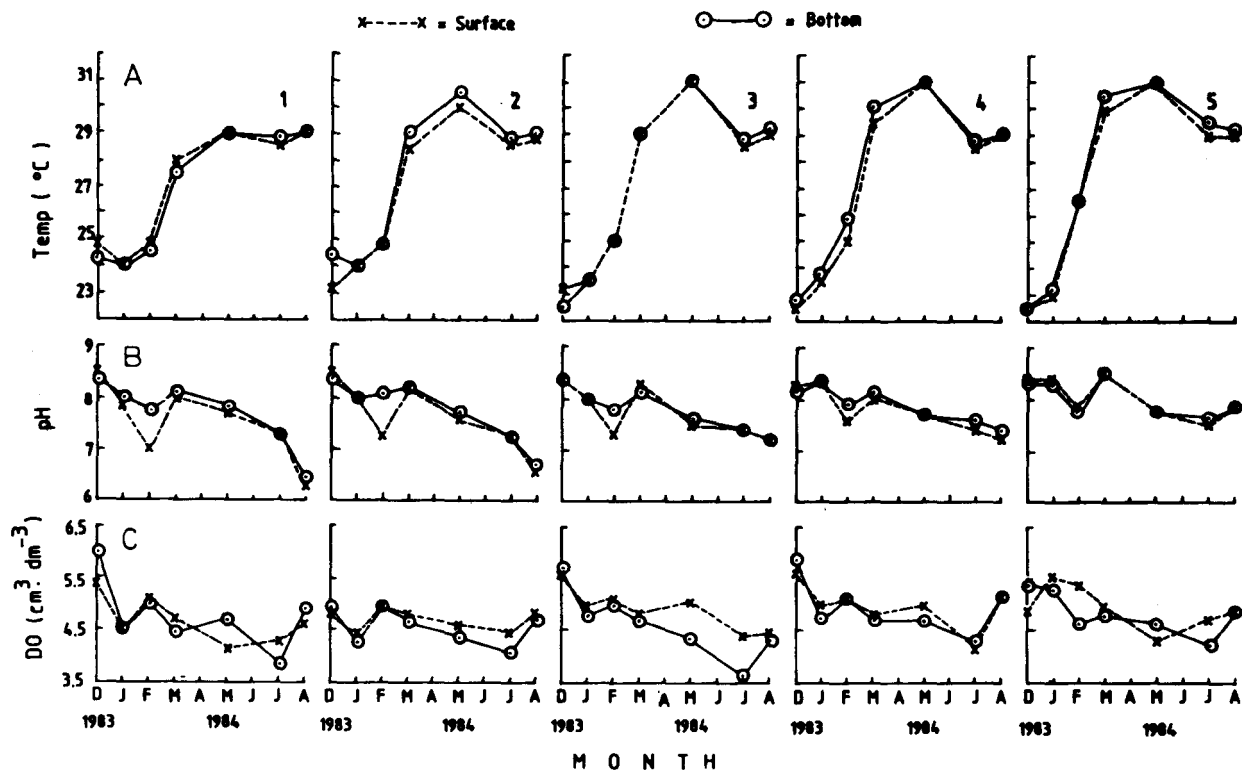


Fig. 3—Seasonal variations in (A) temperature, (B) pH and (C) dissolved oxygen at different stations in the Mahanadi estuary

upstream along the estuarine system except in mid-winter (December). During this period a marked DO maxima followed by high pH values were observed in the mouth zone. Comparatively high DO associated with high pH values along the estuarine system during December suggest the abundant growth of phytoplankton and related zooplankton leading to high biological activity in the period while the corresponding low values during monsoon would, perhaps, indicate bio-degradation of organic matter in the water column.

PO_4^{3-} -P—Phosphate is low in monsoon inspite of massive land washings (Fig. 4A) and it is high during other seasons. The concentration of PO_4^{3-} -P varies from 1.07 to 4.01 $\mu\text{mol.dm}^{-3}$ during premonsoon, from 0.54 to 2.46 $\mu\text{mol.dm}^{-3}$ during monsoon and from 0.53 to 3.21 $\mu\text{mol.dm}^{-3}$ during postmonsoon. Phosphate concentration of the surface waters is higher than the bottom layer along the whole estuary during monsoon due to high land drainage. The rest of the period is characterized by a mixed pattern at the mixing zone of the mouth regions of the river due to high turbulence and disturbance at the water-sediment interface while in the middle and upper reaches of the estuary phosphate content of the bottom layer was significantly higher than the surface waters.

Mahanadi river carries very high sediment load in the flood waters during rainy season which may be

the reason for phosphate removal, with adsorption being favoured by acidic environment ($pH \sim 6$) causing unusually very low value during the period⁹⁻¹¹. During postmonsoon, however, the range is quite normal even though there is biological utilization since desorption of phosphate is favoured by alkaline environment ($pH > 8$). The trend of desorption in dry summer season being of the same order or accelerated due to disturbance at the water-sediment interface owing to seawater penetration along the river-bed and with lesser biological activities, high phosphate value in this period is quite reasonable. Relatively high phosphate values at the mouth region (sts 1 and 2) would, perhaps, indicate addition from sources other than aquatic which could be anthropogenic or by human activities.

NO_3^- -N— NO_3^- -N rather than PO_4^{3-} -P seems to play a significant role in the primary production which is evident from the pattern of seasonal nitrate profiles (Fig. 4B) in comparison with corresponding phosphate profiles. With the onset of monsoon nitrate concentration suddenly increased along the whole estuary (4.5 to 5.25 $\mu\text{mol.dm}^{-3}$). This was believed to be due to high land drainage and precipitation¹². The progressive decrease, however, during the postmonsoon reaching the minimum (0.14 to 1.37 $\mu\text{mol.dm}^{-3}$) can be attributed to biological utilization of NO_3^- -N indicating that nitrate-N rather than phosphate-P regulates this process. In addition,

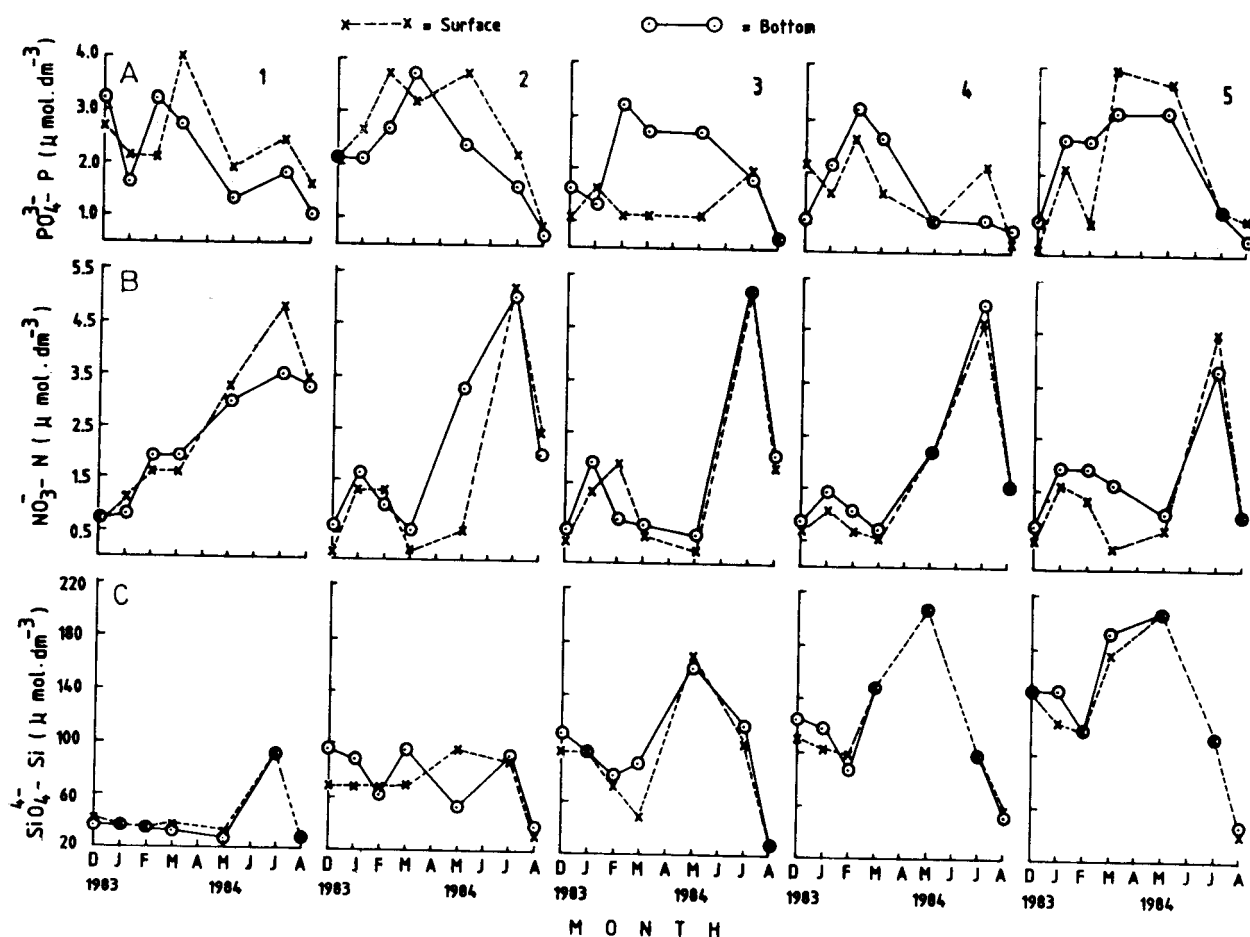


Fig. 4—Variations in the concentration of nutrients: (A) $\text{PO}_4^{3-}\text{-P}$ (B) $\text{NO}_3^-\text{-N}$ and (C) $\text{SiO}_4^{4-}\text{-Si}$ at different stations in the Mahanadi estuary

the inverse relation between $\text{NO}_3^-\text{-N}$ and DO would support this phenomenon in the light of $\text{NO}_3^-\text{-N}$ depletion versus oxygen saturation during primary production in the aquatic system.

$\text{SiO}_4^{4-}\text{-Si}$ —Silicate concentration ranges from 24 to $207 \mu\text{mol}\cdot\text{dm}^{-3}$ (Fig. 4C), which is similar to earlier reported values^{1,2}. Si content in river water is usually at least one order of magnitude greater than that found in surface seawater and the anticipated inverse relationship between the salinity and the concentration of reactive silicate is apparent¹³. But the general dilution hypothesis maintaining a linear relationship between chlorinities and silicates has been obsolete¹⁴. Distribution of silicate showed high concentration at the river end which decreased gradually downstream with low value at the sea end in conformity with the pattern found in most of the estuaries.

Low values of $\text{SiO}_4^{4-}\text{-Si}$ during postmonsoon (Dec.-Jan.) might be due to removal by biological processes. But comparatively a low value than the expected at the time of high river discharge (monsoon) has been observed in the Mahanadi estuary. It

is more likely that a major portion is removed by inorganic precipitation^{9,13-15}. Also dilution effect due to large river runoff may have considerable influence, thus limiting the build-up of reactive silicate in the water column.

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