

## Monitoring of Some Environmental Parameters at the Mouth of the Zuari River, Goa

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Environmental parameters like temperature, salinity, dissolved oxygen, nitrate, nitrite, ammonia and phosphate were studied at a station in the Zuari estuary ( $15^{\circ}27'N$ ;  $73^{\circ}48'E$ ) during June 1974-September 1975. Marked seasonal variations were noticed both in surface and bottom (4-5 m). Phosphate levels were generally higher in bottom samples while nitrate contents were higher at the surface. There was similarity in the patterns of nitrite and ammonia distributions. Changes observed during the monsoon were attributed to the influence of precipitation and fresh water influx from land.

**H**YDROGRAPHY, circulation and sediment load of the waters of Mormugao Bay and the adjoining sea have been reported<sup>1,2</sup>. A similar study of the waters of the Cumbarjua Canal which links the two main rivers of Goa, Mandovi and Zuari, has been made<sup>3</sup>. Bhargava and Dwivedi<sup>4</sup> have studied diurnal variations in phytoplankton pigments in Zuari estuary and in Cumbarjua Canal while Dehadrai and Bhargava<sup>5</sup> have discussed diurnal variations of these pigments in Zuari estuary in relation to environmental parameters. Dehadrai<sup>6,7</sup> has discussed changes in environmental features in this area in relation to tides. The latter study also reports changes of inorganic phosphate concentration during monsoon and postmonsoon. Diurnal variations of chemical parameters of these waters were reported by Singhal<sup>8</sup>. Ecology and environmental monitoring of Mandovi, Zuari and Cumbarjua canal complex during monsoon months has been reported by Dwivedi *et al.*<sup>9</sup>. The present work has been made to understand more about temporal changes in the background levels of various physico-chemical factors and the impact of marine and land areas. Emphasis is given more to the chemical factors which are known to react considerably to natural and artificial changes within the system.

### Description of Area

Sampling area was near Dona Paula ( $15^{\circ}27'N$ ;  $73^{\circ}48'E$ ) in the Mormugao Bay which is an estuary of the river Zuari. Depth of the water column at the station varied between 4 and 5 m depending on the height of the tide. The estuary is more or less a one layer tidal one<sup>3</sup> except during monsoon months when, due to land drainage, it assumes a temporary 2 layer structure<sup>1,2</sup>. Normal annual rainfall in this area is 2760 mm of which the major part falls during June to August<sup>10</sup>.

### Materials and Methods

Water samples were collected from surface and bottom once a week at high tide through all the

seasons. Surface samples were collected in a plastic bucket while a Nansen reversing bottle was used to collect bottom samples. Samples were analysed for salinity, dissolved oxygen, phosphate, nitrate, nitrite and ammonia within 1 hr of collection employing following methods:

Salinity was measured by Mohr-Knudsen titration method. Reversing thermometer was used for measuring the bottom temperature while the surface temperature was measured by ordinary thermometer. Dissolved oxygen was measured by the Winkler method as modified by Carritt and Carpenter<sup>11</sup>. Inorganic phosphate was estimated by ascorbic acid-potassium antimonyl tartrate method of Murphy and Riley<sup>12</sup> as modified by Fonselius and Carlberg<sup>13</sup>. Nitrate was estimated by the Cadmium amalgam reduction method of Morris and Riley<sup>14</sup> as modified by Grasshoff<sup>15</sup>. Nitrite was determined by the method of Bendschneider and Robinson<sup>16</sup>. Ammonia was determined by the indophenol blue method of Koroleff<sup>17</sup> using citrate buffer.

### Results and Discussion

To facilitate interpretation, the data obtained are analysed seasonwise as follows: February-May (premonsoon), June-September (monsoon), October-January (postmonsoon).

*Premonsoon* — In this season the water showed increasing salinity, temperature, dissolved oxygen and nutrients (Figs. 1 and 2). Temperature which was low during the cold season started rising in February reaching the peak values in April,  $31.5^{\circ}C$  (surface) and  $32.0^{\circ}C$  (bottom), when the atmospheric temperature also was the highest. Maximum atmospheric temperature ranged between  $32$  and  $34^{\circ}C$  while the minimum was between  $26^{\circ}$  and  $28^{\circ}C$  during the last week of April<sup>10</sup>. The slight decrease in water temperature in May, before the onset of monsoon might be due to the prevailing winds. Salinity during this season was the highest of the year reaching peak values of  $35.8\text{‰}$  (surface) and  $35.9\text{‰}$  (bottom). In fact highest salinity ( $36.1\text{‰}$

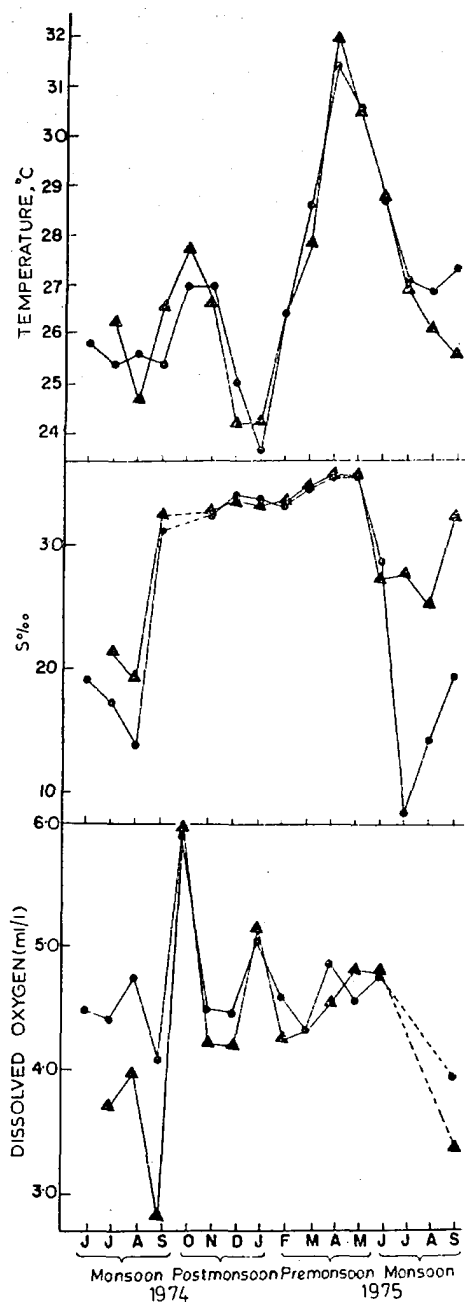


Fig. 1 — Monthly average values of temperature, salinity and dissolved oxygen [●—●, surface and ▲—▲, bottom]

and 36.2‰ respectively) was recorded during the last week of May, a few days before the onset of monsoon. The near uniform value of temperature and salinity in the surface and bottom waters was due to the mixing of the waters<sup>1,2</sup> and confirms the tidal nature of the estuary<sup>3</sup>. Dissolved oxygen concentration was generally high during this season. Surface water showed fluctuations in oxygen concentration ranging between 4.3 and 4.9 ml/litre while the bottom water concentration showed an increasing trend. Phosphate content of surface water

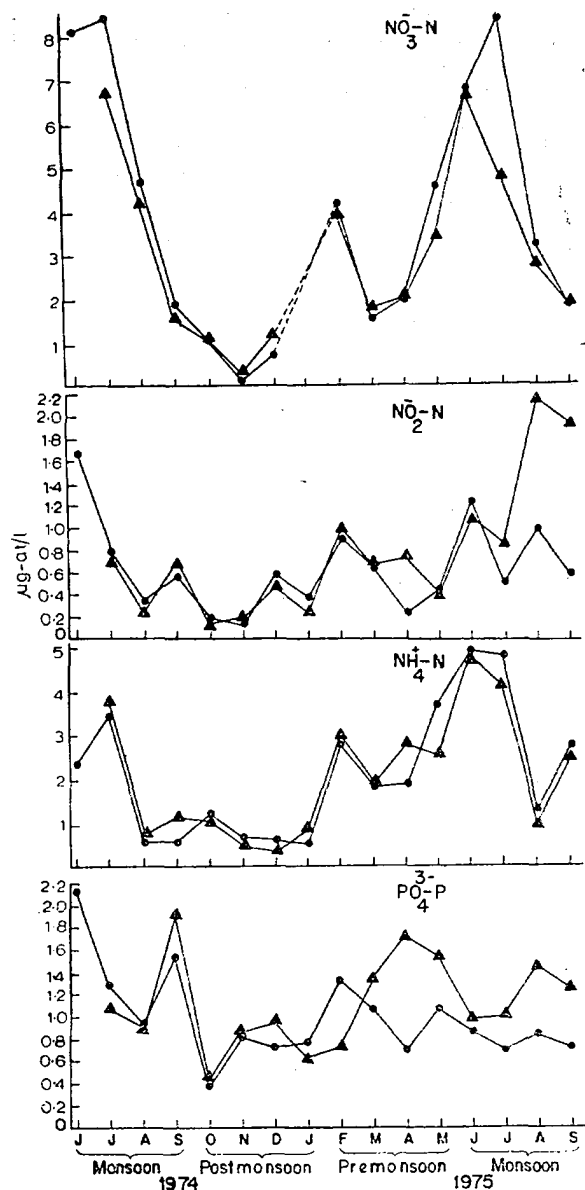


Fig. 2 — Monthly average values of nitrate, nitrite, ammonia and phosphate [●—●, surface and ▲—▲, bottom]

showed an initial decrease till April followed by an increase in May. Bottom phosphate, on the other hand, showed increasing concentration till April and thereafter it started decreasing. A similar trend was observed in case of nitrogen compounds.

In general all nutrients showed an initial decrease from February to March followed by increase in April and May. Initial fall in concentration of the nutrients may be due to their utilization by the phytoplankton which normally shows high productivity in this season<sup>5,18</sup>. However, concentration of nutrients showed increasing trend towards the end of the season accompanied by high salinity, low dissolved oxygen and decreasing temperature

indicating probably, the effect of intrusion of upwelled waters in the estuary<sup>19</sup>, which have similar character.

**Monsoon** — The water showed low temperature, low salinity and low dissolved oxygen but high nutrient content. Surface salinity in monsoon 1975 was much lower than that in 1974, the difference being due to the differing amounts of rainfall. In 1974 the rainfall for June-October was 2986 mm while in 1975 during the same period it was 3374 mm (the normal rainfall for this period being 2597 mm)<sup>10</sup>. During this season the estuary was mainly fed by monsoon precipitation<sup>3</sup> exhibiting two-layer nature<sup>1,2</sup> as was evident from the differing values of temperature, salinity and dissolved oxygen from surface to bottom (Fig. 1). Nutrients showed high concentration in the beginning of the monsoon (Fig. 2) but as the monsoon progresses their concentration gradually decreased. High nutrient content in this period may be attributed to 2 factors, land drainage and precipitation. The former contributes to nitrate, nitrite, ammonia and phosphate content of the waters but precipitation affects only the content of nitrogen compounds and plays an important part in the nitrogen cycle in nature<sup>20</sup>. It has been observed that the early rains have high concentration of nitrate and ammonia. Nitrate concentration ranging from 0.27 to 3.77  $\mu\text{g-at/litre}$  and ammonia from 2.08 to 9.94  $\mu\text{g-at/litre}$  was recorded during this study, in monsoon 1975 while phosphate concentration was negligible. It was also observed that the early rains have higher concentration of these components and as the monsoon progresses, their concentration decreases. These trends are reflected through the peak values of nitrate and ammonia observed in the beginning of monsoon (Fig. 2). High phosphate in the beginning of the monsoon (1974) recorded decrease in August followed by an increase in September, and since the primary productivity is low in this season and there is no marked rise in oxygen concentration, it suggests that part of the phosphate might have been adsorbed by the silt particles or locked up in the interstitial spaces of the sediment<sup>21,22</sup> followed by its subsequent release from the sediments in September. Occurrence of high salinity, high phosphate, low temperature and low dissolved oxygen especially in the bottom water in August-September (1975) is note worthy and this may be due to the effect of upwelled waters<sup>19</sup>.

**Postmonsoon** — During this season waters were characterized by high salinity, high dissolved oxygen, low temperature and low nutrients. The temperature which showed a rising trend towards the end of monsoon reached a secondary peak in October and thereafter it started falling till it reached lowest value in January coinciding with the prevailing cold season in the area. Salinity showed a rapid rise in the beginning and thereafter the change was very slow. There was no marked difference in salinity and temperature between surface and bottom samples indicating the 1 layer nature of the estuary<sup>1,3</sup>. High concentration of dissolved oxygen in October showed a steep fall in subsequent months followed by a secondary peak in January. Nutrients, in general, were low in this season.

Both nitrate and phosphate showed (Fig. 2) a decrease in concentration during 2 periods, October-November and March-April. Decrease in nitrate was from 8.35 to 0.16  $\mu\text{g-at/litre}$  and from 4.2 to 1.5  $\mu\text{g-at/litre}$  while the corresponding decrease in phosphate concentration being 1.53 to 0.36  $\mu\text{g-at/litre}$  and from 1.32 to 0.69  $\mu\text{g-at/litre}$ . This shows that the decrease of nitrate for any period is proportionately more than that of phosphate for the same period and since these 2 periods correspond to periods of high productivity<sup>18</sup> it can be said that in Zuari estuary concentration of nitrate rather than that of phosphate regulates the productivity of phytoplankton.

The above observations can be summarized as follows: (1) The estuary shows one-layer characteristics throughout the year except for temporary 2 layer structure during monsoon. (2) Thermal conditions of the water are governed by atmospheric conditions. (3) Salinity is high during pre- and postmonsoon seasons whereas it is low during monsoon, (4) Dissolved oxygen is high in pre- and postmonsoon while it is low in monsoon months. (5) Nutrients show 2 peak levels in concentrations, one during monsoon (June-July) and the other (secondary) during premonsoon (February-March) months. (6) Phosphate levels are generally high in the bottom water indicating its origin from the exchange between mud-water interface and water exchange with the sea. Nitrate is high in the surface water showing that it comes mainly from land drainage and precipitation. (7) Nitrite and ammonia show similarity in their trend of variations with monsoon high and low during pre- and postmonsoon, there being not much difference between their concentration at the surface and bottom.

From the foregoing it is evident that the waters of the Zuari estuary exhibit significant changes in the physico-chemical parameters largely influenced by monsoon rains. During the rest of the year characteristics of water are predominantly marine. The trend of variation especially of nutrient salts, during pre- and postmonsoon seasons indicate active recycling. Marine dominance of the estuary as well as the relatively high concentration of nutrients indicate that flushing is considerably restricted especially during pre- and postmonsoon seasons. This aspect may have significant bearing from the view point of discharging pollutants into the river.

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