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Diurnal Variations of Some Physico-chemical Factors in the Zuari Estuary of Goa

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Diurnal variations of temperature, salinity, dissolved oxygen and nutrient salts at two locations in the Zuari estuary were studied in different seasons as a part of the project on the Ecology of Mandovi and Zuari estuaries with special reference to changes in living resources. Marked changes were noted in all the parameters. Temperature and salinity variations followed the tidal rhythm in all the seasons. Except silicates the other chemical factors, viz. dissolved oxygen, phosphates and nitrates, showed distribution independent of tidal variations, the silicate behaved more as a non-conservative factor within the estuary. Probable reasons and significance of the variations were discussed.

DYNAMICS of estuarine systems revealing the complexity of the operating forces of both marine and fresh waters, induced mainly by the tidal incursion, current patterns and the magnitude of fresh water discharge at different periods and seasons have been discussed[1-3]. The concentrations of nutrients are also relatively high in estuaries as a result of close proximity to the land drainage[4]. Apart from the general interest in understanding the conditions of the estuaries and its impact in the inshore environment, observations on the short term changes on the physico-chemical parameters may also have practical implications in pollution studies.

The present work deals with the diurnal variations of some of the physico-chemical parameters of Zuari estuary. Earlier studies on this aspect were made by Dehadrai[5] on a few hydrographical features in two seasons, but the observation points happened to be very close to the banks. The present observations in the Zuari estuary made half way from the banks at suitably selected stations, include also the diurnal variations of the nutrients in different seasons.

Materials and Methods

The Zuari river runs along the southern boundary of the Panaji island and flows into the Mormugao Bay (Fig. 1). The Zuari river is connected to the Mandovi river running along the northern boundary of the Panaji island by the narrow Cumbarjua canal. The tides in this region are of semi-diurnal type with a range of about 2 m. Two high and 2 low tides occur with significant variations in the range and time (Fig. 2). The general pattern of circulation conforms to the 2-layered flow; during the ebb, fresh or brackish water is discharged from the estuary into the sea, and during the flood, the sea water intrudes deep into the estuary. It may also be mentioned that during the active monsoon period (June-August), maximum rainfall (about 300 cm) occurs in this region, flooding the rivers.

The station locations are shown in Fig. 1. Water samples were collected at intervals of 3 hr covering the entire tidal cycle once in different seasons (August 1971, and February and April 1972). The samples were analysed for temperature, salinity, dissolved oxygen, phosphates, nitrates and silicates. Standard methods were adopted for the analysis of chemical parameters[6,7].

Results and Discussion

Temperature — The general trend of variation in the temperature of the waters at the 2 locations are more or less same except the magnitude of the range is higher at station B than at station A (Figs. 3-5 and Table 1). Superimposed on the short period variations due to insulation and cooling during nights, the temperature variations follow broadly the tidal rhythm. The changes are less pronounced during the early February in both the stations as compared to other 2 periods. During the flood period the temperature tends to fall due to the incursion of seawater and during the ebb the temperature slowly rises as the landlocked brackish or fresh water pervades the region. Maximum variation occurs during the fall seasons and this is well reflected at station B which is located in the narrow channel. Distinct 2-layered feature could be inferred by the significant temperature difference between surface and bottom waters at the

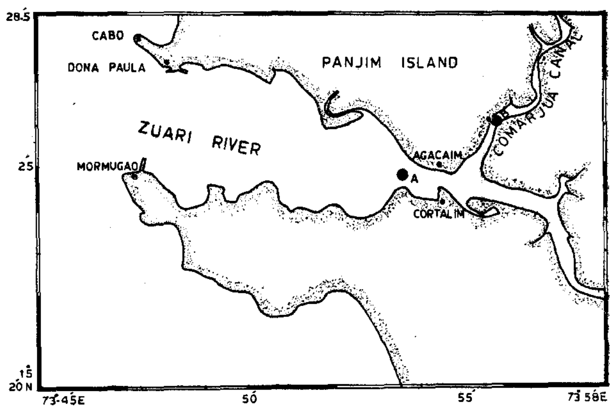


Fig. 1 — Map showing station positions

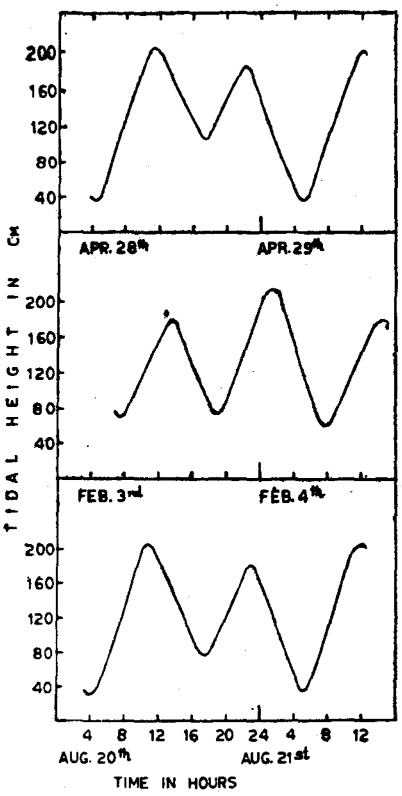


Fig. 2 — Tidal cycle in the estuary during different periods (August 1971 and February and April 1972)

2 stations in different seasons. The temperature of bottom waters is generally lower than the surface, except on few occasions (February); apparent inversion occurred probably due to mixing processes.

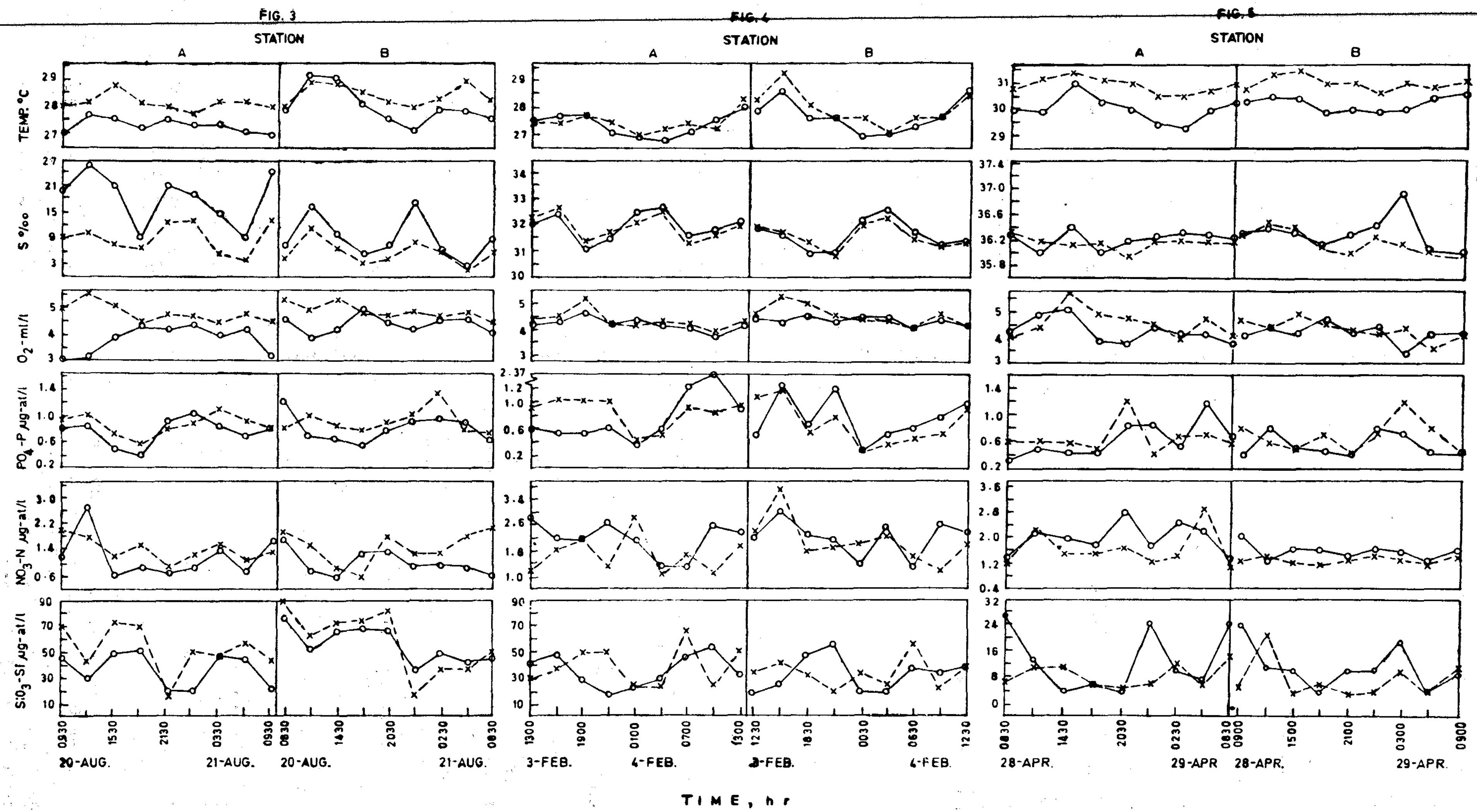
Salinity — During monsoon period salinity variations are more pronounced following tidal pattern and during the other seasons, the variations are not quite significant (Figs. 3-5 and Table 1). This diverse feature is obviously dependent on the extent of fresh water discharge during the ebb tide; the variations are more in monsoon period and less or practically nil during the rest of the period. In the premonsoon and postmonsoon months the range is very much narrowed and more or less same at both stations with minimum in the postmonsoon period. The near uniform values of surface and bottom water during these periods is attributed to the marine dominance in the estuary. In general, the observations on salinity conditions of this region conform to those of other estuaries reported[8-11].

Dissolved oxygen — Diurnal variations in the dissolved oxygen at the 2 stations do not show any significant pattern, except that during the day time there is an increase in the levels occurring towards midday extending some time to evening hours (Figs. 3-5 and Table 1). Relatively more changes are observed during the monsoon period, and the effect of tides could be followed by careful examination of the profiles. At station B the tidal changes are more clearly seen while at station A the effect of tides is considerably masked. This feature at station A might be due to its location in relatively wider part of the estuary as compared to station B (Fig. 1), facilitating intense mixing of the waters augmented by the biological and chemical effects. During night hours at both stations there is a general decrease in the oxygen levels.

TABLE 1 — VARIATIONS IN PHYSICO-CHEMICAL PARAMETERS AT STATIONS A AND B IN RELATION TO PERIOD, TIDE AND DEPTH AS OBSERVED DURING EACH DIURNAL CYCLE

Date*	Height of tide, m	Depth, m Max.	Depth, m Min.	Sample	Temp., °C Max.	Temp., °C Min.	S‰ Max.	S‰ Min.	O_2, ml/litre Max.	O_2, ml/litre Min.	PO_4-P, µg at/litre Max.	PO_4-P, µg at/litre Min.	NO_3-N, µg at/litre Max.	NO_3-N, µg at/litre Min.	SiO_3Si, µg at/litre Max.	SiO_3Si, µg at/litre Min.
							STATION A									
20 Aug. 71	HHW 2·02	6·0	4·0	S	28·8	27·75	13·69	4·31	5·50	4·45	1·09	0·55	2·04	0·86	69·83	10·71
21 Aug. 72	LLW 0·36			B	27·7	26·9	26·27	9·29	4·39	3·01	1·02	0·39	2·70	0·71	52·37	20·14
3 Feb. 72	HHW 2·14	6·0	3·5	S	27·8	26·5	32·63	31·20	4·48	3·81	1·10	0·35	2·78	1·10	67·95	24·36
4 Feb. 72	LLW 0·64			B	27·5	26·2	32·63	31·02	4·60	3·70	2·37	0·32	2·86	1·31	49·99	20·51
28 April 72	HHW 2·05	7·0	5·0	S	31·40	30·5	36·36	35·59	5·71	4·03	1·25	0·44	2·45	0·64	15·38	6·41
29 April 72	LLW 0·27			B	31·0	29·3	36·42	36·07	5·15	3·81	1·25	0·34	2·30	0·84	26·92	3·85
							STATION B									
20 Aug. 71	HHW 2·02	6·0	3·0	S	29·0	28·0	11·49	1·70	5·37	4·45	1·36	0·58	2·17	0·60	88·64	10·74
21 Aug. 71	LLW 0·36			B	29·3	27·1	16·69	2·45	4·59	3·86	1·23	0·55	2·26	0·60	76·65	37·60
3 Feb. 72	HHW 2·14	3·5	6·0	S	28·80	26·5	32·27	30·68	5·15	4·15	1·13	0·20	3·70	1·14	56·41	19·23
4 Feb. 72	LLW 0·64			B	28·10	26·23	32·45	30·84	4·37	3·81	1·22	0·20	3·03	1·31	56·41	19·23
28 April 72	HHW 2·05	4·5	6·5	S	31·50	30·75	36·56	35·98	4·93	3·58	1·25	0·46	1·03	0·74	21·79	3·85
29 April 72	LLW 0·29			B	30·50	29·0	36·98	36·05	4·70	3·26	0·86	0·42	1·64	0·84	24·35	3·85

*Spring tide. HHW = highest high water, LLW = lowest low water; B = bottom and S = surface.



Figs. 3-5 — Diurnal variations of physico-chemical parameters in August 1971 (Fig. 3), February 1972 (Fig. 4), and April 1972 (Fig. 5) [×---×, surface; and ○—○, bottom)

Phosphates — Similar to dissolved oxygen the diurnal changes in the phosphate concentration show very little relation with the tides. From Figs. 3 to 5 it could be seen that during the day the variations are considerable in both the surface and bottom waters at the two locations. The changes are in general more during the pre- and postmonsoon months. This feature may perhaps be due to greater biological involvement of phosphates under more stable conditions of the waters prevailing in pre- and postmonsoon seasons as compared to monsoon period when considerable hydrographical fluctuations do occur. It is also noted that during the night hours there is a general tendency of increase in phosphate levels in the waters in different seasons, followed by a fall in the early hours of morning. This feature might be due to regenerative activity of the bacteria associated with the water and the sediment.

Nitrates — Diurnal changes of nitrate in the water follow the same trend as phosphates except that the extent of fluctuations appear to be slightly more in the case of nitrate. The variation is of the same order at station A in all the seasons and at station B, except during the postmonsoon period, the variations are of minor order (Figs. 3-5 and Table 1). Station B being relatively shallow and situated in a narrow channel, the processes of bacterial activity and phytoplankton production occurring simultaneously may be responsible in maintaining the nitrate levels more or less constant.

Silicates — Silicates show high degree of variation at both the stations during the entire day in all the seasons (Figs. 3-5 and Table 1). One significant feature is that the variation follows the tidal rhythm unlike phosphates and nitrates. The values are generally high during the ebb and low durings the flood period. This feature is consistent with the expected concentrations in sea water and fresh water and also due to its biological involvement being different from that of the other nutrients. Bottom concentrations are lower than the surface concentrations during the greater part of the day during the monsoon period, while the conditions are reverse during the other seasons. Influx of fresh water carries larger amounts of silicates during the monsoon period and it is responsible for the high surface values and during the other periods, the concentrations into the bottom waters tend to increase due to active exchange with the sediment.

In conclusion it may be stated that the present studies reveal some interesting features in the diurnal variations of some of the conservative and non-conservative factors during different seasons. The conservative factors like temperature and salinity follow the tidal rhythm in different seasons. Except silicates, the other non-conservative factors like phosphates and nitrates show distribution independent of tidal variations perhaps due to their extensive biological involvement. Silicate tends to be more conservative in view of its limited need biologically, in relation to the very high concentrations observed in the estuary at different times. The observed high concentration levels of nutrients in general, in relation to the diurnal changes in all the seasons, indicate restricted amount of flushing by sea water, whereby the estuarine constituents are subjected to a cumulative effect. This feature may have an important bearing on the discharge of industrial effluents into the estuary or river. Similar studies with more coverage within the estuaries are in progress.

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