MAHASAGAR
Vol.26, No.2 (December), 1993, pp. 73-85.

MONTHLY VARIATIONS OF SOME HYDROGRAPHIC PARAMETERS IN THE RUSHIKULYA ESTUARY, EAST COAST OF INDIA

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ABSTRACT

Monthly variations of temperature, salinity, dissolved oxygen (DO), pH and transparency in the Rushikulya estuary were studied over two annual cycles (January 1988 - December 1989) at 5 stations covering the entire stretch of the estuary. Each of these hydrographic parameters showed significant spatial and seasonal variations. The water temperature was mostly influenced by atmospheric temperature rather than the ingress and outgress of seawater into and from the estuary. Salinity variations were more conspicuous than the other parameters analysed. The surface water salinity ranged from <1.0 to 34.7×10^{-3} during 1988, from <1.0 to 35.7×10^{-3} during 1989. Vertical salinity gradient was prominent only in July during the first year and from July to September in the second year. Annual cycle of salinity is unimodal with peak in April/May and low in August/September. The spatial and seasonal distribution of DO showed considerable variability. It is bimodal at stations 2, 4 & 5, whereas it is irregular at stations 1 & 3. Measured pH values indicated that the estuarine water is alkaline throughout the year, eventhough the salinity is reduced to $<1.0 \times 10^{-3}$. Light penetration was low through the entire period of observation. The Secchi disc values varied between 0.10 & 1.28 m and 0.13 & 1.30 m during 1988 and 1989 respectively. Presence of suspended matter is the key factor influencing the transparency behaviour of the water column in this estuary.

Key-words : Hydrography, Rushikulya estuary, East coast of India.

INTRODUCTION

Estuaries act as natural laboratories to study the (i) dynamics of terrigenous chemical constituents borne by the river waters on their way into the sea and (ii) interactions and adaptations of organisms to a wide range of environmental situations. Hydrographic features like temperature, salinity, DO, pH and transparency constitute the important environmental requisites which govern the distribution and abundance of flora and fauna in eastuaries. Sharp, Culberson and Church (1982) further contended that, the first hand information about the fate and effect of different chemicals entering into estuaries, can be obtained from the existing correlation between salinity and other physico-chemical parameters. Therefore, it is always considered worthwhile to acquire adequate knowledge on short and long term variations of different hydrographic events in each and every estuary. It becomes more necessary in tropical estuaries, where significant alterations are apparent as a consequence of the tidal and monsoonal influences.

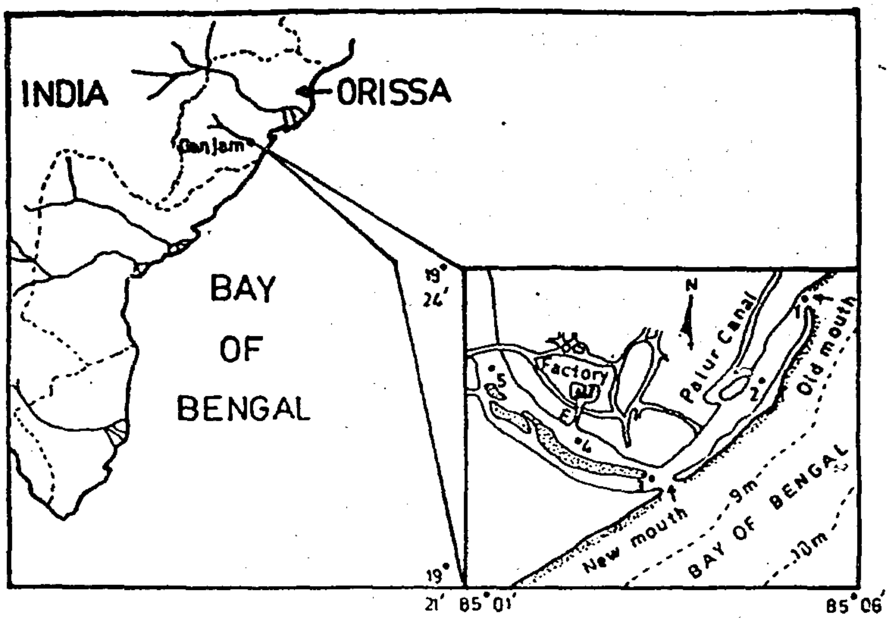

Fig. 1. Map of the Rushikulya estuary showing location of stations.

The Indian subcontinent is bestowed with several estuaries occupying about 2.6 million hectares. Perusal of available literature (Qasim, 1973; Anonymous, 1981; 1982) reveals that, although ecological aspects including hydrography of some estuaries have been studied quite exhaustively, many more are yet to be studied. This is especially true for the estuaries of the Orissa coast where a few studies have only been undertaken in the recent years (Upadhyay, 1988; Gouda and Panigrahy, 1991; Mishra, Panda and Panigrahy, 1993). The present communication deals with the monthly variations of some hydrographic features in the Rushikulya estuary along the south Orissa coast.

MATERIALS AND METHOD

The Rushikulya estuary is a shallow tidal estuary situated between Lat. 19°22′ - 19°24′N and Long. 85°02′ - 85°05′E along the east coast of India (Fig. 1). It is influenced by semi-diurnal tide and thus ingress and outgress of seawater occur twice daily. The estuary basin near the mouth and head region is sand dominated, while its mid reaches is characterised by silt and clay dominated sediments. Northward shifting of mouth is noticed as a consequence of long shore drift deposits. The estuary is in receipt of alkaline effluents from a nearby Chloroalkali plant. The effluents are discharged periodically from the treatment tanks imposing subtle changes in water quality. A second mouth was opened on 20.9.88, and since then the estuary experienced many morphological changes. The notable changes are the seawater penetration further upstream and change in the direction of riverflow.

As a part of the environmental inventory hydrographic data at fortnightly interval from 5 stations (Fig. 1) spreading over two years (Jan. 1988 - Dec. 1989) have been collected. Temperature and pH were measured using a thermometer of $\pm$ 0.01 °C accuracy and a pre-standardised Bio-chem field pH meter (accuracy $\pm$ 0.01) respectively. Transparency was measured using a Secchi disc and the extinction coefficient was computed adopting the formula $K = 1.5/d$ (d = Secchi disc depth in metres) as suggested by Qasim, Bhattathiri and Abidi (1968). Salinity and DO were estimated adopting the titrimetric methods given by Knudsen (1962) and Parsons, Yoshiaki and Lali (1984) respectively. The expected accuracies of salinity estimation is $\pm 0.06 \times 10^{-3}$ at salinity 35×10^{-3} (Standard seawater), while that for oxygen is $\pm$ 0.044 $ml.l^{-1}$.

RESULTS AND DISCUSSION

Temperature

Monthly variations of air, surface water and bottom water temperature, measured at stations 1-5, are presented through Figs. 2A-6A. The surface water temperature on many occasions followed the atmospheric temperature and the correlation between these parameters yielded significant positive relationships ($p \leq 0.05$). Except for a few months at stations 1 & 4, the bottom water temperature always followed the surface water temperature. Similar findings have also been reported by Chandran and Ramamoorthi (1984) in Vellar estuary, Varma, Rao and Cherian (1975) in Mandovi estuary and Mishra, Panda and Panigrahy (1993) in Bahuda river estuary. The temperature conditions of the present study show that atmospheric variation including insolation play major role governing temperature and water exchange between the sea and the estuary is of less significance. Similar conclusions have also been drawn for several other Indian estuaries (Chandran and Ramamoorthi, 1984; Upadhyay, 1988; Mitra, Patra and Panigrahy, 1990; Gouda and Panigrahy 1991; Mishra, Panda and Panigrahy, 1993). In tropical estuaries, the annual temperature variations usually remain <10°C compared to the temperate estuaries (Chandran and Ramamoorthi, 1984). In the present case, the surface water temperature varied from 25.8 - 32.0°C in 1988 and from 23.5 - 33.2°C in 1989. Occurrence of low temperature during December could be ascribed to the effect of atmospheric cooling. Bottom water temperature too exhibited less variations *i.e.*, 25 -32°C in 1988 and 24 - 32°C in 1989. This shows that the annual gradient of temperature remained less prominent and were comparable with the earlier observations elsewhere (Chandran and Ramamoorthi, 1984; Upadhyay, 1988; Mitra, Patra and Panigrahy, 1990; Gouda and Panigrahy, 1991). Inter-station comparison of temperature data revealed significant variations in 1988 but not so in 1989. This could possibly be due to the change in the geomorphology of the estuary. The formation of a new mouth opposite to station 3 has greatly favoured the ingress of seawater into the estuary far beyond station 5 which obviously changed the thermal property in the upper reaches.

Comparatively higher temperatures were observed during summer season of 1988 at stations 4 & 5 than that of the same season in 1989 eventhough the air temperatures were almost alike during both the years (Table I). This shows that the role of insolation became more effective in the upper reaches during 1988 than 1989. The vertical temperature gradient, in general, remained less prominent (<3°C). Such insignificant vertical temperature gradient could be attributed to the shallowness of the estuary. Similar instances have also been reported in many other Indian estuaries earlier (Chandran and Ramamoorthi, 1984; Upadhyay, 1988; Mishra, Panda and Panigrahy, 1993).

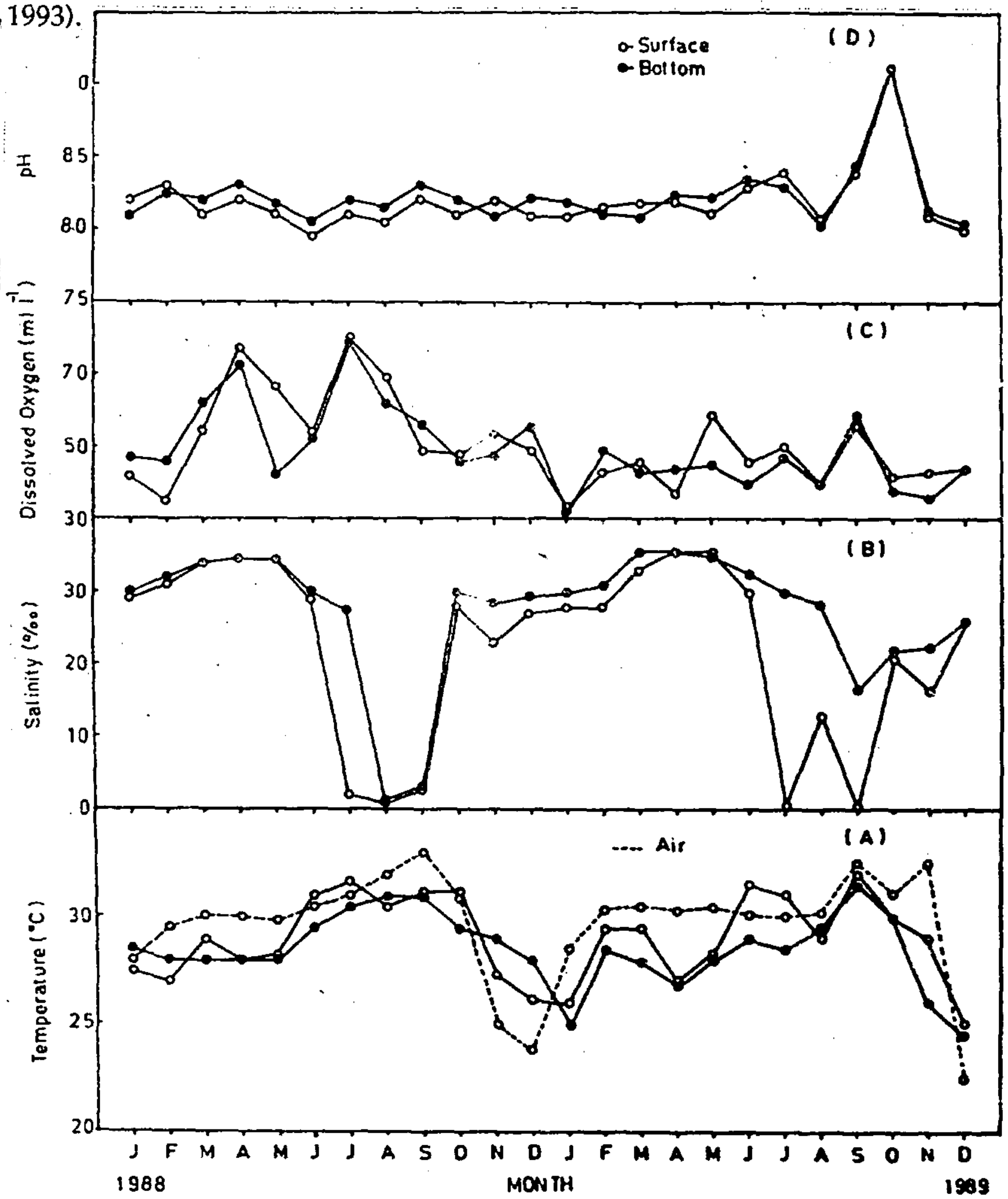

Fig. 2. Monthly variations of hydrographical parameters at station 1 during January 1988 - December 1989.

Salinity

Salinity variations are depicted in Figs. 2B-6B. The annual cycle is unimodal with its peak in April/May and low in August/September. The variations in annual range of salinity is more conspicuous than all other hydrographic parameters analysed. During 1988, it varied from 0.50 - 34.70 x 10^{-3} at the surface and 0.68 - 34.70 x 10^{-3} at the bottom, whereas in 1989, the variation at the surface and bottom were from 0.04

Table I – The minimum, maximum and annual means of different hydrographic parameters in the Rushikulya estuary during January 1988 - December 1989.

Parameter		1988					1989				
		Stn.1	Stn.2	Stn.3	Stn.4	Stn.5	Stn.1	Stn.2	Stn.3	Stn.4	Stn.5
Secchi disc visibility (m)	Min	0.13	0.13	0.15	0.10	-	0.13	0.15	0.14	0.14	-
	Max	1.18	1.28	1.28	0.98	-	1.18	1.20	1.26	1.30	-
	Mean	0.5	0.62	0.69	0.45	-	0.58	0.63	0.86	0.74	-
Air temperature (°C)	Min	23.8	25.0	24.5	26.0	25.0	22.5	24.0	25.0	28.0	28.0
	Max	33.0	33.0	33.0	32.0	31.3	32.5	34.0	33.3	33.5	33.5
	Mean	29.4	29.2	29.0	28.5	28.8	29.9	30.0	30.1	30.0	31.2
Surface water temperature (°C)	Min	26.2	27.0	25.8	28.0	28.0	25.0	24.5	26.0	23.5	27.0
	Max	31.6	31.5	32.0	32.0	32.0	32.0	32.2	33.2	32.5	32.0
	Mean	28.9	29.1	28.9	30.0	29.8	29.0	29.1	29.5	29.1	29.8
Bottom water temperature (°C)	Min	28.0	26.0	25.3	25.0	-	24.5	24.0	26.5	24.1	-
	Max	31.0	31.0	31.5	32.0	-	31.5	31.0	31.5	32.0	-
	Mean	29.0	28.4	28.2	29.4	-	27.9	28.5	28.6	28.5	-
Surface salinity (‰)	Min	0.75	0.71	0.50	0.68	0.70	0.68	0.56	0.30	0.40	0.04
	Max	34.7	34.70	34.10	32.80	29.60	35.50	35.50	35.70	35.20	31.50
	Mean	22.9	18.91	17.74	15.80	11.05	22.34	23.26	19.79	19.30	17.61
Bottom salinity (‰)	Min	0.83	0.79	0.68	0.80	-	16.50	18.30	0.30	10.40	-
	Max	34.70	34.70	34.10	32.80	-	35.70	35.40	35.70	35.60	-
	Mean	26.14	23.09	21.30	16.39	-	28.75	27.17	25.28	25.50	-
Surface DO (ml l^{-1})	Min	3.47	4.01	3.08	3.39	3.00	3.39	3.00	4.32	3.70	3.93
	Max	8.02	7.25	7.87	8.02	8.48	5.68	6.17	7.87	6.09	7.25
	Mean	5.64	5.76	5.78	6.00	5.84	4.49	4.66	5.84	5.02	5.54
Bottom DO (ml l^{-1})	Min	4.16	3.93	3.20	3.00	-	3.24	3.24	3.08	3.08	-
	Max	7.87	7.70	7.56	8.41	-	5.86	6.09	7.33	5.71	-
	Mean	5.56	5.65	5.20	5.91	-	4.32	4.61	5.01	4.69	-
Surface pH	Min	7.9	7.90	8.0	8.0	7.7	8.0	8.0	7.9	8.0	7.7
	Max	8.3	8.40	8.3	8.5	8.8	9.1	8.9	9.0	8.9	8.8
	Mean	8.1	8.18	8.2	8.1	8.1	8.2	8.2	8.3	8.2	8.1
Bottom pH	Min	8.0	8.0	8.0	8.1	-	8.0	7.9	8.1	8.0	-
	Max	8.3	8.4	8.3	8.6	-	9.1	9.0	9.0	8.9	-
	Mean	8.1	8.0	8.1	8.2	-	8.3	8.3	8.3	8.3	8.2

- 35.7 and 0.30 - 35.7 x 10^{-3} respectively (Table I). Such wide variations were reported from many other Indian estuaries also (Dwivedi, Bhargava, Parulekar, Selvakumar, Singbal and Sankaranarayanan, 1974; De Sousa, Sen Gupta, Sanzagiri and Rajagopal, 1981; Chandran and Ramamoorthi, 1984; Upadhyay, 1988; Saisastry and Chandramohan, 1990). Examination of salinity data of the present study further revealed that two extreme situations *i.e.* marine dominance (>22 - 35.7 x 10^{-3}) during March-May and freshwater dominance (< 1 x 10^{-3}) during August-September prevailed in this estuary. After the cessation of monsoon flood, the intrusion of

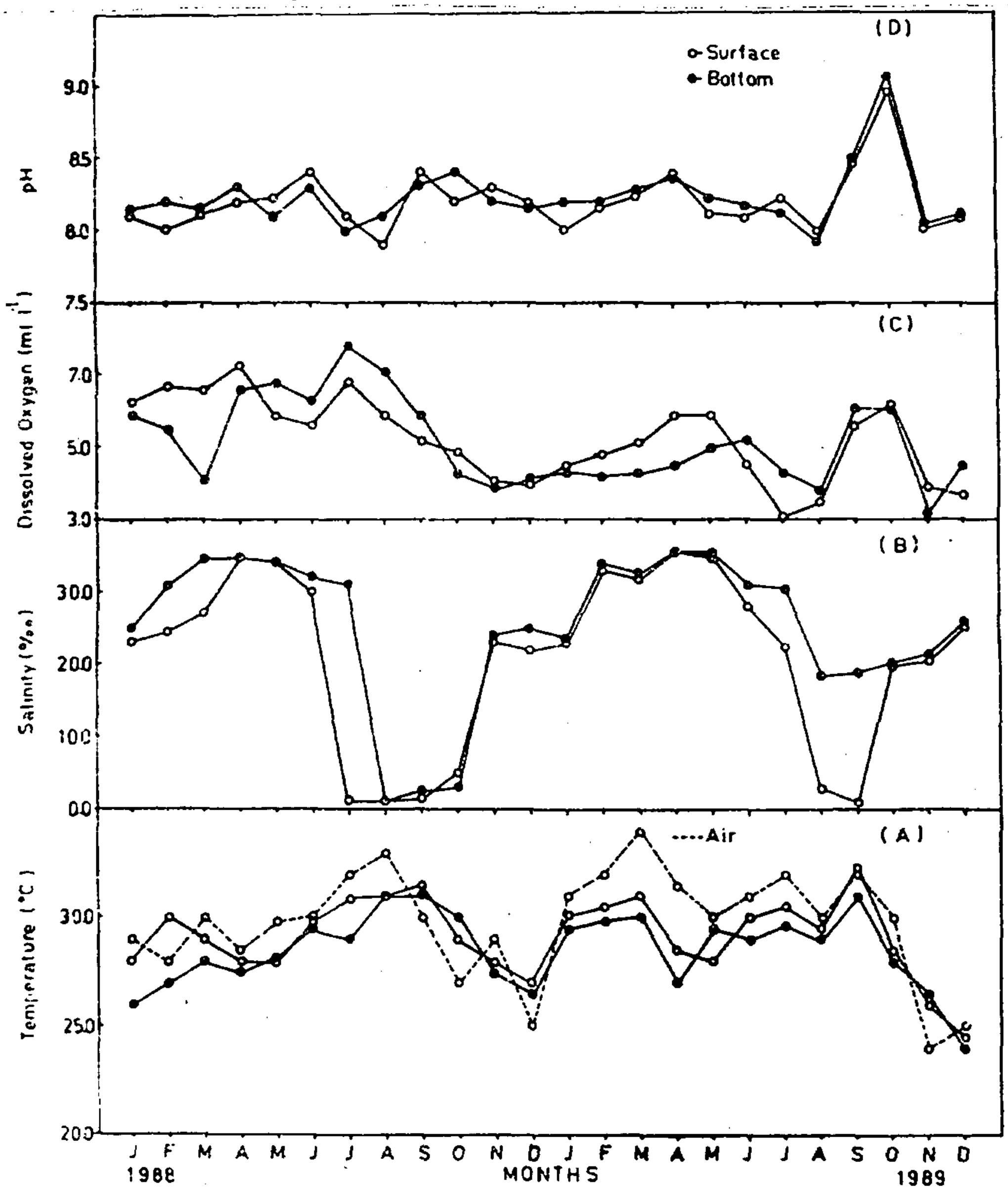

Fig. 3. Monthly variations of hydrographical parameters at station 2 during January 1988 - December 1989.

seawater resulted in a rapid increase in salinity from October till December/January. From February onwards the salinity conditions showed a marginal increase until the highest value was reached in April/May. This, indeed, is a common feature in tropical estuaries, particularly in those which are associated with massive instrusion of freshwater during the active monsoon months. The horizontal salinity gradient remained more prominent only during October-December/Jananuary. The premonsoon season (February-June) was characterised by moderate variations and it was least during the monsoon period (July-September). Interestingly enough, both the surface and bottom water salinities were reduced to <1 x 10^{-3} during July-September

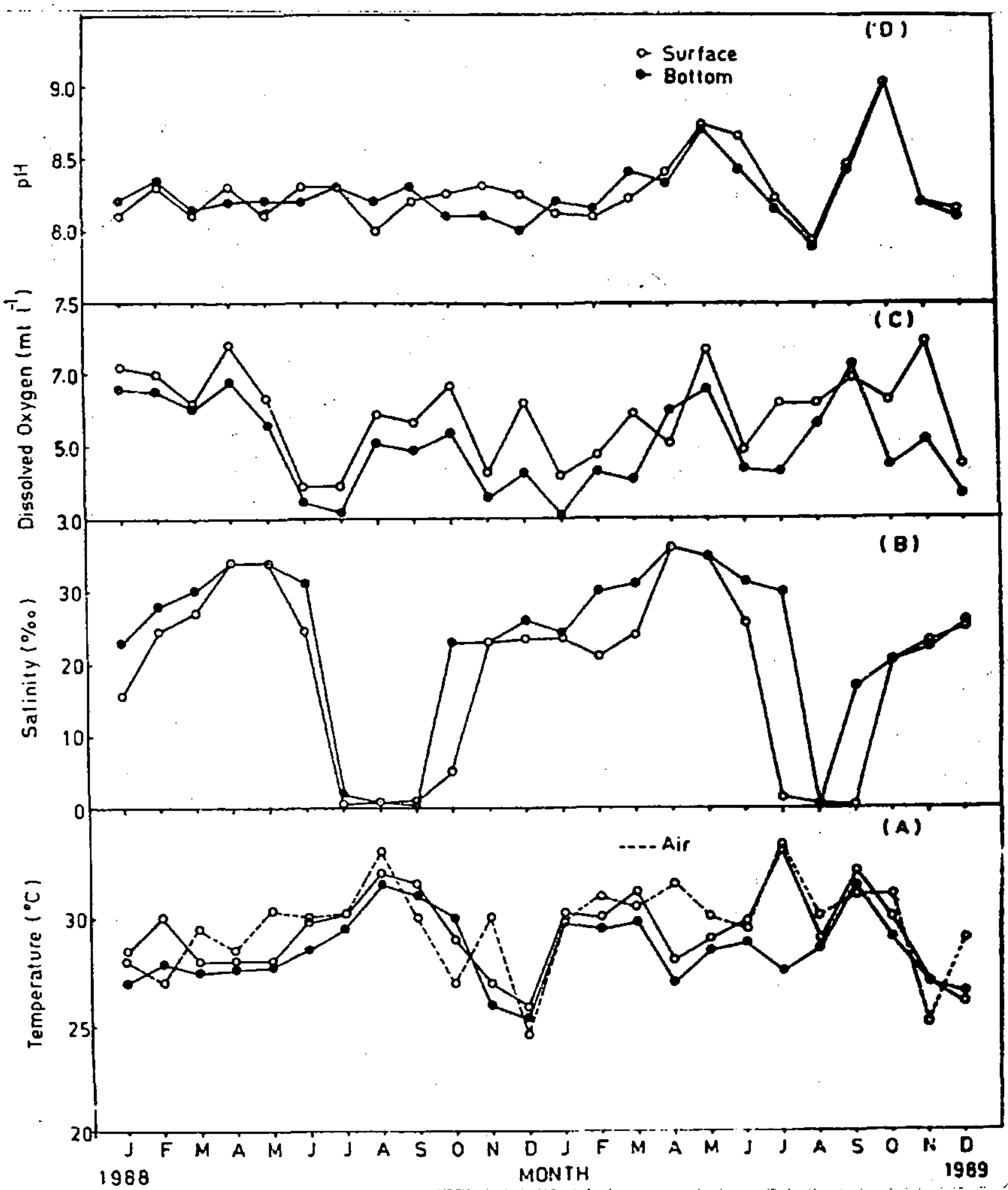

Fig. 4. Monthly variations of hydrographical parameters at station 3 during January 1988 - December 1989.

1988 indicating thereby that the complete scrolling of seawater took place during this period. But during the same months of 1989, comparatively higher bottom salinities were observed suggesting a salt wedge type of circulation at least in the mid and lower reaches of the estuary. This could be due to the opening of a new mouth. Interstation comparison show significant differences in 1988 but was less so in 1989. This denotes that the salinity feature exhibited year to year variations. While, the salinity feature of 1988 could be comparable with the findings of Jacob and Rangarajan (1959) and Chandran and Ramamoorthi (1984) in Vellar estuary, Saisastry and Chandramohan (1990) in Godavari estuary and Mishra, Panda and Panigrahy (1993) in Bahuda

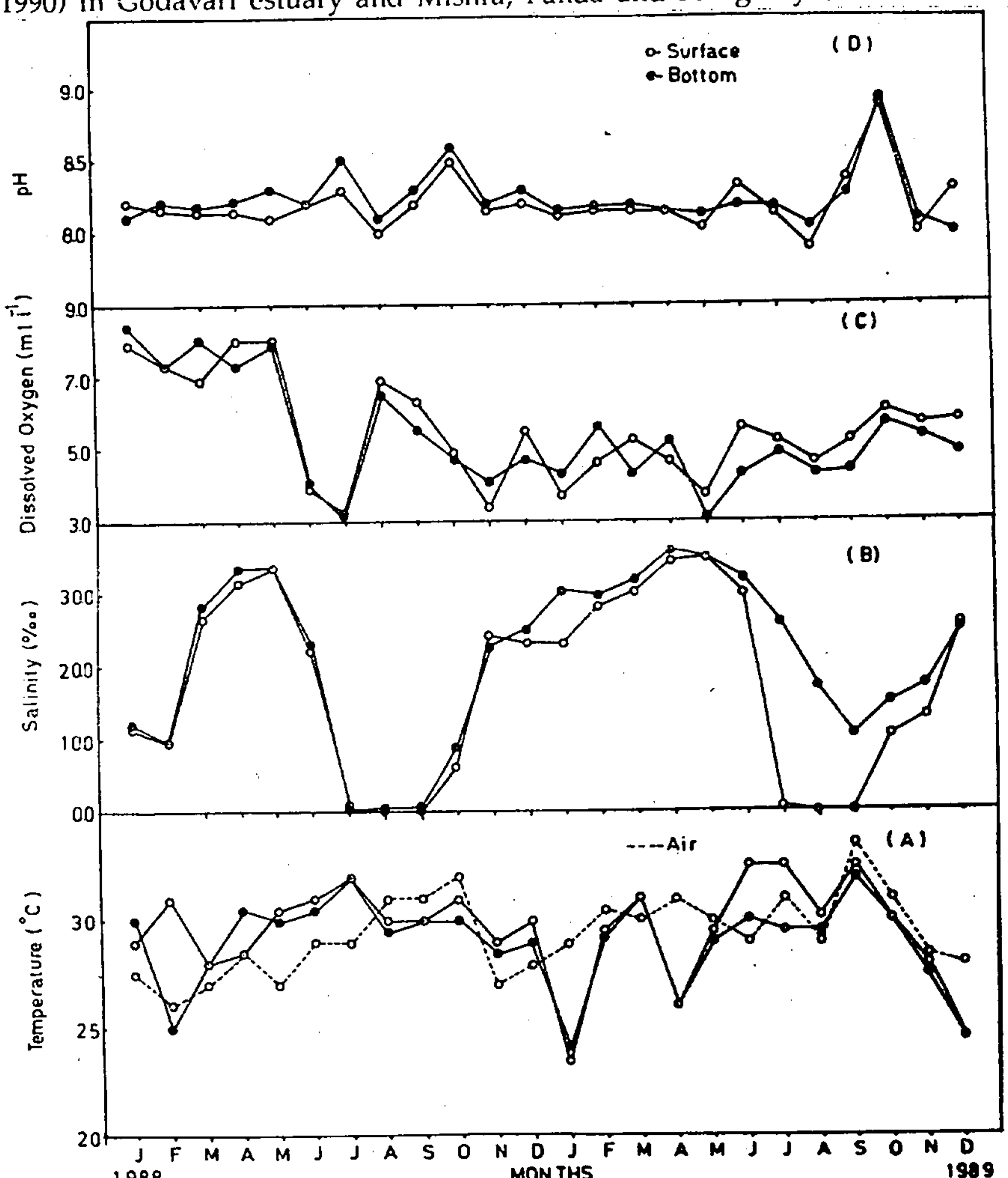

Fig. 5. Monthly variations of hydrographical parameters at station 4 during January 1988 - December 1989.

estuary, those of the year 1989 seemed to be in agreement with the conditions reported in the Mandovi estuary by Varma, Rao and Cherian (1975). The latter situation, *i.e.*, recognisable vertical gradient in 1989 is due to the formation of "new mouth" opposite to station 3.

Dissolved oxygen

Dissolved oxygen (DO) contents showed well marked seasonal variations at all the 5 stations during both the years (Figs. 2C-6C). The annual cycle of DO showed bimodal oscillations at stations 2, 4 & 5 and irregular pattern of distribution at stations 1 & 3. The surface water concentrations varied from 3.00-8.40 and 3.00-7.87 ml l^{-1} during the years 1988 and 1989 respectively. Vertical gradient remained less prominent, and at times higher values were noticed near the bottom than the surface. The bottom water concentrations ranged from 3.00 - 8.41 ml.l^{-1} during 1988 and 3.08 - 7.33 ml l^{-1} during 1989 (Table I). The concentration gradient and mode of annual cycle of DO of the present study are only comparable with that of the Vellar estuary, and it differs significantly from all other estuaries. One more note worthy feature is the occurrence of high oxygen values in April compared to other months of the year. This lead to believe that phytoplankton photosynthesis act as the major factor controlling the oxygen distribution in this estuary, especially during the premonsoon months. Panigrahy and Gouda, (1990) have encountered the formation of *Asterionella glacialis* bloom in this estuary during April-May 1988 which substantiate this contention. The horizontal gradient of DO remained less prominent throughout the study period denoting that influence of freshwater intrusion on oxygen distribution is of limited significance. This does not agree with the reasons ascribed with respect to oxygen distribution in Mandovi and Zuari estuaries (Dwivedi, Bhargava, Parulekar, Selvakumar, Singbal and Sankaranarayanan, 1974; De Sousa, Sen Gupta, Sanzgiri and Rajagopal, 1981), Vellar estuary (Chandran and Ramamoorthi, 1984) and Bahuda estuary (Mishra, Panda and Panigrahy, 1993).

pH

Seasonal variations of pH are presented in Figs. 2D-6D and its station-wise minimum, maximum and annual means are given in Table I. The annual cycle of pH did not show any definite pattern of distribution. The surface water pH ranged from 7.7 - 8.84 and 7.76 - 9.10 during the years 1988 and 1989 respectively. The vertical gradient remained less significant and on most of the occasions higher pH was observed at the bottom than the surface. The bottom water pH ranged from 8.0 - 8.6 in 1988 and 7.9 - 9.1 in 1989. Such wide variations in pH values have also been reported from the Vellar estuary (Chandran and Ramamoorthi, 1984), Mahanadi estuary (Upadhyay, 1988), Uppnar backwaters (Murugan and Ayyakkannu, 1991) and Kali estuary (Bhatt and Neelkanthan, 1988). Peculiarly, high pH was observed in October 1989. It could be due to the discharge of alkaline effluents from the chloro-alkali plant.

Transparency

The monthly mean Secchi disc visibility depths and computed extinction co-efficient of light (*k*) are given in Fig. 7 and Table II respectively. Measured Secchi disc readings from 0.10 - 1.28 m in 1988 and 0.13 - 1.30 m in 1989. The *k* values of the estuary fluctuated between 1.17 & 15.00 and 1.15 & 11.53 respectively during the first and

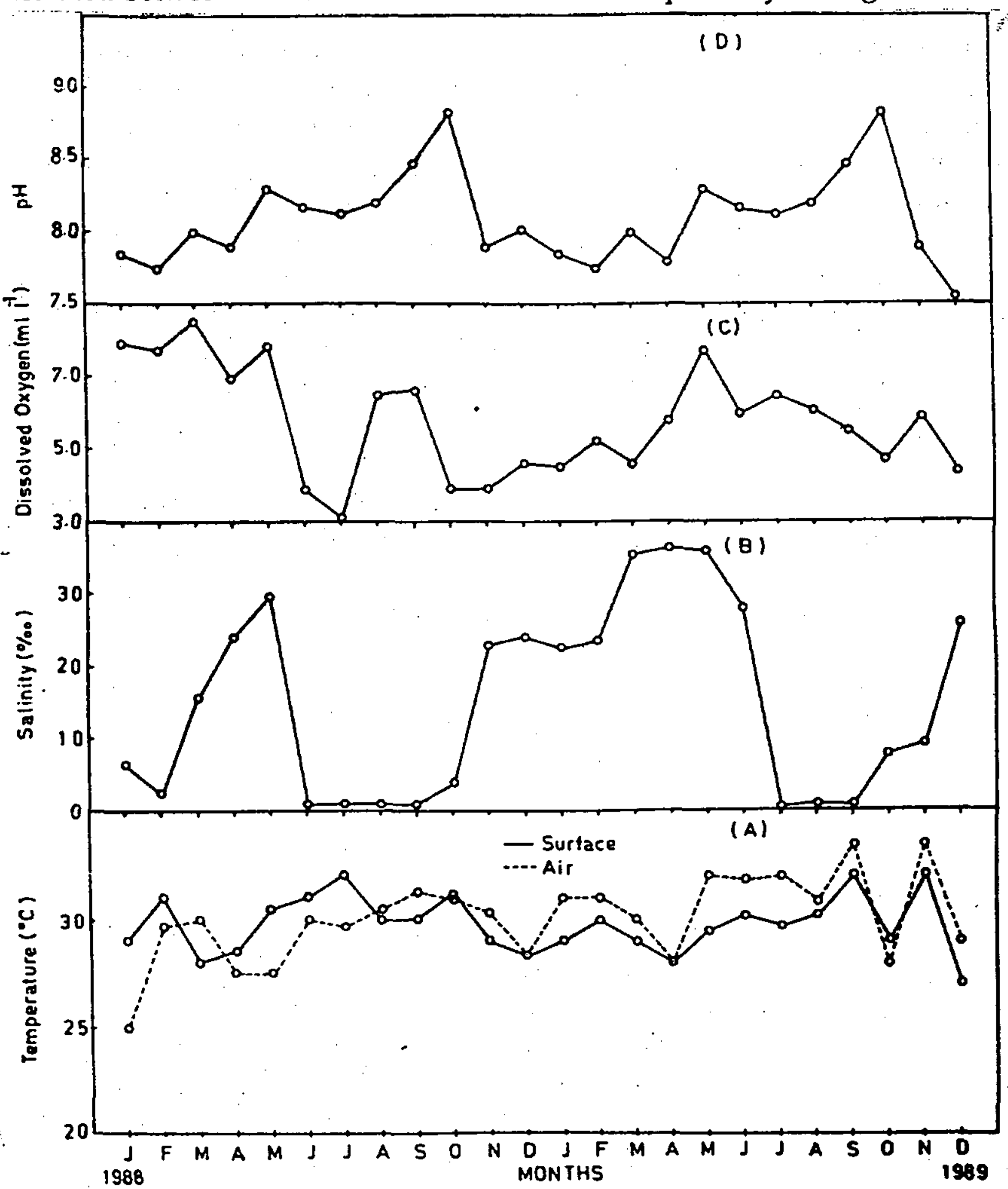

Fig. 6. Monthly variations of hydrographical parameters at station 5 during January 1988 - December 1989.

Table II – Monthly variations in extinction coefficient of light (k) in the Rushikulya estuary during January 1988 - December 1989.

	1988				1989			
Month	Stn. 1	Stn. 2	Stn. 3	Stn. 4	Stn. 1	Stn. 2	Stn. 3	Stn. 4
Jan	6.00	2.09	1.50	3.57	6.00	4.68	3.57	7.5
Feb	5.35	1.5	1.00	5.36	7.10	10.00	8.82	2.5
Mar	4.68	2.73	2.72	6.80	5.17	1.68	4.05	2.11
Apr	1.27	1.17	1.17	1.53	4.10	2.41	4.16	1.23
May	1.47	1.64	1.65	2.05	1.29	1.66	2.34	1.15
Jun	1.89	1.53	1.58	1.82	1.27	1.25	2.67	1.74
Jul	7.89	7.8	6.0	10.0	3.75	2.20	9.37	3.85
Aug	7.50	10.0	7.5	15.0	3.48	3.40	3.40	2.41
Sep	11.53	11.54	10.0	15.0	11.53	10.00	10.70	10.71
Oct	3.57	2.56	6.0	3.12	1.27	1.70	1.20	1.27
Nov	2.8	3.3	1.87	2.20	3.19	2.54	1.60	2.05
Dec	2.1	3.0	1.50	3.0	1.78	1.78	1.4	1.47

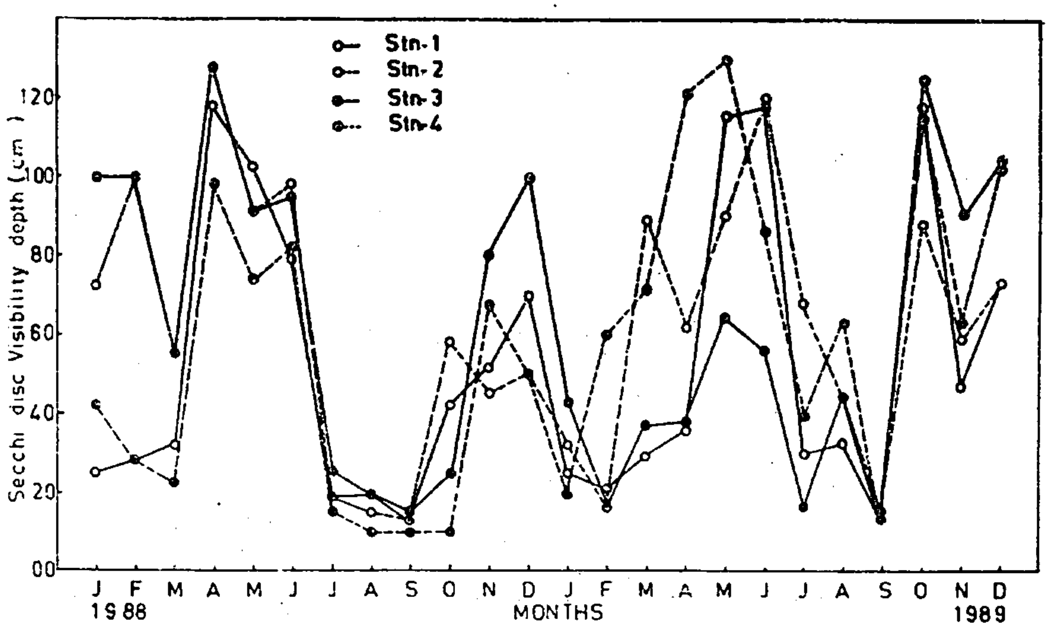

Fig. 7. Monthly variations of Secchi disc visibility depths during January 1988 - December 1989.

second year of observation (Fig. 2). Such wide annual gradient in transparency behaviour have been reported as common feature in several other Indian estuaries (Chandran and Ramamoorthi, 1984; Upadhyay, 1988; Saisastry and Chandramohan, 1990; Gouda and Panigrahy, 1991; Mishra, Panda and Panigrahy, 1993). The annual cycle of Secchi disc reading, in general, showed bimodal behaviour. Peak values were obtained, once during April-June and again November-December. Furthermore, relatively higher values were encountered during the lower reaches (Stations 1 & 2) than the upper reaches (Station 4). Minimum values were obtained during active monsoon months when the estuary was flooded with silt borne surface runoff. The turbidity of the water column is believed to have increased during summer months owing to the intrusion of seawater through bottom thereby causing resuspension of surficial sediment by stirring action. Turbidity, therefore seemed to be the primary factor responsible for low light penetration in this estuary.

ACKNOWLEDGEMENTS

The authors are grateful to Prof. S.Z. Qasim, Member, Planning Commission for suggestions and comments. They also thank the Department of Science, Technology & Environment, Government of Orissa for financial assistance.

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