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Water quality of the Adimalathura Estuary, southwest coast of India

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Abstract

Water quality of Adimalathura Estuary, a small brackish water biotope (8^0 0' - 8^0 24' N latitude and 77^0 01' – 77^0 03'E longitude) on the southern part of Kerala, exposed to pollution from domestic wastes and coconut husk retting was studied for a period of one year. All the physico-chemical parameters (transparency, temperature, salinity, *p*H, dissolved oxygen) and nutrients (nitrate, nitrite, phosphate and silicate) showed significant spatial and temporal variations. The water temperature was mostly influenced by atmospheric temperature. Presence of suspended matter lowered the transparency at the polluted station. Salinity variations were more conspicuous than the variations in other parameters analysed. The sea-estuary interaction and land drainage influenced salinity distribution. Concentration of dissolved oxygen was low at polluted station. Nutrients (No_3-N, No_2-N, PO_4-P and SiO_4-Si) in general showed significant spatial and temporal variations and high values were observed at the polluted station.

Keywords: Hydrography, Adimalathura Estuary, Kerala, coconut husk retting, pollution

Introduction

A chain of brackish water systems exists in Kerala. These water bodies are the breeding and nursery grounds for commercially important fin-fishes and shell-fishes. Adimalathura Estuary (*Karicha Kayal*), a small brackish water biotope (8^0 0' - 8^0 24' N latitude and 77^0 01' – 77^0 03'E longitude) on the southern part of Kerala, is important from the point of view of fishery and seed resources and constitutes the life line of the local economy. The western bank of the estuary where the Adimalathura fishermen reside is considered as the most densely populated area in the state. The high concentration of people has resulted in the coastal waters being degraded due to pollution from a variety of sources. In the absence of adequate facilities for the disposal of sewage and sullage from human settlement around the estuary, these are directly discharged into the backwater system. Hanging latrines are seen along the backwater system. The shallow inlets and margins of the estuary are used as coconut husk retting grounds round the year. Morphological changes in the estuary mouth are also important as they influence the physico-chemical features in the estuary. The establishment of sand bar resulting from massive coastal drift across the estuary mouth and its removal at weekly intervals by the local authority is common in the biotope since the total occlution of the mouth for longer duration results in the overflow of the estuary into the adjacent fishermen locality. When the estuary mouth is open, marine influence can be seen in the whole area.

Although many studies have been undertaken to evaluate the water quality of Indian estuaries, no scientific studies have hitherto been carried out on the water quality of the estuarine and adjoining coastal regions of Adimalathura. The present study aims to get an insight in to the hydrography of this estuary.

Materials and methods

Regular monthly samples of surface and bottom waters were collected for one year between February 1995 and January 1996 from four selected stations in the estuarine and coastal regions of Adimalathura (Fig.1). Station I was located on the upper reaches of the estuary while stn II at the middle, stn III at the estuarine mouth and stn IV on the sea shore. Water samples were collected using a clean plastic bucket from the surface and by a standard Meyer type sampler from the bottom. All the water characteristics were estimated following standard methods (Strickland and Parsons, 1972; Grasshoff *et al.*, 1983; APHA, 1985). For statistical analysis ANOVA has been consulted.

Results and discussion

Temperature: The temperature values for the entire period of observation reflect to a great extent the climatic variations. The air, surface and bottom water temperature reached the maximum during the pre-monsoon period

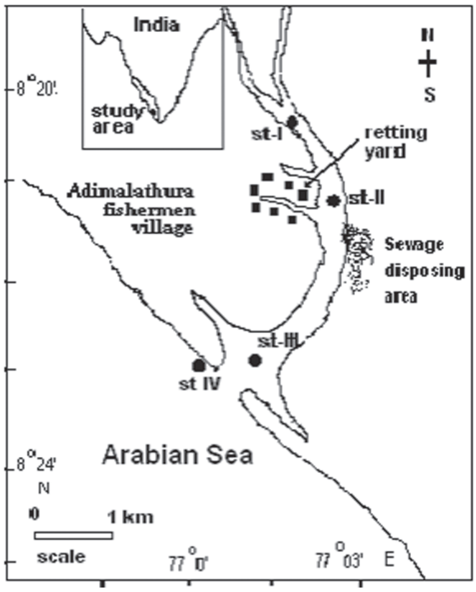

Fig.1. Map showing the Adimalathura Estuary and location of stations

(Feb-May) at all stations (Table I). With the onset of monsoon, there was a decline in temperature everywhere reaching the minimum during July-September. The atmospheric temperature fluctuated from 26^{0}C (Sept.) to 32.5^{0}C (April). The maximum water temperature recorded was 31.5^{0}C for the surface and bottom waters during April. The longitudinal distribution of mean air temperature in the estuary was maximum at stn II and minimum at stn IV. Since the estuary is shallow, the temperature of water was controlled by atmospheric temperature. Mean surface water temperature was also maximum at stn II and minimum at stns I and IV (Table 2). The influx of freshwater into the estuarine system is not the sole factor in bringing down the water temperature in estuarine systems, but that of cold water from the sea may also be a significant factor. The waters were nearly vertically isothermal as the depth of the water column was low as observed in the Vellar Estuary (Chandran and Ramamoorthy, 1984), Uppanar Backwater (Murugan and Ayyakkannu, 1991), Gosthani Estuary (Rao and Sarma, 1995) and in Coleroon Estuary (Thillai Rajasekar *et al.,* 2005). The surface bottom difference ranged from 0 to 1^{0}C.

Transparency: Significant difference (P<0.01) existed between transparency in the different stations. Peak values were observed once during February and again in November (Table 2). Transparency was lowest during active monsoon months when the intensity of solar radiation was minimum and the estuary flooded with silt-borne surface runoff (Table 1). Turbidity, therefore, seemed to be the primary factor responsible for low light penetration here as noticed in other monsoon fed tidal estuaries (Nair *et al.,* 1984 a; Chandran and Ramamoorthi, 1984; Mishra *et al.,* 1993).

p*H*: Surface water *p*H varied from 5.94 (November) at stn I to 8.68 (January) at stn IV. Streams and rivers transporting large quantities of humic material in colloidal suspension are frequently slightly acidic. Upon meeting sea water, the colloidal particles get coagulated and the *p*H shifts towards the alkaline side (Ried, 1961). Hence, the values were higher toward downstream. Statistical analysis also indicates that wide interstation variations occur both in surface and bottom waters (P < .01). Such wide variations were earlier reported from the Indian estuaries (Chandran and Ramamoorthy, 1984; Upadhyay, 1988; Murugan and Ayyakkannu, 1991). The vertical gradient of *p*H remained less significant and on most of the occasions higher value was observed at the bottom water than the surface. At bottom, the values ranged from 5.95 (station I) to 8.69 (station IV). The higher value at bottom could be attributed to the vertical stratification of the water column with regard to salinity, dissolved oxygen, etc. The *p*H values recorded in this estuary did not follow any definite seasonal pattern and the oscillations towards the acidic side during the monsoon season, particularly at stn I could be attributed to the heavier river discharge and land runoff (Table 1). Strong buffering capacity of sea water allows only little *p*H changes to be pronounced normally while in enclosed portions biological activity can cause sizeable variations.

Salinity: The variations in annual range of salinity were more conspicuous than all other hydrological parameters (Table 2). Surface salinity increased from 0.07x10^{-3} at station I to 36.27x10^{-3} at station IV whereas at bottom it ranged between 0.16 x 10^{-3} at stn I and 36.27x10^{-3} at stn IV. Its fluctuations in the estuary varied seasonally depending upon the mixing of high salinity seawater and riverine fresh water in differing properties consequent to the opening of sand bar. Salinity was maximum during the premonsoon period at all stations due to high evaporation, sea water dominance and cessation of freshwater flow from the upper reaches (Table 1). The incursion of high saline water along the bottom resulted in a distinct stratification between the surface and bottom waters at all stations.

Dissolved oxygen: The concentration of dissolved oxygen in the surface layer varied from 1.65 (stn I) to 6.19 m1.l^{-1} (stn III). At bottom the value ranged from 1.65 (stn II) to 6.05 ml.l^{-1} (stn IV). The horizontal gradient of DO remained less prominent (Table 1) and did

Table 1. *Seasonal mean distribution of various physico-chemical parameters at the four stations*

Season	Station	Trans-parency (cm)	Water depth (m)	Air temp. (^{0}c)	Water temp. (^{0}c)		*p*H		Salinity (S. 10^{-3})		Dissolved Oxygen (ml.l^{-1})	
					S	B	S	B	S	B	S	B
	I	34.0	1.34	30.38	30.13	29.88	7.12	7.27	0.78	2.99	5.10	4.68
	II	46.5	1.52	30.63	30.25	30.25	7.02	7.60	1.91	12.45	3.92	3.24
Pre	III	53.5	1.18	30.75	30.38	30.25	7.14	7.65	3.28	15.88	4.27	3.24
monsoon	IV	-	-	30.38	30.50	30.50	7.99	7.93	33.92	34.07	4.82	4.48
	I	20.0	0.98	27.50	28.38	28.38	6.54	6.78	0.66	0.66	4.04	3.91
	II	14.50	1.25	27.63	29.13	29.25	7.15	7.43	1.21	4.87	3.63	3.63
	III	25.25	1.16	26.88	28.13	29.63	7.48	7.72	3.68	13.10	3.56	3.56
Monsoon	IV	-	-	26.63	25.63	29.00	8.19	8.19	32.51	32.51	4.96	4.96
	I	45.75	1.18	28.25	29.50	29.38	6.41	6.64	0.68	0.83	5.78	5.43
	II	65.50	1.18	29.00	29.38	29.25	6.91	7.24	1.76	8.17	5.23	4.82
Post	III	83.75	1.31	28.75	29.75	29.63	7.23	7.88	2.34	11.66	5.88	5.43
monsoon	IV	-	-	28.50	28.88	29.00	8.39	8.40	26.89	27.04	5.64	5.57

S- Surface B- Bottom

not agree with the distribution pattern of oxygen in the Mandovi and Zuari estuaries (Dwivedi *et al*., 1974), Vellar Estuary (Chandran and Ramamoorthi, 1984) and Bahuda Estuary (Mishra *et al.,* 1993). Comparison of surface and bottom values revealed that a vertical gradient was prominent at all stations almost throughout the year. Normally the bottom waters showed less oxygen content and the magnitude of this difference was more pronounced in the freshwater dominated regions (Table 2). Higher values at the surface could be due to the higher photosynthetic activity at the euphotic zone, inputs from atmosphere and higher solubility of oxygen in the lower salinity surface water. Introduction of organic wastes and its decomposition in the water can be the reason for the low concentration of oxygen at stn II compared to other stations. ANOVA also proved variations in DO between stations, months and seasons ($P < .05$). It can be inferred that though huge quantities of wastes are discharged into the estuary near stn II, the oxygen level is maintained to a limit by the high photosynthetic activity and periodic flushing characteristics of the estuary. All stations showed an increase in the oxygen values during the post-monsoon period due to the higher solubility of oxygen in colder and less saline water (Table 1).

Nutrients: The concentration of nitrate-nitrogen in the surface and bottom waters showed significantly wide variations between stations, months and seasons. It varied between 0.20 and 14.89 µ mol. l^{-1} for the surface water and 0.20 and 13.01 µ mol.l^{-1} at the bottom (Table 3). The lowest concentration was at stn IV in marine zone indicating that the seawater does not contribute towards nitrate enrichment in the estuary. Maximum concentration of nitrate was reported from stn II and the possible input sources of high nutrient identified in the region are the waste disposed from the sewage works and coconut husk

Table 2. *Range and mean of various physico-chemical parameters at the four stations*

Parameters	Station I			Station II			Station III			Station IV		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Transparency (cm)	12.0	70.00	33.25	9.00	81.0	42.16	15.00	108.0	54.2	-	-	-
Water depth (m)	0.60	1.74	1.17	0.61	1.77	1.32	0.75	1.85	1.22	-	-	-
Atm. temp. (^{0}C)	27.0	32.50	28.71	27.00	32.0	29.10	26.0	32.00	28.71	26.00	32.00	28.50
Water temp. (^{0}C)	S 28.0	30.50	29.33	28.00	31.5	29.58	27.0	31.00	29.42	24.00	31.00	28.32
	B 28.0	30.50	29.21	27.50	31.5	29.25	27.0	31.00	29.17	24.00	31.00	28.38
*p*H	S 5.94	7.48	6.69	6.42	7.54	7.02	6.73	8.15	7.28	7.53	8.68	8.19
	B 5.95	7.65	6.89	6.43	7.82	7.42	7.26	8.20	7.75	7.54	8.69	8.17
Salinity (S.10^{-3})	S 0.07	1.54	0.70	0.66	3.05	1.63	0.66	8.42	3.10	24.14	36.27	31.11
	B 0.16	7.22	1.49	0.97	25.76	8.50	1.29	31.95	13.55	24.14	36.27	31.20
DO_2 (ml.l^{-1})	S 2.21	6.04	4.97	1.65	5.77	4.26	2.21	6.19	4.57	3.30	6.05	5.14
	B 2.21	5.77	4.67	1.65	5.23	3.89	2.21	5.51	4.08	3.30	6.05	5.00

S – Surface B - Bottom

Table 3. *Range and mean of various nutrients at the four stations*

Parameters		Station I			Station II			Station III			Station IV		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Nitrate –nitrogen	S	1.15	4.25	2.18	0.85	14.89	5.93	0.58	7.00	2.38	0.20	1.20	0.71
(μ mol.l^{-1})	B	1.01	4.01	1.93	0.85	13.01	4.64	0.33	4.50	1.51	0.20	1.20	0.70
Nitrite –nitrogen	S	0.33	2.50	1.36	0.17	5.66	2.53	0.33	3.00	1.40	0.17	0.67	0.49
(μ mol.l^{-1})	B	0.33	2.50	1.24	0.33	4.33	2.10	0.33	2.67	1.03	0.17	0.75	0.46
Phosphate-phosphorus	S	0.15	1.82	0.74	0.76	3.64	1.62	0.45	2.12	1.10	0.21	0.91	0.53
(μ mol.l^{-1})	B	0.15	1.82	0.68	0.45	2.77	1.17	0.23	1.51	0.69	0.21	0.91	0.53
Silicate -silicon	S	8.05	18.24	12.60	7.79	26.40	16.26	5.95	19.81	12.66	1.59	5.55	3.97
(μ mol.l^{-1})	B	9.51	17.16	12.81	6.21	24.54	14.31	4.63	18.47	10.68	1.45	5.55	4.03

S – Surface B – Bottom

retting. Higher nitrate values were reported earlier from the severely polluted areas of Ashtamudi Estuary (Nair *et al.*, 1984 b) and Adayar Mangrove waters (Selvam *et al.*, 1994) due to decomposition of organic matter.

The concentration of nitrite was much lower than that of nitrate, however, both followed a similar trends in fluctuations. The minimum and maximum values were 0.17 and 5.66 μ mol. l^{-1} in the surface and 0.17 and 4.33 μ mol. l^{-1} at the bottom. Although the concentration in surface water remained always higher than at the bottom at all stations, the variations were not significant. Monthly variations were quite irregular. Several factors seem to have individually and collectively contributed to this irregular pattern of distribution. The role of freshwater input, rainfall and land drainage is of paramount importance in this context. The mean concentrations were high at stn II and lower at stn I (Table 3). The high values at stn II could be attributed to the prevailing sewage pollution. Degradation process of organic materials leads to the formation of appreciable quantities of nitrite.

The highest concentration of phosphate – phosphorus in the surface (3.64 μ mol.l^{-1}) and bottom (2.77 μ mol.l^{-1}) water was at stn II and the lowest in both surface and bottom waters (0.21 μ mol.l^{-1}) at the marine station. All stations had the maximum phosphate concentration during the monsoon period (Table 4). Rainfall and river discharge resulted in massive transportation of sediment and a rise in phosphate concentration during the monsoon period. High density of phytoplankton and the resultant increased utilization of phosphate might have resulted in the decrease of the nutrient during the pre-monsoon and late post-monsoon months (Padmavathi and Satyanarayana, 1999; Renjith *et al*., 2004). Comparatively higher values in the surface than the bottom at all stations in all seasons indicate the greater enrichment of the nutrient by terrestrial run off than by neritic water. Stn II showed comparatively higher concentration of phosphate owing to the discharge of sewage wastes from the adjoining villages. Similar wastes input and the enrichment of phosphate was earlier reported from the Cochin backwater (Lakshmanan *et al*., 1987).

Levels of silicate-silicon varied from 1.59 to 26.40 μ mol.l^{-1} at surface and 1.45 to 24.54 μ mol.l^{-1} at bottom (Table 3). The highest and lowest values were observed during May and January respectively. A constant seaward decrease was noticed throughout agreeing with the negative relationship between salinity and silicate along the Indian coast (Nair *et al.*, 1984 b, Sankaranarayanan *et al*., 1984; Nair and Abdul Azis, 1987). It was noteworthy that the maximum concentration was always at stn II which could be attributed to the allochthnous addition of the nutrient from the wastes discharged into the estuary. Rise in concentration of the nutrient in association with the rains during the monsoons and the increasing trend discernible from the marine to the riverine zone revealed that the silicate economy was primarily governed by freshwater intrusion (Table 4). The summer minimum could be due to the weak freshwater flow and the removal by biological process. While there was an abrupt increase during May which may be explained on the basis of unusual behaviour of silicate reported from Kerala backwaters (Nair *et al*., 1984 b) and could mainly be attributed to the sewage discharge coincided with total occlution of the estuarine mouth. ANOVA showed significant variations between stations and months while the variations between seasons were not significant.

The present study has revealed the deleterious effects of waste disposal on the water quality of the estuary. There was marked increase in the concentration level of all nutrients and a decrease in dissolved oxygen at stn II

Table 4. *Seasonal mean distribution of various nutrients at the four stations*

	Station	Nitrate- nitrogen (µmol.l[1])		Nitrate - nitrogen (µmol.l[1])		Phosphate phosphorus (µmol.l[1])		Silicate-silicon (µmol.l[1])	
		S	B	S	B	S	B	S	B
Pre-monsoon	I	1.71	1.29	0.88	0.75	0.73	0.68	13.73	13.04
	II	3.81	2.63	1.59	1.21	1.40	1.06	15.22	13.14
	III	1.48	0.43	0.98	0.44	1.14	0.50	11.95	10.86
	IV	0.58	0.58	0.40	0.42	0.53	0.47	3.69	4.24
Monsoon	I	2.31	2.20	1.42	1.37	0.81	0.80	12.26	11.86
	II	6.05	5.32	2.77	2.25	1.95	1.60	16.54	14.85
	III	1.73	2.43	1.71	1.57	1.29	0.85	14.80	12.98
	IV	0.71	0.76	0.50	0.52	0.96	0.72	5.09	5.13
Post-monsoon	I	2.51	2.29	1.79	1.58	0.68	0.57	15.76	13.54
	II	7.94	5.96	3.23	2.83	1.20	0.85	17.01	14.04
	III	2.40	1.69	1.52	0.83	0.88	0.59	11.21	8.19
	IV	0.85	0.78	0.46	0.44	0.41	0.41	3.09	2.71

compared to other stations. However, the effects of this pollution are greatly reduced at stn III away from the disposal point. Adimalathura, being an estuary with periodic removal of sandbar, the accumulation of wastes in the estuary is prevented to a great extent by the periodic flushing of the estuarine wastes.

References

APHA. 1995. Standard method for examination of water and wastewater. *In:* Michel, J.T., E.G. Arnold, R.D. Hoak and Rand (Eds.). *American Public Health Society Pub.*, Washington D.C., 19th Edn., 874 pp.

Chandran, R.and K.Ramamoorthi. 1984. Hydrobiological studies in the gradient zone of Vellar Estuary 1-Physico-chemical parameters. *Mahasagar –Bull. Natn.Inst. Occanogr*., 17:69-77.

Dwivedi, S.N., R.M.S. Bhargava, A.H. Parulekar, R.A. Selvakumar, S.Y.S. Singbal and V.N. Sankarnarayanan. 1974. Ecology and environmental monitoring of Mandovi, Zuari and Cumburzera canal complex during monsoon months. *J.Indian Fish. Ass.*, (3 & 4):113-130.

Grasshoff, K., M.Ehrharrot and K.Kremling. 1983. *Methods for seawater analysis* (Second revised edition) Verlag Chemic. Weinheim. 419 pp.

Lakshmanan, P.T., C.S. Shynamma, A.N. Balchand and P.N.K. Nambisan. 1987. Distribution and variability of nutrients in Cochin backwater, Southwest coast of India. *Indian J.Mar.Sci.*, 16:99-102.

Mishra, S., D.Panda and R.C. Panigrahy. 1993. Physico chemical characteristics of the Bahuta estuary (Orissa), east coast of India. *ibid.*, 22:75-77.

Murugan, A.and K.Ayyakkannu. 1991.Ecology of Uppanar backwater Cuddalore 1-Physico-chemical parameters. *Mahasagar*, *Bull. Natn.Inst. Occanogr.*, 24:31-38.

Nair, N.B. and P.K. Abdul Azis. 1987. Hydrology of the Ashtamudi Estuary – a tropical system in Kerala. *In:* Nair, N.B. (Ed.) *Proc. Natn. Sem. Estuarine management*, University of Kerala. 268-280.

——————., P.K.Abdul Azis, K.Krishnakumar, K.Dharmaraj and M.Arunachalam. 1984 a. Ecology of Indian estuaries, Part VI: Physico-chemical conditions of Kandinamkulam backwater, southwest coast of India. *Indian J.Mar.Sci.*, 13:69-74.

——————., K.Dharmaraj, P.K. Abdul Azis, M.Arunachalam, K.Krishnakumar and N.K. Balasubramanian. 1984 b. Ecology of Indian estuaries, VIII-Inorganic nutrients in the Ashtamudi Estuary. *Mahasagar*, *Bull. Natn.Inst. Oceanogr.*, 17:19-32.

Padmavathi, D. and D. Sathyanarayana. 1999. Distribution of nutrients in riverine, estuarine and adjoining coastal waters of Godavari, Bay of Bengal. *Indian J. Mar. Sci.*, 28: 345-354.

Rao, G. S. and D.V.R. Sarma. 1995. Temperature and salinity structure of Gosthani Estuary, east coast of India. *J. Mar.Biol.Ass. India*, 37: 80-90.

Reid, G.K. 1961. *Ecology of inland waters and estuaries.* Van Nostrand Reinhold Company, 450 West 33rd Street, New York. N.Y. 10001. 1961 pp.

Renjith, K.R., K.K. Varma, C.K. Haridevi, K.H. Houlath, C.T.Vijayakumar and Prabha Joseph. 2004. Primary productivity and fishery potential of the Panangad region in Cochin estuarine system. *J.Mar.Biol.Ass. India*. 46(2): 126-132.

Sankaranarayanan, V.N., T. Joseph, K.V.Jayalekshmi and K.K Balachandran. 1984. Typical behavior of dissolved silicate in the Cochin backwater, southwest coast of India. *Indian J.Mar. Sci*., 13:60-63.

Selvam.V., K.Hariprasad, R.Mohan and R.Ramasubramanian. 1994. Diurnal variations in the water quality of sewage polluted Adayar mangrove water, east coast of India. *ibid.*, 23: 94-97.

Strickland, J.D.H. and T.R Parsons. 1972. A manual for seawater analysis. *Bull. Fish. Res. Board Canada*, 167: 310pp.

Thillai Rajasekar, K., P. Perumal and P.Santhanam. 2005. Phytoplankton diversity in the Coleroon estuary, south east coast of India. *J. Mar.Biol. Ass. India.* 47(2): 127-132.

Upadhyay, S.1988.Physico-chemical characteristics of Mahanadi estuarine system, east coast of India. *Indian J. Mar. Sci.*, 16: 99-102.

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