The Ecoscan 3 (3&4) : 259-262, 2009

PHYSICO-CHEMICAL QUALITY OF MANDOVI AND ZUARI ESTUARINE SYSTEMS OF GOA, WEST COAST OF INDIA

K. KHELCHANDRA SINGH*, VISHNU M. MATTA[1], B. MANIHAR SHARMA AND KH. USHA
Ecology Laboratory, Department of Life Sciences, Manipur University,
Canchipur - 795 003, Imphal, Manipur, INDIA
[1]Department of Marine Sciences and Biotechnology, Teleigao Plateau,
Goa University, Goa - 403 206, INDIA
E-mail: k_khel@yahoo.com

ABSTRACT

Surface and bottom water samples collected along the Mandovi and Zuari estuaries in Goa, comprising ten sampling stations in each estuary, were analyzed for different physico-chemical parameters such as Temperature, Chlorinity, pH, Alkalinity and Dissolved Oxygen (D.O). The samplings were carried out during three seasons viz. Pre-monsoon (February-May), Monsoon (June-September), Post-monsoon (October-January). Higher water temperature (29°C) observed in non-monsoonal season is explained on the basis of atmospheric heating. Chlorinity was found to be high in non-monsoonal season indicating negligible influence of fresh water. pH (7.6) and alkalinity (1.91 m.eq l-1) registered higher values in non-monsoonal seasons. In both the estuaries concentrations of Dissolved Oxygen were found to be higher (6.40 mg/L-1) in monsoon.

KEY WORDS
Mandovi
Zuari
Estuary
Physico-chemical Quality

Received : 12.03.2009
Revised : 03.09.2009
Accepted : 08.11.2009

*Corresponding author

INTRODUCTION

Estuary is an inlet of the sea reaching into a river valley as far as the upper limit of the tidal rise, and it is usually divisible into three sectors: (a) a marine or a lower estuary in free connection with the open sea; (b) a middle estuary subject to strong salt and fresh water mixing and (c) an upper or the fluvial estuary characterized by fresh water but subject to daily tidal action (Fairbridge, 1980). Estuaries with their associated river systems form an integral part of coastal features. They are complex environments in which diverse processes are closely interlinked. The complexity arises mainly because of the marked gradients in the ionic strength and concentration of suspended matter and its variable composition. The shallowness of most estuaries, with associated possibilities of extensive sediment resuspension, as well as frequent high levels of independent biological and chemical activities introduce additional complexity.

Estuary is a dynamic aquatic ecosystem and it is the most productive natural ecosystem due to the regular interaction between the freshwater discharge and the sea tides (Nath, 2002). Mukherjee *et al.*, (2008) has reported sharp changing pattern of some physico-chemical parameters like salinity, pH, Dissolved Oxygen from the estuarine ecosystem of Sunderbans and Digha estuaries and these changes affects the estuarine ecosystem in greater course. Panse and Somani (2008) reported study of water quality at Sewri creek in Mumbai. Pawar and Kulkarni (2007) monitored the coastal water quality of Karanja creek in Raigad district, west coast of India. Estuaries are rich in nutrients and are potential sources of rich flora and fauna. They connect the ocean and Inland Rivers and are important for recreation and transport. Their often high rate of flux and flush permit disposal of great quantities of wastes. The disposal of waste leads to contamination of these estuaries and also drastically affects the flora and fauna. It may be necessary to examine the factors that adversely affect the water quality of the Mandovi and Zuari estuarine systems. Therefore an attempt has been made to assess the water quality of the Mandovi and Zuari estuarine systems of Goa, West coast of India based on five Physico-chemical parameters.

MATERIALS AND METHODS

Study area

Goa is the twenty fifth state of India. It occupies an area of 3700 km^2 with a population of over one million. It has coastal stretch of about 100 km and lies between 14° 54' N – 15° 48'N and 73° 41' E- 74° 20'E. Mandovi and Zuari basins constitute about 2500 km^2 which is about 68% of the total land area of

Goa. The Mandovi and Zuari estuarine systems in Goa are facing a threat of mining activity along its shoreline.

The area of investigation covers the Mandovi and Zuari estuaries in Goa (West Coast of India). It comprises ten sampling stations each in Mandovi and Zuari estuaries. These stations cover the entire course of the river i.e. from the head to the mouth region. Water samples for the study were collected in three seasons viz. Pre-monsoon (May), Monsoon (July) and Post-monsoon (November). Surface and bottom water samples were collected using GO-FLOW Niskin water sampler fastened on to a plastic rope and was triggered by a messenger. The depth of water varied from 452 cm to 172 cm between Station I and 10 in both the estuarine systems.

Water temperature was measured immediately after collection using a sensitive thermometer. Chlorinity was determined by Mohr-Knudsen Chlorinity titration method (Grasshoff, 1983) using silver nitrate as the titrant and potassium chromate as the indicator. pH was measured using a pH meter of pen type model. Total Alkalinity was calculated as described in Martin (1972). Dissolved Oxygen was analyzed following the modified winkler's method (Carrit and Carpenter, 1966).

RESULTS AND DISCUSSION

The results on Physico-chemical analysis of the water samples in the Mandovi and Zuari estuaries in the different seasons are presented in Table 1 and 2.

Water Temperature

The surface temperature in Mandovi and Zuari estuaries varied from 28.0 to 30.0°C and 28.0 to 29.50°C during pre-monsoon, 25.0 to 25.8°C and 26.4 to 27.2°C during monsoon and 26.0 to 27.8°C and 26.5 to 27.8°C during post-monsoon seasons respectively. However, the bottom temperature in from 25.0 to 25.5°C and 26.0 to 26.75°C during monsoon and 25.9 to 27.6°C and 26.3 to 27.6°C during post-monsoon seasons respectively.

In both the estuaries surface waters registered higher temperature as compared to those in the bottom in all seasons. Water temperature is found to be higher during the non-monsoonal seasons. The surface temperature during different seasons can be attributed to the ambient air temperature Both surface and water temperatures were found to be higher during pre-monsoon in the Mandovi estuary when compared with those is Zuari estuary. In the monsoon and post-monsoon season both the surface and bottom water temperature were found to be higher in Zuari estuary. The present observation is in accordance with the study in Thane creek by Quadros *et al.*, (2002). Similarly higher water temperature of 33.8°C during pre-monsoon season was reported by Mukherjee *et al.*, (2008) from Digha coast. Higher water temperature during the non-monsoonal season was also reported by Panse and Somani (2008) in Sewri creek near Sewri Jetty. Pawar and Kulkarni (2007) also reported higher temperature range 26.17 to 34.27°C during the non-monsoonal seasons.

Chlorinity

Chlorinity provides valuable information on the intrusion and distribution of seawater in the estuary, and the same varies with the tidal stage and the magnitude of riverflow. Chlorinity (mg L^{-1}) in surface waters in Mandovi and Zuari estuaries varied from 4.57 to 18.21 and 0.14 to 16.44 (mg L^{-1}) during pre-monsoon and from 0 to 16.22 and 2.27 to 17.71 (mg L^{-1}) during post-monsoon seasons respectively. However, the chlorinity in bottom water in the Mandovi and Zuari estuaries varied from 5.26 to 18.07 and 0.22 to 16.88 (mg L^{-1}) during pre-monsoon and from 0 to 16.88 and 2.27 to 17.44 (mg L^{-1}) during post-monsoon seasons respectively. High chlorinity of surface waters during pre-monsoon was due to excessive summer evaporation and negligible input of fresh water (NIO, 1992). However, in both the estuaries during the monsoon chlorinity was non-detectable in all stations except for few stations located in the mouth regions. This is due to heavy precipitation that occurs during the monsoon season. Mukherjee *et al.*, (2008) reported similar higher values of chlorinity during the non-monsoonal seasons and the lowest in monsoon at all the study sites in Digha coast. Pawar and Kulkarni (2007) also reported higher chlorinity values during pre-monsoon season at Karanja Creek in West coast of India.

In general, surface water values registered lower concentrations compared to bottom waters because of the dilution of surface water. The chlorinity variations between surface and bottom waters in both the estuaries are very less and hence they could be considered as a well-mixed estuary. In both the estuaries, stations near the mouth regions revealed higher values indicating negligible influence of fresh water, whereas, stations in the upstream revealed significant variations with the definite decrease at low tide, because of the substantial increase in the input of river discharge. However, as expected there was a steady decrease in the salinity from first to last station (i.e. from mouth to the head region) thus exhibiting an apparent decreasing trend from mouth to head region.

pH

The pH of surface water in Mandovi and Zuari estuaries varied from 7.24 to 7.94 and 7.21 to 8.53 during pre-monsoon, 6.8 to 7.14 and 6.53 to 6.96 during monsoon and 7.77 to 8.31 and 7.0 to 7.96 during post-monsoon seasons respectively. However, the pH of the bottom waters in the Mandovi and Zuari estuaries varied from 7.42 to 7.93 and 7.26 to 7.98 during pre-monsoon, v 6.85 to 7.05 and 6.62 to 6.97 during monsoon and 7.70 to 8.19 and 7.2 to 8.04 during post-monsoon seasons respectively. In general, higher pH was registered during the post-monsoon and pre-monsoon seasons in both the estuaries. Pawar and Kulkarni (2007) also observed higher pH values during the post-monsoon. The pH range in the present study are in conformity with the one reported by Panse and Somani (2008) in Sewri Creek, Mumbai and Mukherjee *et al* (2008) from estuarine ecosystem of Sunderbans and Digha coast.

The pH in seawater is controlled by the concentrations of CO2, HCO3 and CO3. Other electrolytes such as borate, phosphate and silicate slightly augments this effect. In estuarine and coastal region, variation over a greater range are often observed due to several other factors such as interaction with suspended matter, influence of fresh water inputs, pollution, photosynthesis etc. The higher pH observed during pre-monsoon and post-monsoon as compared to monsoon season may be caused by the removal of carbon dioxide due to high photosynthetic activity during these seasons and the low

Table 1: Data on physic – chemical parameters in the Mandovi river at different seasons

Station	Depth	Premonsoon					Monsoon					Postmonsoon				
		Temp (°C)	Chlo. (mg/L^{-1})	pH	D. O (mg/L^{-1})	Alkalinity (m. eq L^{-1})	Temp (°C)	Chlo. (mg/L^{-1})	pH	D. O (mg/L^{-1})	Alkalinity (m.eq L^{-1})	Temp (°C)	Chlo. (mg/L^{-1})	pH	D.O (mg/L^{-1})	Alkalinity (m. eq L^{-1})
ME1	S	-	-	-	-	-	25.00	0.14	7.04	6.54	0.50	26.00	16.22	7.96	2.80	2.50
	B	-	-	-	-	-	25.00	0.14	7.05	5.84	0.50	25.90	16.88	8.01	2.80	2.60
ME2	S	28.00	18.21	7.79	3.92	2.50	25.00	0.14	7.05	6.31	0.50	26.10	13.89	7.92	2.80	2.50
	B	28.00	N.A.	7.83	4.23	2.50	25.00	0.14	6.90	6.08	0.48	25.90	15.22	7.91	2.40	2.50
ME3	S	28.50	17.96	7.94	3.92	2.50	25.20	0.00	6.91	6.08	0.48	26.40	12.07	7.89	3.00	2.50
	B	28.20	18.07	7.93	4.00	2.50	25.20	0.00	6.96	6.08	0.49	26.00	15.00	7.91	2.60	2.50
ME4	S	29.00	13.23	7.71	5.69	2.10	25.50	0.00	6.80	6.08	0.45	27.00	8.69	7.77	4.00	2.50
	B	28.80	13.70	7.76	3.61	1.95	25.25	0.00	6.87	5.84	0.46	26.00	8.91	7.73	3.20	2.00
ME5	S	28.25	14.81	7.74	3.54	2.50	25.00	0.00	6.87	6.31	0.47	26.80	9.40	7.85	5.60	2.00
	B	28.50	15.08	7.78	3.69	2.30	25.00	0.00	6.85	6.31	0.46	26.60	8.36	7.85	5.40	1.50
ME6	S	28.80	14.49	7.52	1.77	1.90	25.80	0.00	7.14	6.08	0.45	27.10	8.03	8.19	5.40	1.50
	B	28.80	12.04	7.56	3.61	1.80	25.50	0.00	7.02	6.31	0.45	27.20	8.14	8.19	4.00	1.60
ME7	S	29.10	10.46	7.54	3.77	1.70	25.00	0.00	6.98	6.54	0.44	27.10	5.15	8.22	4.60	1.50
	B	29.00	10.74	7.51	3.69	1.70	25.00	0.00	6.88	6.31	0.43	27.00	6.14	8.16	5.20	1.50
ME8	S	30.00	9.47	7.41	3.08	1.60	25.00	0.00	6.90	6.31	0.43	27.80	2.44	8.15	4.80	1.40
	B	29.10	9.69	7.46	4.08	1.60	25.00	0.00	6.99	6.54	0.45	27.60	3.87	7.70	5.40	1.40
ME9	S	29.90	7.97	7.42	3.77	1.60	25.30	0.00	6.98	6.31	0.45	27.00	0.99	8.29	5.80	1.30
	B	29.20	8.08	7.42	4.00	1.60	25.00	0.00	6.98	6.31	0.45	27.00	1.27	8.05	5.20	1.30
ME9a	S	30.00	6.09	7.24	4.00	1.40										
	B	29.70	6.59	7.44	3.61	1.40										
ME10	S	30.00	4.57	7.43	3.27	1.50	25.20	0.00	6.99	6.31	0.45	27.50	0.00	8.31	5.00	1.15
	B	29.20	5.26	7.53	3.61	1.50	25.10	0.00	6.98	6.54	0.45	26.80	0.00	8.16	4.40	1.00
Average		29.00	11.40	7.60	3.59	1.91	25.15	-	6.96	6.25	0.46	26.74	8.03	8.01	4.22	1.84

ME = Mandovi Estuary; S = Surface; B = Bottom; NA = Not Analysed; D.O = Dissolved Oxygen; Chlo. = Chlorinity

solubility of this gas due to higher water temperature (George, 1989).

Dissolved oxygen

Dissolved oxygen (mg L^{-1}) in Mandovi and Zuari estuaries in surface waters varied from 1.77 to 3.99 and 3.076 to 4.076 (mg L^{-1}) during pre-monsoon, 6.08 to 6.5 and 6.08 to 6.54 (mg L^{-1}) during monsoon and 2.79 to 5.79 and 2.59 to 4.198 (mg L^{-1}) during post-monsoon seasons respectively (Tables 1 and 2). However, in the bottom waters of the Mandovi and Zuari

Table 2: Data on physic – chemical parameters in the Zuari River at different seasons

Station	Depth	Temp (°C)	Chlo. (mg/L^{-1})	pH	D. O (mg/L^{-1})	Alkalinity (m. eq L^{-1})	Temp (°C)	Chlo. (mg/L^{-1})	pH	D. O (mg/L^{-1})	Alkalinity (m.eq L^{-1})	Temp (°C)	Chlo. (mg/L^{-1})	pH	D.O (mg/L^{-1})	Alkalinity (m. eq L^{-1})
ZE1	S	N.A	N.A	N.A	N.A	N.A	26.50	0.00	6.96	6.08	0.50	26.50	16.83	7.93	3.60	2.50
	B	N.A	N.A	N.A	N.A	N.A	26.00	0.97	6.97	6.08	0.55	26.40	17.44	8.04	3.80	2.50
ZE2	S	29.50	16.44	7.79	3.69	2.50	26.50	0.00	6.82	6.31	0.45	27.00	16.61	7.96	4.00	2.50
	B	29.00	16.88	7.85	3.54	2.50	26.50	0.00	6.97	6.31	0.50	26.50	17.16	7.97	2.60	2.50
ZE3	S	28.00	15.83	8.53	4.00	2.50	26.50	0.00	6.81	6.31	0.45	27.00	17.16	7.69	2.60	2.50
	B	28.50	16.38	7.94	3.85	2.50	26.50	0.00	6.88	6.08	0.46	27.00	16.05	7.86	2.30	2.50
ZE4	S	28.80	13.84	7.86	3.92	2.20	26.50	0.00	6.73	6.31	0.45	27.00	13.62	7.74	3.60	2.20
	B	28.80	14.39	7.86	3.77	2.15	26.40	0.00	6.70	6.19	0.42	27.00	13.45	7.87	3.40	2.00
ZE4a	S	28.80	12.73	7.98	4.00	2.10	N.A	0.00	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
	B	28.80	13.01	7.98	3.38	2.00	N.A	0.00	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
ZE5	S	28.50	11.62	7.91	4.08	2.00	26.40	0.00	6.68	6.43	0.40	27.50	13.40	7.83	3.60	2.20
	B	28.50	12.04	7.98	3.69	1.90	26.30	0.00	6.78	6.54	0.41	27.50	11.40	7.81	3.00	2.30
ZE6	S	29.00	9.13	7.68	3.38	1.90	26.80	0.00	6.66	6.31	0.39	27.70	11.40	7.63	3.80	1.60
	B	29.00	9.30	7.72	3.46	1.80	26.50	0.00	6.65	6.54	0.35	27.50	11.40	7.52	3.60	1.50
ZE7	S	29.00	6.81	7.34	3.61	1.70	26.80	0.00	6.53	6.31	0.34	27.80	7.14	7.50	4.20	1.30
	B	28.90	7.31	7.62	2.92	1.60	26.60	0.00	6.67	6.66	0.40	27.60	7.58	7.27	3.80	1.30
ZE8	S	29.00	6.53	7.45	3.31	1.60	26.70	0.00	6.60	6.43	0.36	27.80	5.46	7.11	4.00	1.00
	B	29.90	6.80	7.50	3.35	1.50	26.60	0.00	6.85	6.54	0.45	27.50	5.87	7.15	4.00	1.00
ZE9	S	28.90	4.84	7.28	3.23	1.40	27.00	0.00	6.72	6.54	0.40	27.80	3.21	7.00	3.90	0.80
	B	28.70	5.04	7.34	3.15	1.40	26.75	0.00	6.65	6.78	0.36	27.50	3.43.	7.20	4.00	0.90
ZE9a	S	28.80	2.21	7.27	3.35	1.30	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
	B	28.70	2.27	7.32	3.08	1.30	N.A	N.A	N.A	N.A	N.A		N.A	N.A	N.A	N.A
N.A																
ZE9b	S	28.50	1.38	7.27	3.08	1.20	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
	B	28.40	1.27	7.28	2.73	1.20	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
ZE10	S	28.50	0.14	7.21	3.77	1.10	27.20	0.00	6.65	6.31	0.34	27.50	2.27	7.02	4.20	0.82
	B	28.20	0.22	7.26	3.00	1.00	26.20	0.00	6.62	7.01	0.34	27.50	2.27	7.61	4.00	0.90
Average		28.74	8.60	7.63	3.47	1.76	26.56	-	6.41	6.40	0.42	24.80	9.69	6.90	3.59	1.58

ZE = Zuari Estuary; S = Surface; B = Bottom; N.A = Not Analysed; D.O = Dissolved Oxygen; Chlo. = Chlorinity

estuaries the values varied from 3.61 to 4.20 and 2.73 to 3.85 (mg L^{-1}) during pre-monsoon, 5.8 to 6.5 and 6.08 to 7.01 (mg L^{-1}) during monsoon and 2.39 to 5.39 and 2.229 to 3.998 (mg L^{-1}) during post-monsoon seasons respectively. In both the estuaries the surface waters registered higher concentrations of dissolved oxygen when compared to those in the bottom waters in all seasons. Concentration of dissolved oxygen is found to be highest during the monsoons in both the estuaries. This may be due to the high solubility of gases at lower salinity (George, 1989). The values of the Dissolved oxygen are found to be higher in the upstream regions of the estuaries. Similarly higher dissolve oxygen above 6 mg L^{-1} were reported during monsoon season by Mukherjee *et al.*, (2008) from estuarine ecosystem of Sunderbans and Digha coast and Panse and Somani (2008) from Sewri Creek, Mumbai.

Total Alkalinity

Total Alkalinity (m.eq L^{-1}) during the study period in Mandovi and Zuari estuaries in surface waters varied from1.4 to 2.5 and 1.1 to 2.5 (m.eq L^{-1}) during pre-monsoon, 0.43 to 0.5 and 0.34 to 0.5 (m.eq L^{-1}) during monsoon and 1.15 to 2.5 and 0.8 to 2.5 (m.eq l^{-1}) during post-monsoon seasons respectively (Tables 1 and 2). However, alkalinity in bottom waters in the Mandovi and Zuari estuaries varied from 1.4 to 2.5 and 1.0 to 2.5 (m.eq L^{-1}) during pre-monsoon, 0.43 to 0.5 and 0.34 to 0.55 (m. eq L^{-1}) during monsoon and 1.0 to 2.6 and 0.9 to 2.5 (m.eq L^{-1}) during post-monsoon seasons respectively.

In both the estuaries the values of alkalinity in the surface waters registered higher values compared to bottom waters. Alkalinity values were found to be high in pre-monsoon and post-monsoon periods in both the estuaries. This can be attributed to the intense growth of phytoplanktons during pre-monsoon and early post-monsoon seasons. The overall trend of alkalinity in both the estuaries shows that the stations near the mouth region showed higher values compared to stations in the upstream. Higher values in the mouth region can be attributed to dominant marine conditions while the lower values towards the upstream may be due to fresh water influx.

CONCLUSION

In conclusion, the concentrations of the Physico-chemical parameters reported in the present investigation reveal the clean water status when compared with the river-estuarine systems from the other regions, suggesting comparatively lesser level of contamination in the area of investigation. Industrial and mining activities are being concentrated along the two river basins. All the future developmental activities around these river basins will have impounding impacts on these waters. So, it is strongly suggested to carry out constant monitoring on the Mandovi and Zuari estuarine systems of Goa to keep a close vigil on the level of pollution.

REFERENCES

Carrit, D. E and Carpenter, J. H. 1966. Comparision and evaluation of currently employed modification of the wrinkler's method for determining dissolved oxygen in seawater. A NASCO report, *J. Mar. Res.* **24:** *286-318*

Fairbridge, R. W. 1980. The Estuary: Its definition and geodynamic cycle. In "Chemistry and biogeochemistry of estuaries" (E. Olausson and I. Cato, Eds.), John Wiley and Sons, New York, pp. 1-35.

George, M. D. 1989. Some Aspects of Chemical Speciation of Cadmium, Lead and Copper in some Indian estuaries and Coastal waters. Ph.D.Thesis. University of Poona.

Grasshoff, K. 1983. In Methods of seawater analysis, K. Grasskhoff, M. Ehrdardt and K. Krembling (Eds) Verlag Chemie, Weinneim pp. 419.

Martin, D. F., 1972. In Marine Chemistry, Marcel Dekker Inc., New York *pp 281-288.*

Mukherjee, D.,Banerjee, A and Sen, G.K.2008. Present ecological status at estuarine ecosystem of Sunderbans and Digha in relation to fish catch. *Ecol. Env. and Cons.***14(2-3):** 387-392.

Nath, D.2002. Estuaries in India-their present ecological status in relation to fish health. Ecology, Fisheries and fish stock assessment in Indian rivers, CIFRI, Barracpore. pp 26-31.

National Institute of Oceanography (NIO) 1992. Marine environmental studies: Environmental quality along the northwest coast of India. (National Institute of Oceanography, Goa, India) pp165

Panse, C. and Somani, V.2008. Study of water quality at Sewri Creek *near Sewri jetty (Mumbai). Eco.Env.and Cons.* **14(2-3):** 495-498

Pawar , P . R . and Kulkarni , B . G. 2007. Assessment of water quality in Karanja Creek (Dist- Raigad) Maharashtra, west coast of India. *Indian J. of Environment and Ecoplanning.* **14(3):** 469-480.

Quadros Goldin, R. P., Athalye Vaishali, U., Somani, Mangal, U., Borkar and Patil, N. N. 2002. Present status of water quality of Thane creek and Ulhas river estuary. In-Proc. The national seminar on creeks, estuaries and mangroves pollution and conservation, Thane. Pp.58-62.