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IMPACT OF WATER QUALITY ON THE CHANGING ENVIRONMENTAL SCENARIO OF SUNDERBANS

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Abstract : Changes in the local hydrology in the estuarine river waters of Sunderbans are the most important contributory factors attributable to the changing scenario of mangrove ecosystems. Changes in river courses impede fresh water flow towards Sunderbans. All these changes as a result of regional and global processes and climatic changes cause the changes in the salinity, pH, dissolved oxygen, temperature and all other changes in the physico-chemical parameters in the brackish waters of the Sunderbans. Mangrove distribution is limited worldwide depending principally on temperature and salinity variations of the estuarine river waters.

Keywords : Brackish waters, temperature variations, salinity declining trends, coastal waters.

1. Introduction

Sunderbans (of both India and Bangladesh) is the single largest chunk of deltaic mangrove zones of the planet. Covering an area of 9630 sq km, Indian Sunderbans is a part of the world's largest Ganga-Brahmaputra delta at the confluence of the Bay of Bengal i.e. a part of the deltaic plain of fluvio-marine deposits [1]. It is a well-known Biosphere Reserve of India (located between Lat. 21° to 22°-30′N and Long. 88° to 88°-29′E) intersected by numerous tidal creeks and rivers and is famous for its mangrove ecosystem in the tropical region.

A large number of tidal rivers, creeks, tidal inlets, estuaries and network of intricate minor salt water courses along with submerged swamps and marsh together constitute the water body of the Sunderbans. The sea-land interphase mangrove ecosystem comprises of about 55% forest land and 45% water spread area in the forms of tidal rivers, creeks, inlets and vast estuarine mouths of the river Hooghly, Muriganga, Saptamukhi, Thakuran, Matla, Gosaba and Haribhanga. The rivers (31 in numbers) of Sunderbans along with its numerous tidal creeks and canals render this entire area like a criss-cross network. Water courses including rivers, creeks, tidal inlets, salt water courses are characterised by low saline brackish water where saline waters get diluted with the freshwater only from precipitation. Waters of these estuarine rivers and creeks have much potential for the growth of the mangroves as well as for nurturing vast quantities and varieties of both fin fish and shell fishes.

Sunderbans provides low lying deltaic plains with meso-macrotidal amplitude that helps generating the luxuriant growth to mangroves. A large number of mangrove species and their associates or back mangroves are characteristically salt-tolerant. A few species are grown at high salinity substrate whereas maximum mangrove species prefer the low salinity region. Some mangrove species are inundated twice daily

in the semidiurnal tidal regime during flood tide. Soil and water salinity including other physico-chemical parameters are important factors in controlling the growth and occurrences of mangroves in Sunderbans areas.

2. Methodology

Surface water samples were collected for the estimation of physico-chemical parameters of the water. Water samples from different stations were collected in polythene bottles of 1 litre capacity for the estimation of pH, conductivity, TSS, TDS, Turbidity, DO, BOD, COD, etc. using standardized equipment and procedures.

Air and water temperature were recorded by using glass-in-mercury thermometer. Water salinity was readily determined by ATAGO Hand Refractometer S/Mill (Japan) having a capacity of salinity determination within 0-100 ppt range. TDS (Total Dissolved Solids) and DO (Dissolved Oxygen) were measured by the TDS meter and DO meter respectively supplied by Systronix (India). A pH meter measured pH after calibrating the electrode with two standard buffer solution of pH 4.0 and 9.2.

3. Results and Discussions

3.1 Physico-Chemical Properties

Most of the mangrove species prefer low saline substratum. The mangrove species inundated by two times daily of tides prefer soils hyper-salinity areas whereas species those occur in the centre portion of islands prefer their habitat with low salinity. Mangrove species diversity and richness depend upon the preferred salinity of respective mangrove species. Mangrove zonation occurs in response to the salinity of both soil and water. Water being the primary requisite to support aquatic life its physico-chemical properties is responsible for maintaining the aquatic environment and the water quality parameters are likely to influence the growth of the organisms and thereby, productivity of the ecosystems.

3.1.1 pH

In the river waters of the Sunderbans pH is an important factor in the mangrove ecosystem to influence the physico-chemical reactions as well as many biological activities. pH activates microbial growth rate which in turn influences the bio-degradation of mangrove litters and other microbial mediated biochemical reactions. Most favourable pH condition is 6.0 to 8.0 for microbial degradation of biodegradable materials. pH measured in the tidal courses and inlets ranging between 7.3 to 7.7 is within the permissible limit in the waters of Sunderbans (Table 1) for the growth of mangrove vegetations.

3.1.2 Temperature

Water temperature of the river waters depends mainly on climate, sunlight and depth of water. All metabolic and physiological activities and life processes such as growth, feeding, reproduction and movement of the aquatic organisms are influenced by water temperature. The solubility of oxygen in water is inversely related whereas other solutes are directly related to water temperature. The rate of decomposition of organic matter of bottom soil is also regulated by temperature to a great extent. In tropical tidal estuarine environment of the Sunderbans water temperature undergo a wide diurnal and seasonal variation, which normally do not show adverse effect.

Water temperature is one of the most

important physical factors, which influence the growth of aquatic organisms in the estuarine systems. The mean water temperature decreases with the channel length from the source point towards the river mouth in the deltaic Sunderbans. As the amount of suspended solids decreases and depth of the channel increases, water is observed to retain lesser amount of heat. Water temperature varying between 18.1 to 21.5°C is well within the range. Mangroves cannot tolerate cold temperature less than 20°C for a continuous period. For these reasons, mangroves are found only in the tropical and sub-tropical region including Sunderbans. The shallow depth estuarine brackish water temperature is always a few degrees higher than the adjacent coastal waters of massive influence.

3.1.2.1 Temperature Variations

Temperature of the flood-tidal river waters of Sunderbans is recorded higher than that of the ambient temperature on the month of December during winter time. Increased water temperature is a local phenomenon in the Sunderbans region and may be due to the heat of mixing of the silt particles heavily and also the different chemicals occurred in the vortex of sediment-laden river waters particularly due to asymmetric bottom topography during flood tide situation when waters vigorously enter into the upstream of the river course coming out of the Bay of Bengal.

It happens that the sediment laden river waters of Sunderbans carry a large content of silt particles, which results in high TDS values (Table 2). There are innumerable vortices in the river waters due to irregular bottom topography and helicoidal tidal flows during flood tide in almost all the rivers having meandering bends along their courses in the Sunderban region.

Table 1 Water sample analysis in the rivers of Sunderbans on December, 2010

Flood(F) Ebb(E)	Sample Location	pH	Temp (°C)	DO (mg/L)	Salinity (ppt)
E.	Hogal R.	7.5	21.2	7.2	18
E.	Bidya R.	7.7	21.5	4.9	20
F.	Sajnekhali	7.5	21.4	3.8	23
F.	Gumdi	7.3	18.8	4.4	25
F.	Bharani-2	7.3	19.4	4.5	25
F.	Pirkhali	7.3	19.7	4.0	25
F.	Gazikhali	7.4	20.0	4.4	25
E.	Panchamukhani-1	7.5	20.1	4.6	25
E.	Dobanki	7.4	20.4	4.7	25
E.	Panchamukhani-2	7.4	20.6	3.5	25
E.	Jharkhali	7.5	20.8	3.6	25
E.	Netidhopani	7.5	21.1	3.3	25
E.	Chamta	7.4	21.4	6.8	21
E.	Deul Bharani	7.3	21.1	6.0	21

Table 1 Contd...

Flood(F) Ebb(E)	Sample Location	pH	Temp (°C)	DO (mg/L)	Salinity (ppt)
E.	Chora Gazi	7.3	20.7	5.2	22
E.	Bara Gazi	7.4	20.3	5.2	23
E.	Andharbani	7.4	20.2	4.0	23
E.	Sundarkhali	7.4	19.1	4.6	24
E.	Banbibi Bharani	7.3	18.1	3.3	24
E.	Sudhanyakhali R.	7.4	18.7	3.4	25
F.	Pakhirala	7.6	18.3	3.0	24
F.	Pakhir Khal	7.3	18.2	3.0	23
F.	Guritana Khal	7.4	19.9	5.2	23
F.	Sakuntala Khal	7.3	20.4	3.3	23
F.	Sudhanyakhali	7.4	20.5	4.0	23

Silt particles undergone mixing with water and the resultant heat of mixing as a result of the kinetic energy from those vortices may make the water temperature warmer than the ambient temperature (Table 2). During flood tide water molecules move faster resulting in higher temperature. Temperature change is the response of the water substance due to the removal of heat energy for high TDS value of river waters. Comparatively warm temperature of the river waters in the Sunderbans during winter may have significant control over the zonation and speciation of mangroves.

3.1.3 Dissolved Oxygen (DO)

The equilibrium solubility of O_2 in water at 25°C is 2.7 x 10^{-4} mol L^{-1} (8.7 mg L^{-1}). DO is essential for not only the survival of aquatic organisms and growth of primary productions in the waters of Sunderbans but also for various oxidation processes in physico-chemical interactions.

Very high DO of surface water (more than 9 mg/L) is detrimental as high DO will enhance the growth of phytoplankton, zooplankton and bacteria leading to eutrophication which will consume oxygen at a higher rate within water converting the water body into a dead pool of water. The eutrophication, which may be detrimental to aquatic life, are compounded by day light excursion in dissolved oxygen due to photosynthesis and respiration. The dissolved oxygen content varied from 1.8 to 7.2 mg/L, the lower values being found in the estuaries of the river Gumdi near Pakhirala and the higher values in the water of Hogol River at Sonakhali (Table 1 and Table 2).

3.1.4 Salinity

Salinity represents the quantity of dissolved salts in a given unit of water and is usually expressed in parts per thousands (‰). Growth and reproduction of the many aquatic flora and fauna and natural food production depend to a large extent on salinity of water. Most of the brackish water species are euryhaline in nature which is related to their osmoregulatory adoptions. Salinity is one of

the important parameters as the mangroves are grown in a special type of environment where these plants are flooded with saline waters twice daily. Salinity of coastal waters ranges from 23 to 31 ppt, which becomes less in estuary. Water salinity in the rivers of Sunderbans changes with the seasonal variation. Salinity varies from 8.6 ppt to 31 ppt from monsoon to pre- and post monsoon times. It ranges between 6 and 25 ppt in the surface waters during post monsoon periods (Table 2 and Table 3) in the Sunderbans. On the contrary, the salinity of open seawater off the mouth of the Rivers varies between 23 and 31 ppt.

3.1.4.1 Role of Salinity

Sunderbans is the habitat of densely populated mangrove vegetation with a large number of varied species. Drastic changes are revealed with the mangrove zonation on the riverbanks or natural levees influenced by the changing soil and water salinity from downstream to upstream tidal water courses. Increased salinity causes increased osmotic potential of the water in interstitial soil, which makes the root system difficult for uptaking water. In such condition mangroves are undergone into different adaptive mechanisms through some physiological modifications either by storage, excretion or exclusion of excess salts. Habitats of different mangrove species are generally befitted to their habitats upon the magnitude of salinity tolerance. The growth of mangroves may be accelerated with the influence of soil and water salinity [2].

High concentration of salinity of soil and water restricts the growth of densely vegetated mangroves. Upstream fresh water discharges which mix up with the saline water results brackish water situation i.e. low salinity condition where mangrove proliferates. It is observed that Avicennia, Aegialitis, Bruguiera sp etc are occurred abundantly at the high salinity situations in contrast to Heritiera, Excoecaria, Xylocarpus, Rhizophora, Ceriops sp etc which have been occurred at comparatively low salinity conditions. Even minute variations of salinity induce changing habitats for mangroves of different salt tolerant categories.

Table 2 Analysis of the water samples collected during winter time (December, 2011) from the rivers of Sunderbans

Sl. No.	Sample Location	Atoms. Temp. (°C)	Water Temp. (°C)	pH	Salinity (ppt)	TDS (ppm)	DO (mg/L)	Flood (F) / Ebb (E)
1	Sonakhali	27.8	22.4	7.5	12	990	1.8	E
2	Gosaba	24.9	22.6	7.9	14	775	3.9	E
3	Sajnekhali	25.3	22.3	7.9	17	860	3.5	E
4	Gumdi	22.4	24.1	7.8	16	560	3.6	E
5	Dayapur	22.0	18.1	7.9	15	865	2.9	E
6	Satjelia	19.9	20.4	7.9	15	790	2.3	F
7	Chotomollakhali	20.7	23.1	7.9	15	825	2.3	F
8	Malmelia khal	21.4	22.3	8.0	14	750	2.3	F
9	Korankhali	21.4	23.4	7.9	14	810	2.3	F
10	Marichjhapi	22.4	23.1	7.9	14	790	2.5	F
11	Kumirmari	23.3	23.6	7.9	11	695	2.6	F
12	Jhilla R.	22.8	21.6	7.9	6	440	2.5	F
13	Jhilla	24.0	22.8	7.9	7	485	2.8	E

Table 2 Contd.....

Sl. No.	Sample Location	Atoms. Temp. (°C)	Water Temp. (°C)	pH	Salinity (ppt)	TDS (ppm)	DO (mg/L)	Flood (F) / Ebb (E)
14	Burir Dabri K.	24.2	23.5	7.8	8	655	5.6	E
15	Katuajhuri	24.4	24.1	7.8	7	565	5.7	E
16	Burir Dabri	25.9	21.4	7.9	10	590	2.9	E
17	Pakhirala	21.4	22.2	7.7	16	685	2.4	F
18	Sudhanyakhali	24.8	21.7	7.9	16	800	6.0	F
19	Sudhanyakhali K.	22.1	21.6	7.9	18	775	2.5	F

Table 3 Seasonal variations of salinity in the river waters of Sunderbans

Sl. No.	Sample location	Salinity in ppt		
		Pre-monsoon	Monsoon	Post-monsoon
1	Debnagar	21	14	17
2	Namkhana	21	14	18
3	Basanti	22	15	18
4	Gosaba	24	16	20
5	Sajnekhali	28	18	23
6	Gumdi	27	19	25
7	Bharani No.2	28	19	25
8	Pirkhali	29	20	25
9	Gazikhali	28	20	25
10	Panchamukhani-1	29	20	25
11	Dobanki	28	19	25
12	Panchamukhani-2	28	20	25
13	Jharkhali	28	19	25
14	Netidhopani	29	20	25
15	Chamta	25	18	21
16	Deul Bharani	26	16	21
17	Chora Gazi	26	16	22
18	Bara Gazi	27	15	23
19	Andhar Bani	27	16	23
20	Sunder khali	29	16	24
21	Ban Bibi Bharani	28	15	24
22	Sudhanyakhali	28	17	25
23	Pakhiralaya	28	15	24
24	Pakhir Khal	29	14	23
25	Guritana Khal	28	15	23
26	Sakuntala Khal	27	14	23
27	Sudhanyakhali	28	14	23
28	Ramganga	25	12	20

Table 3 Contd.....

Sl. No.	Sample location	Salinity in ppt		
		Pre-monsoon	Monsoon	Post-monsoon
29	Patharpratima	23	11	18
30	Mandir Ghat	20	9	14
31	Banstala	18	8	10
32	Jata	20	11	15
33	Bhubaneswari	22	11	16
34	Saheber Ghat	23	11	17
35	Maipith	28	14	21
36	Harinala Khal	26	14	20
37	Paschim Sripatinagar	25	14	20
38	Chilkamari Khal	26	14	21
39	Purba Sripatinagar	26	15	20
40	Upendranagar	27	15	21
41	Rakhalpur	28	15	22
42	Sridharnagar	28	16	23
43	Lakshmi Janardanpur	29	18	25
44	Dakshin Kashinagar	25	16	20
45	Dhanchi-1	25	13	23
46	Dhanchi-2	26	14	21
47	Dhanchi-3	26	14	20
48	Dhanchi-4	29	15	23
49	Dhanchi south	30	18	23
50	Bakkhali	31	19	24
51	Fraserganj	31	19	24

Table 4 Salinity variations in the coastal waters at Bakkhali in the Sunderbans

Month / Year	Salinity (‰)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1994	31	26	26	28	29	31	22	20	20	16	16	31
2011	30	25	26	28	29	31	22	20	19	15	15	30

Table 5 Physico-chemical parameters of coastal waters at Bakkhali of Sunderbans

Parameters	Dec-Feb			March-May			June-August			Sept-Nov		
	Stn1	Stn2	Stn3	Stn1	Stn2	Stn3	Stn1	Stn2	Stn3	Stn1	Stn2	Stn3
pH	8.46	8.49	8.45	8.65	8.64	8.52	8.26	8.24	8.26	8.5	8.48	8.5
Temp (°C)	27.5	27.5	27.7	31.5	31.8	31.4	29.8	30	30.1	28.9	28.6	28.7
DO (mg/l)	7.5	7.7	7.8	8.5	8.7	8.9	6.8	7.2	7.6	8.1	7.9	8.5
BOD (mg/l)	4.2	5.3	5.8	3.9	4.4	4.1	5.3	5	3.3	4.1	4.8	3.9
COD (mg/l)	540	556	676	520	560	490	560	496	500	420	468	464
Salinity (‰)	28.5	28.9	28.6	31.6	31.5	31.7	16.5	16.6	16.2	22.5	22.9	22.6
TDS (mg/l)	934	897	676	740	787	780	994	910	887	700	680	720
Turbidity (NTU)	601	757	602	550	600	480	929	808	628	549	550	580
Conductivity (Ms/C)	1.86	1.79	1.97	1.81	1.72	1.87	1.97	1.81	1.77	1.78	1.75	1.81
Bacteria (B/ml)	150	120	86	80	92	76	150	100	96	96	106	80

(Data computed on an average of three months in each station)

3.1.4.2 Impact of Salinity

Growth and productivity of mangroves depend on the climate, hydrology, topography and tidal inundation. But the decreasing rate of respiration may cause damage to the mangrove vegetation if it is inundated for long period even in the fresh water. Rhythmic inundation two times daily in a semidiurnal situation is normal to the mangroves of tropical region.

High salinity of the river waters round the year may be detrimental to the mangrove community. Long periods of high salinity in an area may trigger complete destruction of mangrove vegetation. Hyper-salinity retards growth of the trees in A. Marina community [3] and lessens biomass of Bruguiera gymnorhhiza [4]. Hyper-salinity in the interstitial water of the saline soil decreases leaf area of mangroves, enhances leaf-sap osmotic pressure, reduces total NPK and accelerates leaf sap osmotic pressure [5]. Sometimes mangrove plays a vital role in changing the salinity level in the interstitial water where salt flat is caused due to low rainfall and high evaporation [6].

It is expected that arise in sea level would lead to coastal erosion, tidal shift, sea water ingress and degradation of coastal ecosystem. Tidal amplitude will increase and bring changes in the current pattern due to an average sea level rise of 3 mm per year [7,8]. The changed current pattern will alter sediment transport, erosion and deposition. The changed tidal regime and sea ingress will affect the present coastal ecosystem and probably destroy it. In this context the role of salinity over the occurrences, growth and development of mangroves in the Sunderbans region is very important. Perhaps mangroves are grown in the substratum of different salinity inundated by brackish waters twice daily.

3.1.4.3 Trend of Salinity Decline

The salinity of coastal waters of the Bay of Bengal has been decreasing slowly as recorded during the period 1994-2011 (Table 4). The seawater is diluting very slowly because the ice sheet of Antarctica has been

melting and is releasing an estimated 36 cubic miles of water into the sea each year. The Antarctica is playing a major role in the rise of global sea level at the rate of 3 millimeters a year [8]. The melting ice sheet adds water to the oceans that leads to sea level rise as well as decreasing salinity due to dilution of seawater. The coastal water of the Bay of Bengal shows sharp decline particularly on the month of November in every year. Although the agricultural land run off during October-December has the seasonal contribution for dilution of seawater locally.

3.2 Water Quality of Coastal Areas of Sunderbans

Coastal water of the Bay of Bengal at Bakkhali in the extreme southern portion of South 24 Parganas district of Sunderbans sets polluted as the analyzed Chemical Oxygen Demand (COD) value and Total Dissolved Solids (TDS) of the coastal water samples cross the permissible limit of water quality index (Table 5). Spatial variations of some physico-chemical properties of the coastal waters of Bay of Bengal at Bakkhali were measured. The mixing of river waters from Hooghly flowing through Haldia industrial belt (basically Chemical detergents, batteries, petrochemicals and plastics) in coastal areas are the primary causes of nutrient enrichment, hypoxia, harmful algal blooms, toxic contamination, sedimentation and other problems that plague coastal water at Bakkhali.

4. Conclusion

The present environmental scenario of the Sunderbans is quite different and has been changing slowly from what was three decades earlier. The physico-chemical characteristics of the brackish waters of Sunderbans including salinity, the most important parameter for the mangrove ecosystem have been changing for several reasons. Almost all the rivers of Sunderbans have lost their connections with the river Hooghly due to the change of the river course for the gradual easterly tilt as a result of neo-tectonic movement [1] and for that reason, fresh water supply to these estuarine rivers of Sunderbans has been stopped. The Sunderbans river water is almost saline along the entire stretch of the rivers due to lack of head water discharge. Only the river Hooghly in the extreme west of the Sunderbans meets the Bay of Bengal carrying fresh water from the upstream. As a result, tidal sea waters coming through the estuarine river mouths of 2-8 km width to the upstream have become more saline. Sewage discharges, urban emissions, accidental spillage of toxic pollutants in the river waters are the inputs from anthropogenic interferences. The quality of brackish waters has been gradually deteriorating because of squeezing of areas for rapid encroachment of mangrove regions either for the agricultural purposes or for the aquaculture of both prawn and fish.

Some physico-chemical parameters of the river waters of Sunderbans of late have been gradually changing. Salinity around 1 ppt is observed in the pre-monsoon time in the Hooghly river water even at Nurpur which is about 50 km upstream from its confluence to the Bay of Bengal. Salinity of the river water has been declining very slowly due to the sea level rise and encroaches into the fresh water domain. A temperature variation of river water during winter is a result of shallowing of river beds due to rapid rate of siltation. Occasional low dissolved oxygen level is observed either for heavily sediment laden waters or for the mixing of sewage released from the urban areas. All these

changing parameters in the river waters of the Sunderbans have vast impacts on the growth and distributions of the mangroves. The expansion of mangroves into the salty marshy areas is observed in the Sunderbans due to increased tidal amplitudes and changes in the water quality of estuarine rivers.

References

[1] Das, G.K., Sunderbans- Environment and Ecosystems, Levant, Kolkata, p.254, 2006.

[2] Bandyopadhyay, B.K., Sen, H.S., Maji, B. and Yadav, J.S.P., Saline and Alkali Soils and Their Management, ISCAR Monograph Series 1, p.72, 2001.

[3] Selvam, V., Mohan, R., Ramasubramaniam, R. and Azariah, K., Plant Communities and Soil Properties of Three Mangrove Stands of Madras Coast, Indian Journal of Marine Sciences, Vol.20, pp.67-69, 1991.

[4] Naido, G., Effects of Nitrate, Ammonium and Salinity on Growth of the Mangrove Brugeira Gymnorrhiza (L) Lam, Aquatic Botany, Vol.38(2-3), pp.209-219, 1990.

[5] Medina, E., Lugo, A.E. and Novelo, A., Mineral Content of Foliar Tissues of Mangroves Species in Laguna de Soutecomapan (Veracruz, Mexico) and its Relation to Salinity, Biotropica, Vol.27(3), pp.317-323, 1995.

[6] Ridd, P.V. and Sam, R., Profiling Ground Water Silt Concentration in Mangrove Swamps and Tropical Salt Flats, Estuarine, Coastal and Shelf Science, Vol.43(5), pp.627-635, 1996.

[7] Brunn, P. and Nayak, B.U., Manual on Protection and Control of Coastal Erosion in India, NIO, Dona Paula, Goa, p.134, 1980.

[8] IPCC 2007, Climate Change: Impacts, Adaptations and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom. p.1000, 2007.