COMPARATIVE STUDY OF THE PHYSICO-CHEMICAL PARAMETERS OF THE COASTAL WATERS IN RIVERS MATLA AND SAPTAMUKHI: IMPACTS OF COASTAL WATER COASTAL POLLUTION

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A qualitative and quantitative research has been performed on the physico-chemical parameters of the neighboring coastal waters of the rivers Matla and Saptamukhi in the Sunderban district, West Bengal. The distribution pattern of eight physico-chemical parameters, namely pH, salinity, dissolved oxygen, suspended solids, nitrogen and phosphorus concentrations (inorganic and total) has been graphed and compared for the two rivers over a time period of ten years ('90s decade). A statistical analysis has been carried out and the correlation data between these parameters has been rationalized based on both natural and man-made activities during that time. This has pointed to various causes behind coastal pollution of river waters. The changes in water quality have been related to flood impacts, storm surge, eutrophication, domestic sewage, agricultural and industrial wastes. In order to avoid coastal degradation and maintain environmental balance, it is very important to understand the impact of these parameters on coastal zones.

Keywords: algal bloom, Bengal, coastal impact, coastal zon, physico-chemical parameters, pollution, Sunderban.

1. Introduction

Coastal pollution is one of the serious problems retarding coastal development which can lead to severe environmental imbalance. Polluted effluents are often the most common source of adverse effects on coastal and marine ecosystems. Here, the physico-chemical parameters of the rivers Matla and Saptamukhi has been analyzed for the first time. The Bengal delta is the largest in the world and this is where this study assumes much importance. The major objectives of this research includes analysis of the distribution pattern of physical and chemical aspects such as salinity, dissolved oxygen, pH, suspended solids, nitrogen and phosphate content (inorganic and comparison with their total content); rationalize the causes (both natural and man-made) behind this distribution and to find its impact on environment. The importance of these factors is described below:

Salinity. This is the primary information when dealing with any sample of seawater. It is defined as the weight in grams of the dissolved inorganic matter in one kilogram of seawater after all the bromide and iodide have been replaced by the equivalent amount of chloride and all carbonates have been converted to oxide.

Dissolved oxygen. Oxygen is produced in all parts of the ocean where light is sufficient for photosynthesis. It is consumed everywhere in the ocean, all the time, except for those regions where there is no signs of life.

Suspended solids. Suspended solids refers to small solid particles which remain in suspension in water as a colloid or due to the motion of the water. It is used as one indicator of water quality.

pH. pH is a measure of the acidity or alkalinity of a solution. In this respect, the concentration of H^+ strongly determines the presence of other anions in sea-water.

Nutrients. Phosphates and nitrates are major constituents that are used by photosynthesizing planktons to maintain life activities. Nutrients in optimal concentrations cause phytoplanktons to flourish while an excess concentration of nutrients might cause algal bloom. These contrasting effects were found during our study of the rivers Matla and Saptamukhi.

Phosphorus. Commensurate to its crucial role in biological activity, phosphorus is amongst the most extensively studied elements in the sea. Phosphorus has certain unique properties that qualifies it role both as an essential constituent of genetic material (DNA and RNA) and as an essential participant in many energy transforming mechanisms (via ATP, etc) (Westheimer, 1987). Since all living organisms require phosphorus and the element is present in seawater in low concentrations, it often sets an upper limit to the biomass of living organisms that can grow within a body of water. All dissolved phosphorus is present as inorganic phosphate in its various ionized forms, while in surface waters it is apparently combined with dissolved organic matter that may often exceed 50 % of the total.

Nitrogen. Nitrogen is biologically produced and consumed through nitrogen fixation reactions and de-nitrification respectively. As with phosphorus, nitrogen is an absolutely essential ingredient for all living organisms, and is required in amounts perhaps sixteen times greater than phosphorus (Downing, 1997). For most plants in the sea to access the nitrogen, it has to be converted to nitrates. Apart from nitrates, the remaining nitrogen exists as dissolved organic nitrogen. The multiple valence states of nitrogen in the oceans, and sinks of biologically active forms all contribute to the importance and the difficulty of studying this inert element.

2. Coastal zone

Coasts often change their shape and location in response to natural and human activities (Mukherjee, 1995). However, a general accepted definition is that it is a 20 km zone from the shoreline (Mukherjee, 1998). Approximately, 15 % of the world land areas are classified as coastal zones inhabited by around 50 – 70 % of the world population. Coastal zone contain extensive areas of rapid industrialization. Their specialized ecosystems are sources of a significant portion of global food production and this has generated enormous economic activities around them. Perhaps most importantly, the coastal areas having a great propensity of being affected by climatic changes represent an interesting case-study for accessing the global environment.

Along the coast, the breaking waves of the sea cause erosion on one hand, and on the other, sands are brought to the beach by tidal cycles. The degree to which a particular process controls coastal change depends on local factors like sediment deposition, river, topography, tectonic activity, composition of land, prevailing winds and weather patterns. The coastal crisis is worldwide.

Mukherjee (1991, 1998) stated that one of the major problems of the coastal zones was the pollution of coastal waters due to industrial waste, sewage, agricultural pesticide run off, oil spills, bile discharges and toxic contamination of living beings. Thus, this present work relates directly to the major problems of coastal water pollution.

3. Experimental

The data for the aforesaid eight parameters was obtained from the regional office of Central Pollution control board (CPCB), West Bengal. For "suspended solids", only data from 1992 – 1999 were available for both the rivers. The trends of "total phosphorus" and the "nitrate nitrogen" for River Saptamukhi were available only from 1992 – 1999. The yearly trend of the physico-chemical parameters of rivers Matla and Saptamukhi over a period of ten years has been graphed (Fig. 1) and its effects on environment during that period was rationalized.

The correlation between the eight parameters was computed in order to understand the degree of relationship between them. The formula for the correlation "r" is given by

$$r = \frac{1/n\,\Sigma(x - <x>)(y - <y>)}{\sqrt{1/n\,\Sigma(x - <x>)^2}.\sqrt{1/n\,\Sigma(y - <y>)^2}},$$

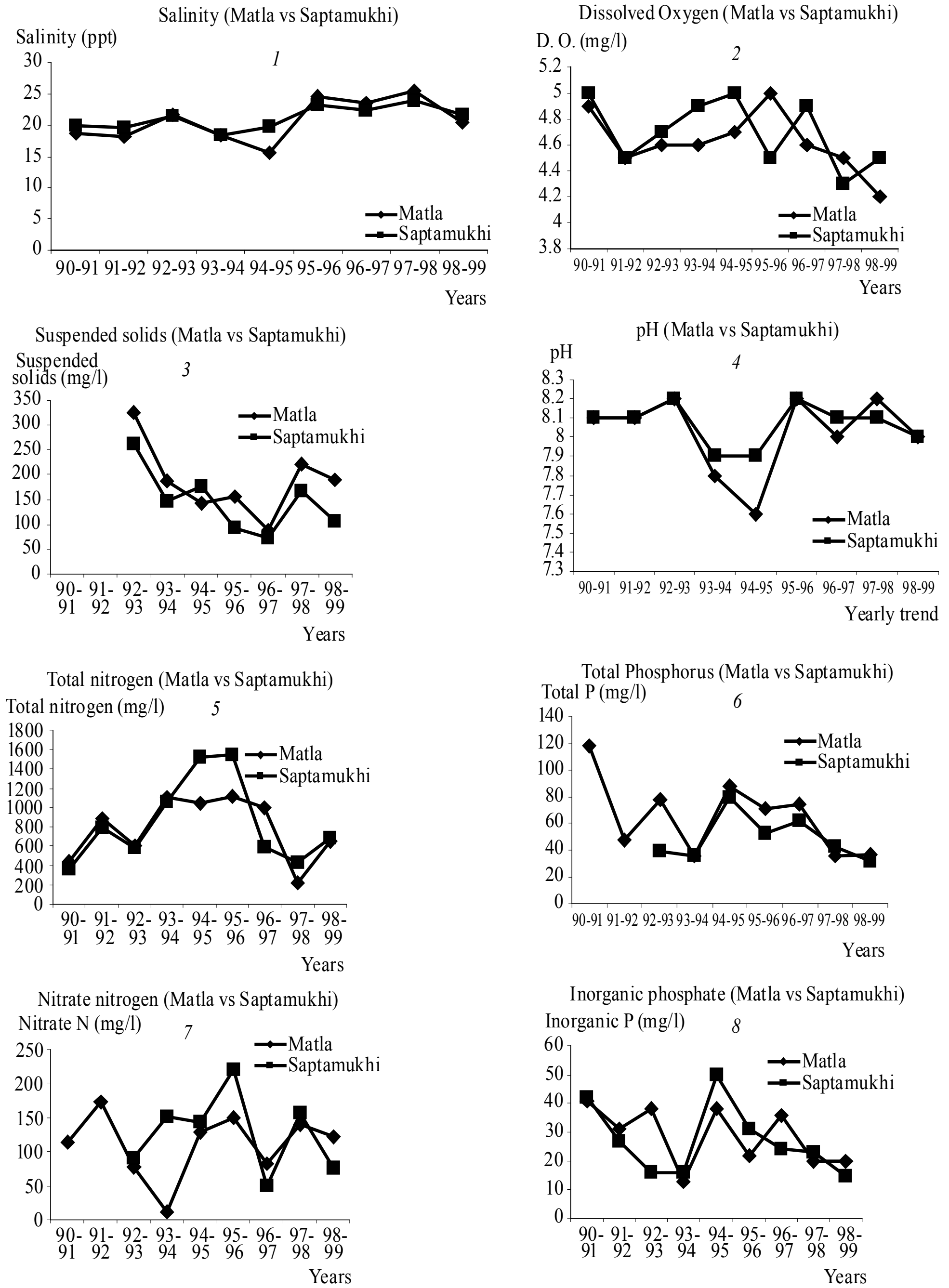
where x and y are the two parameters whose relation is under investigation. $<x>$ and $<y>$ is the average of parameter x and y compounded over ten years. Various correlation values, both positive and negative, were computed between each of the eight parameters. The correlation values between 0.0 and 0.5 were determined as "positive", while those between 0.5 and 0.1 were considered as "good positive" correlation values. Values between 0 and – 0.5 were considered as "negative", while those between – 0.5 and –1 as "good negative" correlation values. Finally, these correlation values between the parameters and their effects on the environment were rationalized on the basis of events that had transpired during those years.

4. Results and discussion

4.1. Yearly trend. Rivers Matla and Saptamukhi show variations in parameters over ten years (Fig. 1). There is a similarity in salinity in both the rivers. The sharp decrease in salinity in the year 1994 – 1995 might have resulted from the great flood in North Bengal in the year 1993 (EKA, 2003; Moore, 1997). This was possibly due to the huge influx of fresh water during the flood. From 1995 – 1998, the salinity was high and its highest point was in 1997 – 1998. Those years were amongst the hottest, while 1998' has been recorded as the hottest year during the last 100 years. Possibly due to high rates of evaporation in this year, salinity precipitation was at a maximum in both the rivers (Fig. 1.*1*).

Dissolved oxygen shows slightly opposite trend for both rivers in the years 1994 – 1997 (Fig. 1.*2*). In the year 1995 – 1996, Matla shows high D. O. concentration whereas Saptamukhi shows a low concentration. This implies that this was a localized phenomenon in Sunderban district as reflected from the location of Matla river flowing on the east of Binmari island while river Saptamukhi between Namkhana and Lothian islands. Decrease in D.O. concentration was possibly because of water discharge from Calcutta sewage into river Saptamukhi even after its en-route use in East Calcutta wetlands.

River Matla shows an abrupt decrease in suspended solid content in the year 1994 – 1995, and further decrease in 1996 – 1997 (Fig. 1.*3*). This was possibly the result of the July 1993 flood event. There appears to be a huge increase in suspended solid content in the years 1997 – 1998. This was possibly due to the storm surge impact which helped in concentrating the suspended solids.



*For "suspended solids", only data from 1992 – 99 were available. The trends of "Total Phosphorus" and the "Nitrate Nitrogen" for River Saptamukhi were available only from 1992 – 1999.

Fig. 1. Comparative study for rivers Matla and Saptamukhi of eight parameters; 1 – salinity, 2 – dissolved oxygen, 3 – suspended solids, 4 – pH, 5 – total nitrogen, 6 – total phosphorus, 7 – nitrate nitrogen, 8 – inorganic phosphate.

This storm surge was an occasional phenomenon in coastal areas that was responsible for mixing of waters and the water mass was observed to move towards the river thus increasing the suspended solid content in the river water. Saptamukhi river also shows its peak concentration of suspended solids in the year 1997 – 1998, but an abrupt lowering in the year 1996 – 1997. The rise was possibly due to severe impact of storm surge while the abrupt decrease was possibly due to flood which diluted the suspended solid concentration. However, it is noteworthy that the suspended solid content shows a good overall decrease since the flood in 1993.

River Matla shows a sharp decrease in the year 1994 – 1995, while the pH concentration for both the rivers is nearly the same for rest of the years (Fig. 1.*4*). Both the rivers remain alkaline throughout the duration of study. Both the rivers show maximum alkalinity in the years 1992 – 1993 and 1995 – 1996 (pH 8.2); while slightly lower pH range in the year 1994 – 1995. This alkaline nature of the river water was possibly due to excess run off from upstream sub-alkaline regions.

Total nitrogen involves both organic (ammoniacal) and inorganic (nitrate) nitrogen. Saptamukhi shows a very high total nitrogen concentration during 1994 – 1996 and a peak nitrate nitrogen (inorganic nitrogen) concentration in 1995 – 1996 whereas Matla shows a relatively low total concentration during the same period (Fig. 1.*5* and 1.*7*). This characteristic rise in nitrogen content in Saptamukhi in the years 1995 – 1996 possibly came about as a result of sewage output (this same factor caused a reduction in the dissolved oxygen content around the same period). This could also have been because of a possible agricultural wash. In the years 1997 – 1998, both the rivers show a high nitrate nitrogen concentration. This was probably because of the severe surge impact around this time which concentrated the inorganic nitrogen load (this same factor caused an increase in the suspended solid content in 1997 – 1998).

Matla has a greater concentration in Total phosphorus in the year 1992 – 1993 (Fig. 1.*6*). Overall, both the rivers show a marked increase of total phosphorus and inorganic phosphate concentration on going from 1993 – 1994 to 1994 – 1995. This peak was possibly observed after Barren Island Eruption (Laluraj et al., 2006). The release of phosphorus from volcanic eruption in Bay of Bengal was wind drifted to Sunderban district. This probably increased the phosphate concentrations in both the rivers during 1994 – 1995 (Fig. 1.*6* and 1.*8*).

4.2. Correlation between various parameters for river Matla.

4.2.1. Variation in salinity, suspended solids, pH, total nitrogen and dissolved oxygen. pH shows a high positive correlation with salinity and a positive correlation with suspended solids (Fig. 2, *a* and Fig. 3, *a*). Increase in salinity increases in Na^+ and K^+ ion thus leading to slightly more alkaline conditions. Increase in salinity on the other hand, helps in formation of colloidal suspension (by the "salting out" effect) which in turn increases the load of suspended solids. The rise in salinity and suspended solids could also be the synchronous result of severe surge impact. Total nitrogen shows a negative correlation with salinity, suspended solids and pH. These suspended solids were probably brought by industrial wastes and not domestic sewage, which contain less amount of total nitrogen. Increase in salinity decreases total nitrogen content. High salinity in river water forces the microbial organisms to consume more nutrients, resulting in the fall of total nitrogen content in water. Besides, acidic industrial wastes (nitrogenous compounds) caused the river water to be slightly less alkaline (decrease in pH) while increasing the total nitrogen concentration.

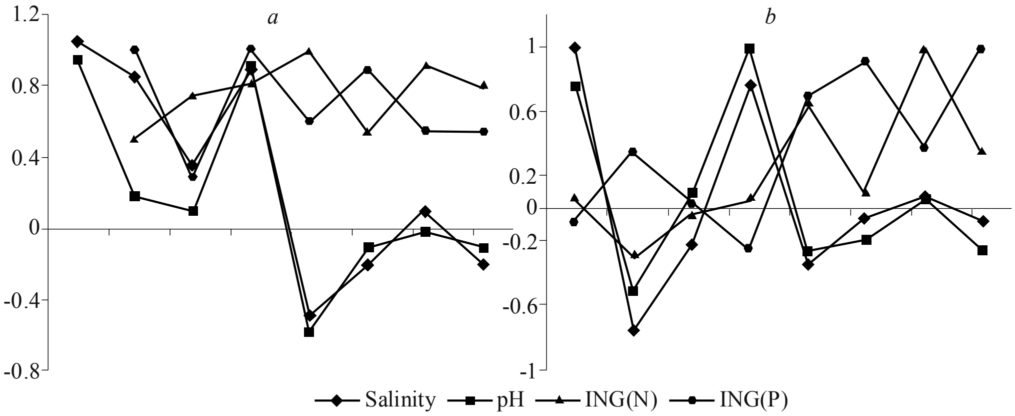


Fig. 2. Correlation plot of salinity, pH, nitrate nitrogen, and inorganic phosphate for rivers Matla (a) and Saptamukhi (b).

Suspended solids have a positive correlation with salinity and pH, and all these parameters have a negative correlation with dissolved oxygen. An increased concentration of suspended solids lead to loss of transparency in water thus inhibiting the photosynthetic activity; thereby resulting in the decline of dissolved oxygen content in water.

4.2.2. Variation in dissolved oxygen, nitrate nitrogen, total nitrogen, total phosphorus, and inorganic phosphate. Positive correlation exists between all the parameters (Fig. 2, *a* and Fig, 3, *a*). Loading of nitrogen and phosphorus in the coastal water augments photosynthesis, thereby increasing the release of oxygen in water. The special significance of this correlation lies in the fact, that there are higher chances of survival of aquatic life in river Matla as the organisms get sufficient amount of dissolved oxygen as well as nutrients for their survival (Fig. 1.*2* and 1.*7*).

4.3. Correlation between parameters for river Saptamukhi.

4.3.1. Variation in pH, salinity, inorganic phosphate, suspended solids, total nitrogen and total phosphorus. A highly positive correlation existing between pH and salinity (Fig. 2, *b*) for reasons discussed in Section 6.2. An acidic pH leads to a corresponding increase in the concentration of the phosphate ion and hence, inorganic phosphate maintains a negative correlation with salinity and pH. Rise in salinity in coastal water depresses the phosphate radical leading to depletion of inorganic phosphate and eventually, the coastal water becomes more acidic. Salinity has a positive correlation with the concentration of insoluble suspended solids as explained earlier. Suspended solids maintain a negative correlation with total nitrogen and total phosphorus (Fig. 3, *b*) which is clear by their inverse effects on the concentration of dissolved oxygen. The flood in river Saptamukhi causes further dilution of the suspended solids; thereby the element concentration gets even more diluted in coastal waters thus decreasing total nitrogen and phosphorus concentrations.

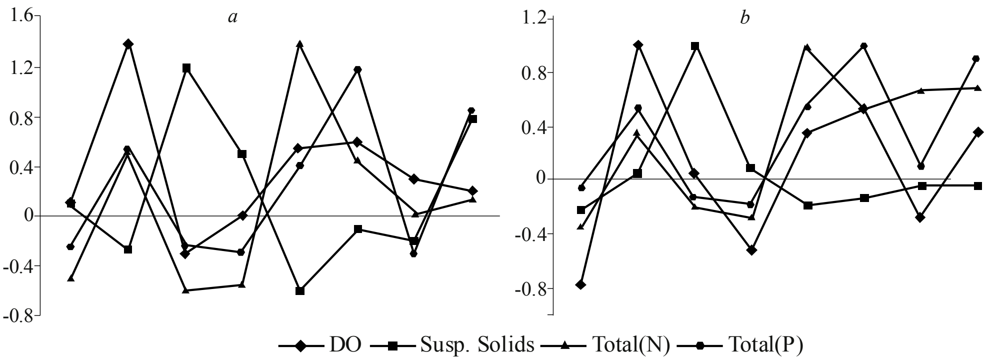


Fig. 3. Correlation plot for dissolved oxygen, suspended solids, total nitrogen and total phosphorus for rivers Matla (a) and Saptamukhi (b).

4.3.2. Variation in dissolved oxygen, total nitrogen, nitrate nitrogen, total phosphorus and salinity. Nitrate nitrogen and total nitrogen leads to a growth of phytoplanktons. This accentuates photosynthesis which releases oxygen, thus having a positive correlation with the dissolved oxygen in the case of river Matla. In the case of Saptamukhi, the dissolved oxygen maintains a positive correlation with total nitrogen and a high positive correlation with total phosphorus but has a slightly negative correlation with the nitrate nitrogen. This is because the average concentration of nitrogen in Saptamukhi is much higher than that in river Matla; and this might be because of the discharge of Calcutta sewage into river Saptamukhi. Because of the increased concentration of the nitrate nitrogen in river Saptamukhi, algal bloom takes place. The death of algae causes anoxic conditions, thereby resulting in decline of dissolved oxygen content.

Finally, the dissolved oxygen shows a high negative correlation with salinity for Saptamukhi. The flood and storm surge could be responsible for this. As a result of surgeimpact, there is a huge influx of fresh water and most of the brackish water gets diluted, causing a big drop in salinity. This turbulent mixing results in excessive dissolved oxygen production.

5. Conclusion

This study on physico-chemical parameters in rivers Matla and Saptamukhi has thrown light on coastal water pollution and its causes. Water quality and quantity have undergone major changes due to human activities (Goudie, 1990). We have shown both qualitatively and quantitatively, how natural and man-made causes can affect the coastal environment by documenting their effect on two neighboring rivers. Study of these parameters will further enhance understanding of the reasons behind coastal degradation. Following Clark (1991, *a, b*) some of the most common sources of pollution and their impacts are related to domestic sewage, eutrophication, agricultural waste, industrial wastes and oil spills. Domestic sewage may result in eutrophication by overloading the marine environment with nutrients further introducing pathogens and toxic matter. Eutrophication is caused by excessive nutrients from organic wastes and its harmful effects on river Saptamukhi have been shown. Dramatic enhancement of nuisance species like algae pollutes the coastal environment and other susceptible environments such as the coral reefs. Industrial wastes also contain a variety of toxic substances like Pb, Hg, Cu, Ni, radioactive elements, etc. Oil spills are becoming increasingly common with increase in sea traffic.

If the coastal water pollution gets aggravated, this will lead to coastal degradation and further result in a great loss of coastal resource generation. An appropriate abatement policy as a part of integrated management needs to be implemented. Finally, this research assumes great importance as the physico-chemical analysis of river waters performed will assist in sustainable development and disaster management of this vulnerable yet highly resourceful region.

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Резюме. Исследованы физико-химические параметры (pH, минерализация, растворенный кислород, взвешенные частицы, концентрации азота и фосфора (неорганического и общего) прибрежных вод соседствующих рек Матла и Саптамухи провинции Сандербан (Западный Бенгал). Показано распределение указанных параметров для этих двух рек в течение 10 лет (90-е годы). Проведен статистический анализ и установлена корреляция между параметрами на основе как природных, так и антропогенных воздействий за этот период. Изменения в качественном составе воды связаны с влиянием наводнений, штормов, эвтрофикации, коммунальных, сельскохозяйственных и промышленных сточных вод. Чтобы избежать ухудшения состояния прибрежных районов и сохранить природный баланс, очень важно понимать влияние указанных параметров на прибрежные зоны.

Резюме. Досліджено фізико-хімічні параметри (pH, мінералізація, розчинений кисень, зважені частинки, концентрації азоту і фосфору (неорганічного і загального)) прибережних вод сусідніх річок Матла і Саптамухі провінції Сандербан (Західний Бенгал). Показано розподіл зазначених параметрів для цих двох річок протягом 10 років (90-і роки). Проведено статистичний аналіз і встановлена кореляція між параметрами на основі як природних, так і антропогенних впливів за цей період. Зміни в якісному складі вод пов’язані з впливом повеней, штормів, евтрофікації, комунальних, сільськогосподарських та промислових стічних вод. Щоб уникнути погіршення стану прибережних районів і зберегти природний баланс, дуже важливо розуміти вплив цих параметрів на прибережні зони.

References

Clark J. R., 1991 (a). Carrying capacity defining the limits to tourism. Miller, N. and Auyong, J. (Eds) proceedings Proc. 1990. Congress on coastal and marine tourism, New Port, Oregon, P.117 – 131.

Clark J. R., 1991 (b). Carrying capacity – A status report on marine and coastal part and reserves. 3rd International seminar on coastal and marine parts and protected areas, Florida.

Goudie A., 1990. The human impact on the natural Environment, 3rd ed. Basil, Blackwell. 388 p.

Downing J. A., 1997. Marine nitrogen: Phosphorus stoichiometry and the global N: P cycle. Biogeochemistry, 37, P. 237 – 252.

< http://www.dartmouth.edu/~floods/Archives/1993sum.htm>

Laluraj C. M., *Balachandran K. K., Sabu P., Panampunnayil S. U.*, 2006. Persistent volcanic signature observed around Barren Island, Andaman Sea, India. Marine Geophysical Researches, 27(4), P.283 – 288.

Moore M., 1997. Monsoon Rains Leave Thousands Dead in India, Nepal and Bangladesh. The Washington Post, Washington, D.C.

Morgan J. P., *McIntyre W. G.*, 1959. Quaternary geology of the Bengal basin, East Pakistan and India, Bull. Geol. Soc. America, 70 (3), P.319 – 342.

Mukherjee A. D., 1991, 1998. Report of the project on study of coastal processes and their effects on environment in certain coastal sector of Sunderban.

Mukherjee A. D., 1995. Our coasts in crisis Banabithi, June month, P.9 – 11.

Niyogi D., 1975. Quaternary geology of the coastal plain in West Bengal and Orissa. Indian Journal of Earth Science, 2 (1), P.51 – 61.

Westheimer F.H., 1987. Why nature chose phosphates. Science, 235, P.1173 – 1178.