Uddin, M. M.; Chowdhury, S.R; . Zafar, M. and Nessa, M.U. 2007. Temporal and spatial variation of dissolved nutrients in the lower Meghna river estuary, Bangladesh. *Khulna University Studies*, 8(1): 117-124.

Khulna University Studies, 8(1): 117-124, 2007

RESEARCH ARTICLE LIFE SCIENCE

TEMPORAL AND SPATIAL VARIATION OF DISSOLVED NUTRIENTS IN THE LOWER MEGHNA RIVER ESTUARY, BANGLADESH

M. M. Uddin[1], S.R. Chowdhury[1], M. Zafar[1] and M.U. Nessa[2*]

[1]*Institute of Marine Sciences and Fisheries, University of Chittagong, Chittagong 4331,Bangladesh*
[2]*Environmental Science Discipline, Khulna University, Khulna 9208, Bangladesh*

KUS 07/09 - 140507
Manuscript received: May 14 2007; Accepted: June 30, 2007

Abstract: An investigation on variation (temporal and spatial) in the contents of some selected inorganic nutrients (nitrite, nitrate, ammonium, phosphate and silicate) was carried out in the lower Meghna river estuary, Bangladesh during September 2001 to May 2002 (covering an annual cycle). All the nutrients studied showed irregular pattern of temporal and spatial fluctuations where most of the nutrients showed peak values during premonsoon and trough values during monsoon. A decreasing trend in nutrient concentrations was observed towards the sea in all the seasons.

Key words: Temporal, spatial, variation, nutrient, Meghna estuary

Introduction

Coastal nations are concerned in management of their coastal resources and spaces. Successful history in the coastal management revealed that establishment of a better understanding on the characteristics of coastal zone with physico-chemical parameters, biogeochemical cycles, primary productivity etc. is essential. Therefore, much attention is being paid to understand the complexity of coastal zone specially the estuaries as an interacting subsystem within the land-ocean-atmosphere-biosphere system.

Bangladesh is a reverine country with more than seven hundred kilometers of coastline and thousands square kilometers of coastal space including several productive estuaries. Among those, the Meghna estuary is the most important one being the combined outlet of the three largest river systems (the Ganges, Brahmaputra and Meghna) of the country collecting water from a vast catchment area (about 1.758 million sq. km) of India, Bangladesh and Nepal (Rogers, 1989). The sediment discharge through the Meghna estuary is the highest, and the water discharge is the third highest among the river systems of the world (MoWR, 2001). Consequently, the estuary receives a huge amount of nutrients from the up streams and finally empties into the Bay of Bengal. The estuary is the ground of potential fisheries, and famous as a rich fishing area in the country which indicates rich nutrients abundance in the area. However, the estuary remains unexplored in respect of scientific investigation to understand its ecological dynamics and environmental condition.

[*] Corresponding author.: Tel: +88-041-720171-3/287; Fax: +88-041-731244; e-mail: <meher.nessa@yahoo.com>
DOI: https://doi.org/10.53808/KUS.2007.8.1.0709-L

Inorganic micronutrients play an important role in primary production as well as in the production of nectonic organisms in the food chain in an estuary. Lack of micronutrients may limit the primary productivity or access nutrients cause eutrophication and results degraded water quality (Selvam, 1992). The distribution and contribution of nutrients may be changed by physical processes such as lateral and vertical movement of water masses, diffusion between air and water, inflows and stratification of water column and nutrient rich wastes mixing from different sources. Therefore, as they changes, the availability of nutrients also changes, and affect the biological productivity in the estuary (Sousa *et al.*, 1981).

Information on nutrients of estuarine and river waters of Bangladesh are scanty. A few information on the hydro-metrological aspect of the coastal region of the Bay of Bengal are available (Lafund, 1958; Islam and Aziz, 1975; Ahmed, 1989; Zafar, 1992; Hossain, 1983; and Jashimuddin, 1993). Hossain (1983) and Jashimuddin (1993) worked on the water quality of the Karnafully river estuary. Hossain *et al*. (1988) investigated salinity, temperature, DO and some other water quality variables of the Karnafully river estuary. Mahmood *et al*. (1976) observed the hydrology of Karnafully estuary. Ali *et al*. (1985) studied the physio-chemical aspect of Moheshkhali channel. Most of these studies revealed that industrial effluent discharge, land drainage in monsoon, and direct contact of domestic sewage with the water body are deteriorating the river and estuarine water quality of Bangladesh. Zingde and Singbal (1985) studied the salinity, DO, pH, total alkalinity, CO_2, phosphate and nitrate of the coastal water of Bing Bay, India. Bhunia and Chowdhury (1981) observed the physical, chemical and biological parameters of the tidal creeks of Sagar Island, Sunderbans, India. Dutta *et al*. (1954) worked on Hoogly estuary and measured some water quality parameters.

The hydro-morphological dynamics of the Meghna river estuary was investigated by Bangladesh Water Development Board (MoWR, 2001), and limnology of the Meghna river by Rahman *et al*. (1992), which are the only information available on Meghna river. Noori (1999) investigated micronutrients and productivity in the southwest coast of Bangladesh and found that monsoon is the driving force of primary productivity in this region. During this period heavy rainfall and flood discharge carries enormous quantity of nutrients and suspended sediments to the shelf seas. Similar study was conducted by Chowdhury (1998) in the southeast coast of Cox's Bazar and found almost the same results. This paper reports the status of temporal and spatial variations of dissolved nutrients in the waters of the lower Meghna river estuary.

Materials and Methods

Five stations (Station-1 Chandpur, Station-2 Barisal, Station-3 Bhola, Station-4 Hatyia, and Station-5 Sandwip) ranging from an inland location at Chandpur to off shore coastal location at Sandwip Island were selected for water sampling covering a length of about 275 km (Fig. 1). The average depth of the estuary was 5-6 m. Water samples were drawn from surface and sub-surface water layers (about 3 meters depth) at each sampling location during pre-monsoon, monsoon and post-monsoon seasons maintaining a 4 months interval (September-January-May) between the seasons (Table 1). After collection, samples were immediately filtered through 4.7 cm Whatman GF/C filter using electrical suction apparatus; and transported to the laboratory of the Institute of

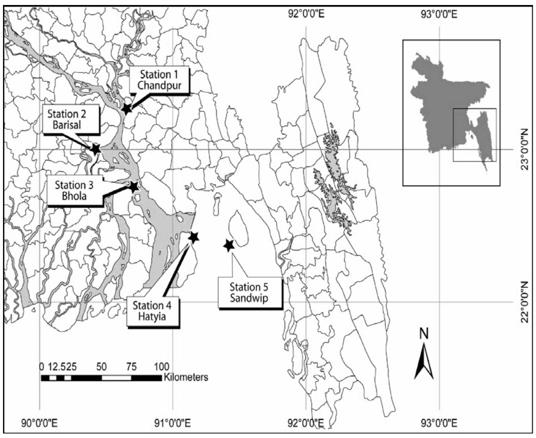

Fig. 1. Meghna river estuary showing the sampling locations.

Marine Sciences and Fisheries, Chittagong University. Frozen samples were brought to the room temperature and analyzed using standard operating procedures. Nitrate, nitrite and silicate were determined following Strickland and Parson (1972). Ammonium-nitrogen was estimated with modified Phenol-hypochlorite method (Jin-Eong *et al.*, 1985). A modified single solution method of Murphy and Riley (1961) was followed for the determination of total inorganic phosphate.

Table 1. Information of sampling in Meghna river estuary.

Sampling Stations	Geographical locations	Sampling season	Date of sampling	Time of sampling	Tidal condition	Air temp °C
1. Chadpur	23°13.77'N 90°38.58'E	Premonsoon	02/05/02	16:30	Low	33.3
		Monsoon	15/09/01	03:00	High	33.0
		Post monsoon	21/01/02	17:30	Low	28.0
2. Barisahal	22°41.96'N, 90°22.52'E	Premonsoon	03/05/02	09:35	Low	35.0
		Monsoon	14/09/01	11:00	High	27.2
		Post monsoon	22/01/02	12:30	Low	29.0
3. Bhola	22°37.15'N, 90°44.56'E	Premonsoon	04/05/02	14:50	Low	28.0
		Monsoon	14/09/01	14:30	Low	25.7
		Post monsoon	23/01/02	15:52	High	23.0
4. Hatiya	22°24.46'N, 91°07.01'E	Premonsoon	04/05/02	09:45	High	30.0
		Monsoon	13/09/01	22:00	High	32.0
		Post monsoon	23/01/02	11:20	High	28.0
5. Sandwip	22°29.32'N, 91°25.67'E	Premonsoon	04/05/02	14:10	High	31.0
		Monsoon	13/09/01	15:45	Low	26.0
		Post monsoon	23/01/02	15:12	Low	25.0

Results

The values of five inorganic micro-nutrients estimated from surface and subsurface water at five selected stations are presented in Fig. 2 and the average (surface and subsurface water) values are presented in Table 2. Temporal and spatial variations in nitrite, nitrate, ammonium, phosphate and silicate concentrations from all the stations for the surface and subsurface waters are also depicted in Fig. 2.

Nitrate-nitrogen (NO_3-N): Present study recorded nitrate-nitrogen to be the most abundant in all the stations amongst all the three forms of nitrogen studied (Fig. 2). However, the variation of nitrate-nitrogen found throughout the investigation period was irregular. The highest value (24.252 μg^{-1}) was found at station 1 during premonsoon while the lowest (2.442 μg^{-1}) was at station 2 and 3 during postmonsoon. The findings also showed a trend of decreasing in concentration towards the sea (Fig. 2).

Nitrite-nitrogen (NO_2-N): The higher values of nitrite-nitrogen were observed during premonsoon at stations 1, and 2 (Table 2) and postmonsoon at station 4, and were found decreasing seawards (Fig. 2). The values during monsoon were recorded comparatively lower. Throughout the study period, the concentrations varied between 0.069 and 1.23 μg^{-1}.

Ammonium-nitrogen (NH_4-N): Maximum value of ammonium (2.81 μg^{-1}) was found at station 4 during postmonsoon while the minimum (0.026 μg^{-1}) was recorded at station 2 during monsoon (Fig. 2). The variation in concentrations was irregular amongst the seasons and the sampling stations as well although, concentrations during premonsoon and postmonsoon showed similarity in values.

Phosphate-phosphorus (PO_4-P): The phosphate concentrations were found very high (66.36 to 91.32 μg^{-1}) during premonsoon, inconsistent (7.41 to 69.36 μg^{-1}) during monsoon and stable (14.66 to 22.11 μg^{-1}) during postmonsoon season (Table 2). The concentrations varied irregularly both at surface and sub-surface level (Fig. 2) showing higher values during premonsoon followed by the monsoon.

Silicate-silicon (SiO_3-Si): Silicate concentrations varied from 0.974 to 53.183 μg^{-1} and the highest concentration was found at station 1 during monsoon. However, on average, the premonsoon period showed higher values of silicate concentration followed by the monsoon period (Table 2). No remarkable variation in surface and sub-surface was observed except a trend of lower concentration towards the sea (Fig. 2).

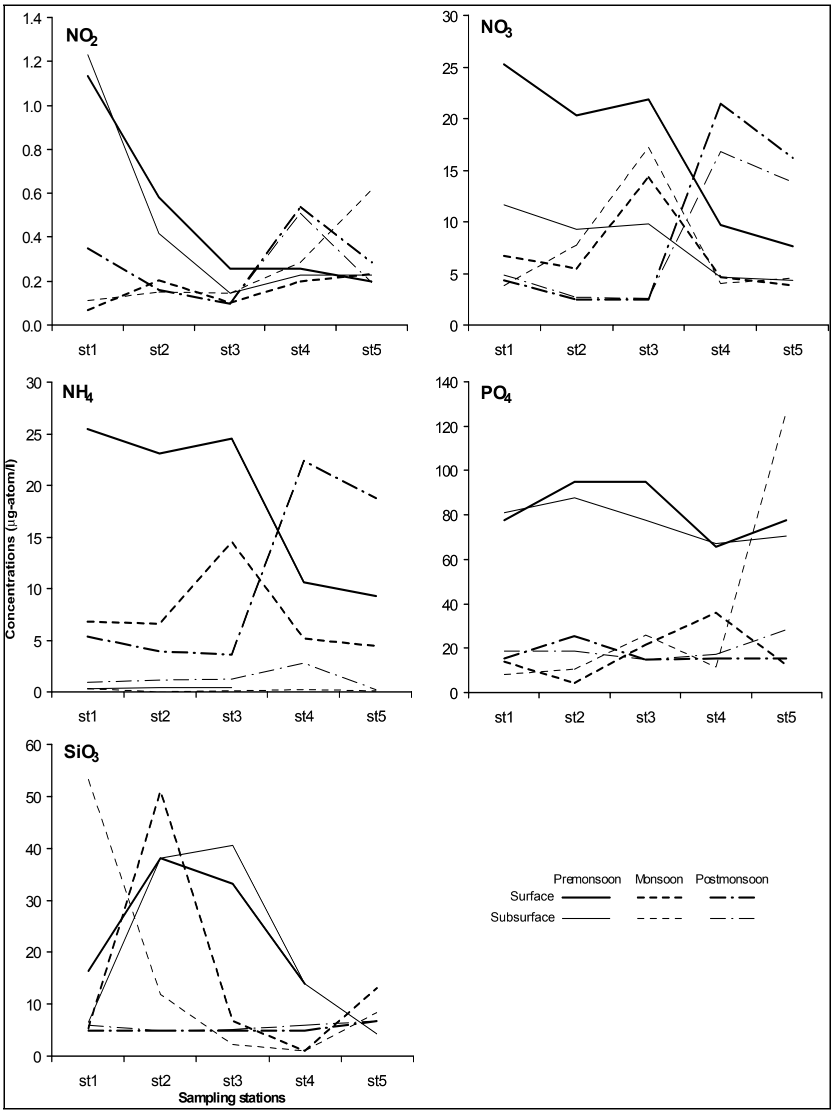

Fig. 2. Temporal and spatial variation in NO_2, NO_3, NH_4, PO_4 and SiO_3 (as μg^{-1}) in surface and subsurface waters in different sampling locations (st1 to st5).

Table 2. Average values of nutrients (as μg^{-1}) in surface and subsurface water of Meghna river estuary.

Stations	Premonsoon					Monsoon					Postmonsoon				
	NO_2	NO_3	NH_4	PO_4	SiO_3	NO_2	NO_3	NH_4	PO_4	SiO_3	NO_2	NO_3	NH_4	PO_4	SiO_3
1.Chandpur	1.182	17.938	0.162	79.272	11.456	0.089	5.243	0.198	10.896	29.222	0.349	4.541	0.810	17.027	5.435
2. Barisal	0.499	14.781	1.340	91.321	38.047	0.178	6.602	0.512	7.407	31.441	0.160	2.541	1.241	22.102	4.967
3. Bhola	0.201	15.863	1.438	86.157	36.838	0.124	15.756	0.102	23.734	4.505	0.097	2.518	1.124	14.660	5.061
4. Hatyia	0.241	7.159	0.653	66.362	13.873	0.243	4.330	0.216	23.734	1.049	0.522	19.147	1.605	16.181	5.435
5.Sandwip	0.214	5.986	2.027	74.108	4.204	0.424	4.165	0.263	69.359	10.760	0.239	15.009	0.921	21.764	6.838

Discussion

The cause of higher abundance of nitrate-nitrogen in all the stations and amongst the other three forms of nitrogen studied could be due to the fact that nitrate is thermodynamically the most stable oxidized form of nitrogen in presence of oxygen and could accumulate if left unutilized (Segar and Heriharan, 1989). The highest value was found at station 1 during the premonsoon perhaps for being located near to the catchment area and also due to higher rate of precipitation. Sarma *et al.* (1982), Nair *et al.* (1984), and Tripathi and Pandy (1990) recorded higher values during monsoon. Jashimuddin (1993) also reported similar results (higher values during monsoon) in the Karnafully river estuary. The results of the present investigation (in case of seasonal variation in concentrations) showed dissimilarity with these records. However, the trend of decreasing concentration towards the sea was harmonious with the findings of Noori (1999) in southwest coast, Rashid (1999) in the Bakkhali river estuary and Chowdhury (1998) in the Cox's Bazar coastal region of Bangladesh.

The lower amounts of nitrite-nitrogen observed in the monsoon could be due to the heavy rainfall and drainage of fresh water. Due to the inverse reasons, the amounts were comparatively higher in the premonsoon followed by the postmonsoon concentrations. The range of concentrations found throughout the study period were found almost similar with those of Selvam (1992) in the coastal water of Kakinda coast, Andrapradesh; Laksmanan *et al.* (1987) in Coachin back waters, south coast of India; Segar and Heriharan (1989) in the surface water of Bangalore coast and Reddy (1977) in the same area. Findings of Noori (1999) in the estuarine station of Karnafully river and Chowdhury (1998) in the southwest coast of Cox's Bazar, Bangladesh showed records of nitrite similar to the present results.

Maximum values of ammonium during the postmonsoon period could be due to the large volume of industrial effluent and rich organic matters coming with the fluvial water laden with sediment which produced ammonium by bacterial action. On the contrary, lower concentrations of ammonium recorded during the monsoon could be due to the heavy rainfall and large volume of water inflow. Hossain (1983) and Jashimuddin (1993) detected ammonium concentration from the Karnafully river close to the present records. They also revealed that the concentration varied with the amount of sewage, garbage and industrial effluents dumped to the river water. Sarma *et al.* (1982) and Verlenger (1987) studied the distribution of nutrients and reported that the industrial effluents and municipal waste materials were responsible for higher concentration of ammonium in the estuarine and harbor water of India.

The higher values of phosphate recorded in the present study indicate the huge receiving of drainage water from the paddy fields and also suspended organic matter with the wastes. According to Zarnova (1962) and Varadochar *et al.* (1969) the higher phosphate content may be due to oxidative regeneration of the suspended organic matter. Bhouyan (1979) and Paul (1981) reported that PO_4-P content came to the Karnafully river from the industrial outlets. Welch (1952), Hutchinsin (1957), Edmonson (1972), and Bolus and Lund (1974) reported that increase of PO_4-P largely results from sewage contamination. However, in the present study, the higher concentrations found during the premonsoon disagree with the results of Gonzalves and Joshi (1945), Zafar (1986), and Tripathi and Pandy (1990) who recorded higher amounts of phosphate during the postmonsoon.

River discharge is the chief source of silicate in the estuary and removal processes are done by biological utilization and abiological adsorption to the suspended sediments (Liss and Spencer, 1970; Bein *et al.*, 1958). The variation in silicate concentration observed in the present study indicates large river discharge in this estuary during the monsoon. Sousa *et al.* (1981) reported its range between 11.2 and 130.6 μg^{-1} in the estuarine zone, southwest coast of India. Pandy *et al.* (1989) reported surface silicate concentration between 16.02 and 126.63 μg^{-1} from the Chilka Lake, East coast of India. According to Sesamal *et al.* (1986) the concentration ranged from 6.4 to 48.9 μg^{-1} in the South Orissa coast of India. Verlencar and Shargalkar (1992) also reported almost the same values for the silicate from the South Indian coast. The present values of silicate concentrations agree more or less with the above records.

Conclusion

As for influx of higher volume of water through the estuary during the monsoon inorganic nutrients were more diluted and consequently showed lower concentrations than the premonsoon followed by the postmonsoon periods. Higher values during the premonsoon were due to higher evaporation and lower drainage of fresh water. The results of the present investigation suggest the need for a long-period monitoring for better understanding of nutrient dynamics in the Meghna river estuary. It is expected that the output of this investigation will be very useful to future workers for drawing a tangible conclusion on estuarine nutrient dynamics.

Acknowledgements: The authors are highly grateful to APN (Asia Pacific Network for Global Change), Dhaka, Bangladesh for financing this research project and to Late Dr. Nuruddin Mahmood, Project Director and Professor, Institute of Marine Sciences and Fisheries (IMSF), Chittagong University, Chittagong, Bangladesh for his excellent cooperation during the period. The authors are also grateful to the IMSF for providing laboratory facilities.

References

Ahmed, H.R. 1989. *Oceanography of the near shore waters off Chittagong with some notes on productivity*. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, 149 pp.

Ali, S.; Saha, S. and Mahmood, N. 1985. Studies on the physical and chemical aspects of Moheshkhali channel, Bay of Bengal. *Dhaka University Studies*, (B): 43-49.

Bein, G.S.; Cantoss, D.E. and Thomas, W.H. 1958. Geochemistry and Cosmos Chemistry. *Acta,* Vol. 14.

Bhouyan, A.M. 1979. Effect of industrial pollution on the biology of the Karnafully river. M.Phill Thesis, Department of Zoology, University of Chittagong, Bangladesh.

Bhunia, A.B. and Chowdhury, A. 1981. Observation of hydrology and quantitative studies on benthic macrofauna in a tidal creek of Sagar Island, Sunderban, West Bengal, India. *Proceedings, Indian National Academy of Sciences,* 5(2).

Bolus, P.M. and Lund, J.W.C. 1974. Some factors affecting the growth of *Cladophora glomerata* in Kintisch stout. *Water Treat Exam*, 23: 25-51.

Chowdhury, M.Z.R. 1998. Study on micronutrients and standing crop of phytoplankton in the coastal waters of Cox's Bazar, Chittagong, Bangladesh. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, 98 pp.

Dutta, N.; Malhorta, I.C. and Bose, B.B. 1954. Hydrology and seasonal fluctuation of the plankton in the Hoogly estuary. In: Proceedings, Indo Pacific Fish Count, Bangkok, pp. 48-54.

Edmonson, W.T. 1972. Nutrients and phytoplankton in the lake Washington. *Journal of Limonlogy and Oceanography,* 1: 172-193.

Gonzalves, E.A. and Joshi, S. 1945. Fresh water algae near Bombay. 1. The seasonal succession of the algae in a tank of Bunbra. *Journal of Bombay National Historical Society,* Vol. 46.

Hossain, M.M. 1983. *Pollution as revealed by macrobenthic organisms in the Karnafully River estuary*. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, 115 pp.

Hossain, M.M.; Mahmood, N. and Bhouyan, A.M. 1988. Some water quality characteristics of the Karnafully river estuary. *Mahasagar*, 21(3): 183-188.

Hutchinsin, G.E. 1957. *A treatise of Limnology,* Vol. 1. John Wily and Sons. Inc. New York.

Islam, A.K.M.N. and Aziz, A. 1975. Study on the marine phytoplankton from the North Eastern Bay of Bengal. *Bangladesh Journal of Botany,* (1-2): 1-32.

Jashimuddin, S.M. 1993. *Environmental Impact Assessment of the municipal sewage discharge through Majhirghat canal on the Karnafully river waters, Chittagong*. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, 76 pp.

Jin-Eong, O.; Wooi-Khoon, G.; Chee-Hoong, W. and Din, Z.B.H. 1985. *Productivity of the Mangrove Ecosystem: A Manual of Methods.* Mangrove Ecosystem Research Group, Universiti Sains Malaysia, 117 pp.

Lafund, E.C. 1958. Seasonal cycle of sea surface temperature and salinities along the east coast of India. *University Memograph in Oceanography,* 49(2): 12-21.

Lakshmanan, C.; Ramamirtham, C.P. and Jayaraman, L. 1987. Seasonal variation of nutrients in Cochin backs water. *Indian Journal of Marine Science,* 20(1): 406-412.

Liss, P.S. and Spencer, C.P. 1970. Geochemistry and cosmos chemistry, *Acta*, 34: 1073

Mahmood, N.; Khan, Y.S.A. and Kabir, A. 1976. Studies on the hydrology of the Karnafully estuary. *Journal of Asiatic Society of Bangladesh (Sc.)*, 2(1): 69-99.

MoWR. 2001. Hydro-morphological dynamics of the Meghna estuary. In: *Meghna Estuary Study*, Vol. I and II. Report prepared by the Department of GIS, Government of Netherlands and Ministry of Water Resources (MoWR), Government of Bangladesh.

Murphy, J. and Riley, J.P. 1961. A modified single solution method for the determination of phosphate in natural waters. Analytical Chemistry*, Acta,* 27(1): 31-36.

Nair, N.B.; Aziz, R.V.A.; Arunachal, M.; Dharmaraj, K. and Kumar, K. 1984. Ecology of Indian estuaries: Ecology and distribution of benthic macrofauna in the Ashtamudi estuary, Kerala. *Mahasagar,* 16(3): 409-414.

Noori, M.N. 1999. *An investigation on seasonal variation of micronutrients and standing crop of Phytoplankton in neritic waters of the southeast coast of Bangladesh*. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, 91 pp.

Pandy, D.; Tripathy, S.K.; Patniak, D.K.; Chowdhury, S.R.; Gouda, R. and Panigraphy, R.C. 1989. Distribution of nutrients in Chilka Lake, eastcoast of India. *Indian Journal of Marine Science,* Vol. 18.

Paul, S. 1981. *Effect of oil pollution upon planktonic organisms of the Karnafully river estuary*. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, 81 pp.

Rahman, M.A.; Mowla, G.; Rahman, M.J. and Mazid, M.A. 1992. Limnology of the River Meghna: I. Physico-chemical characteristics and plankton population study. *Bangladesh Journal of Zoology,* 7: 43-50.

Rashid, M.M. 1999. *Study on the water quality and commercial ichthyofauna of the Bakkhali river estuary*. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, 89 pp.

Reddy, N.A.N. 1977. *Studies on the effect of marine pollution with reference to a few marine organisms*. M.Sc. Thesis, University of Agricultural Science, Bangalore, 197 pp.

Rogers, P. 1989. *Eastern water study: Strategies to manage flood and drought in the Ganges-Brahmaputra basin.* Report submitted to the USAID, Dhaka.

Segar, K. and Hariharan, V. 1989. Seasonal distribution of of nitrate, nitrate, ammonia and plankton in effluent discharge area of Mangalore, West coast of India. *Indian Journal of Marine Science,* 18: 170-173.

Selvam, V. 1992. Diurnal variation in physical, chemical properties and primary production in the interconnected marine, mangrove and fresh water biotopes of Kakinada. *Journal of Hydrobiologia,* 247: 181-186.

Sarma, V.V.; Raju, G.R.K. and Babu, P. 1982. Pollution characteristics in the Visakhapatnam harbour. *Mahasagar*, 15(1): 15-22.

Sesamal, S.K.; Sahu, B.K. and Panigrathy, R.C. 1986. Monthly variations in some chemical parameters of near shore waters along the south Orissa coast, *Indian Journal of Marine Science,* 15: 199-200.

Sousa, S.N.D.; Naqvi, S.W. and Reddy, C.V.G. 1981. Distribution of Nutrients in the western Bay of Bengal. *Indian Journal of Marine Science,* 10: 327-331.

Strickland, J.H. and Parson, T.R. 1972. *A Practical Handbook of Seawater Analysis.* Second edn., Fisheries Research Board of Canada, pp.167-310.

Tripathi, A.K. and Pandy, S.N. 1990. *Water Pollution*. Asish Publishing House. New Delhi.

Varadochar, V.V.R.; Murry, C.S. and Reddy, C.V.G. 1969. Salinity maxima associated with some surface water masses in the upper layers of the Bay Bengal. *Mahasagar,* 38: 338-443.

Verlencar, A.C. and Shargalkar, E.A. 1992. Seasonal variation of nutrient in the south coast of India. *Indian Journal of Marine Science,* 9: 318-321.

Verlenger, X.N. 1987. Distribution of nutrients in the coastal and estuarine water of Goa. *Mahasagar*, 20(49): 205-215.

Welch, P.S. 1952. *Limnology.* Second edn., McGraw Hill, New York.

Zafar, M. 1986. *Study on zooplankton of satkhira in the vicinity of aquaculture farms with spcial reference to penaeid post larvae*. M.Sc. Thesis, Institute of Marine Sciences and Fisheries, University of Chittagong, Bangladesh, 238 pp.

Zafar, M. 1992. *Study on hydro-biological aspects of the south-eastern part of Bangladesh coastal waters in the Bay of Bengal.* M.Sc. Thesis, Fame Free University, Brussels, VUB, 258 pp.

Zarnova, V.V. 1962. Quantitative distribution of the Phytoplankton in the Northern Indian Ocean. Truddy Institue of Oceangraphy. *Oceanography,* 58: 45-53.

Zingde, M.D. and Singbal, S.Y.S. 1985. Characteristics of nearshore water in Bing Bay, Karwar, India. *Mahasagar*, 16(4): 423-428.