



Seasonal Variations in Water Quality of the Ganges and Brahmaputra River, Bangladesh

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Abstract

The Ganges and Brahmaputra rivers in Bangladesh play a fundamental role in local society, as a source of irrigation and drinking water, and as a sink for wastewater. In order to characterize the seasonal variability of surface water quality in these two rivers and its confluence, a Water Quality Index (WQI) was calculated from ten physicochemical parameters, periodically measured at three sampling sites round a year. The results indicated a relatively good water quality in the pre-monsoon and the seasonal order of pollution magnitude is monsoon>post-monsoon>pre-monsoon. Water quality conditions were critical during the monsoon, mainly due to the effects of the terrestrial runoff as well as wastewater of densely populated catchments.

Keywords: *Water quality, monsoon, rivers, Bangladesh*

Introduction

River basin has been a major source of water supply for many purposes and provides fertile lands, which support the development of highly populated residential areas due to its favorable conditions (Mouri et al., 2011). Rivers constitute the main inland water body for domestic, industrial, and agricultural activities and often carry large municipal sewage, industrial wastewater discharges, and seasonal runoff from an agricultural field (Singh et al., 2004; Pradhan et al., 2009). Surface water has played an important role in the development of human civilization. Good water quality resources depends on a large number of physicochemical parameters and the magnitude and source of any pollution load; and to assess that, monitoring of these parameters is essential (Reddi et al., 1993). The population explosion and increasing demands have exerted extra pressure on natural water resources like rivers and lakes. The changed physicochemical characteristics of water have serious repercussions on aquaculture, fisheries and agricultural production (Singh et al., 2002).

Assessment of water resource quality of any region is an important aspect of developmental activities, because rivers, lakes and manmade reservoirs are used for water supply to domestic, industrial, agricultural and fish culture (Jackher and Rawat, 2003). Chemical composition of water is a function of hydrogeochemical processes acting in a given environment, thus, monitoring of water quality parameters provide important information for water management (Matthieu et al., 2005; USEPA, 1983). Water, the most important natural resource in the world, has the unique property of dissolving and carrying in suspension a huge variety of chemicals and hence water can easily become contaminated. About one third of the drinking water requirement of the world is obtained from surface sources like rivers, dams, lakes and canals (Jonnalagada and

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Mhere, 2001). But, these sources serve as best sinks for the discharge of domestic as well as industrial waste water (Das and Achary, 2003; Tukura et al., 2009).

Although several reports on the assessment of water quality based on physicochemical and trace metals distributions in the Ganges and Brahmaputra River have been published by several workers (Datta and Subramanian, 1998; Islam et al., 2012; Singh et al. 2012) very little information is available about the overall status of water quality and seasonal variations in the Ganges and Brahmaputra River passing from Bangladesh. With this background, an investigation was initiated, whose primary objective was to examine the current status of selected physicochemical characteristics of the Ganges and Brahmaputra river water and variations of water quality in various season using modified Water Quality Index (WQI). The physicochemical parameters were also compared with the water quality standards in order to justify/quantify the present water quality condition of these two major rivers. The present baseline information of the physicochemical properties of river water would be a useful tool for further ecological assessment and monitoring of the river quality.

Materials and Methods

Study Area

The Ganges-Brahmaputra-Meghna (GBM) delta system is one of the geochemically youngest and tectonically active river basins in the world (Coleman, 1969) and this two major rivers the Ganges and Brahmaputra contribute huge amount of water to their downstream where the density of population ranges from 400 to over 1200 people/km² (Milliman et al., 1989). Bangladesh has a tropical monsoon climate characterized by heavy seasonal rainfall, high temperatures, and high humidity. About 80 percent of Bangladesh's rain falls during the monsoon season (during June to August). This huge population community depends on the water of the Ganges and Brahmaputra River for such diverse purposes as domestic and industrial supply, crops irrigation, transport, recreation, and fisheries. The sampling locations were selected based on our previous work (Islam et al., 2012) for monitoring of water quality and seasonal variation in selected physicochemical characteristics of the Ganges and Brahmaputra River and its confluence.

Sampling

Water samples were collected from three sites namely Aricha Ghat, (23°8'79"N and 89°77'96"E, Brahmaputra River), Paturia ferry ghat (23°78'47" N and 89°80'64" E) and Daulatdia Ghat (23°77'54"N & 89° 78'73" E, Ganges River) throughout the year (Fig.1). Surface water samples were collected from 15-30 cm below the river water surface and at distances of 40 -80 cm from the bank of the river in labeled sample bottles that were washed with conc. HNO₃ and rinsed repeatedly with distilled water. Before the sample collection, sample bottles were rinsed three times also with the river water.

Analysis

Physicochemical parameters of river water were measured in-situ at a monthly frequency. Hydrogen ion concentration (pH), Dissolve Oxygen (DO), Total Dissolve Solid (TDS), Redox potential (Rh), and temperature of river water were determined by using a calibrated digital multi-meter (HACH, 51910) and a thermometer (SH-135), respectively.

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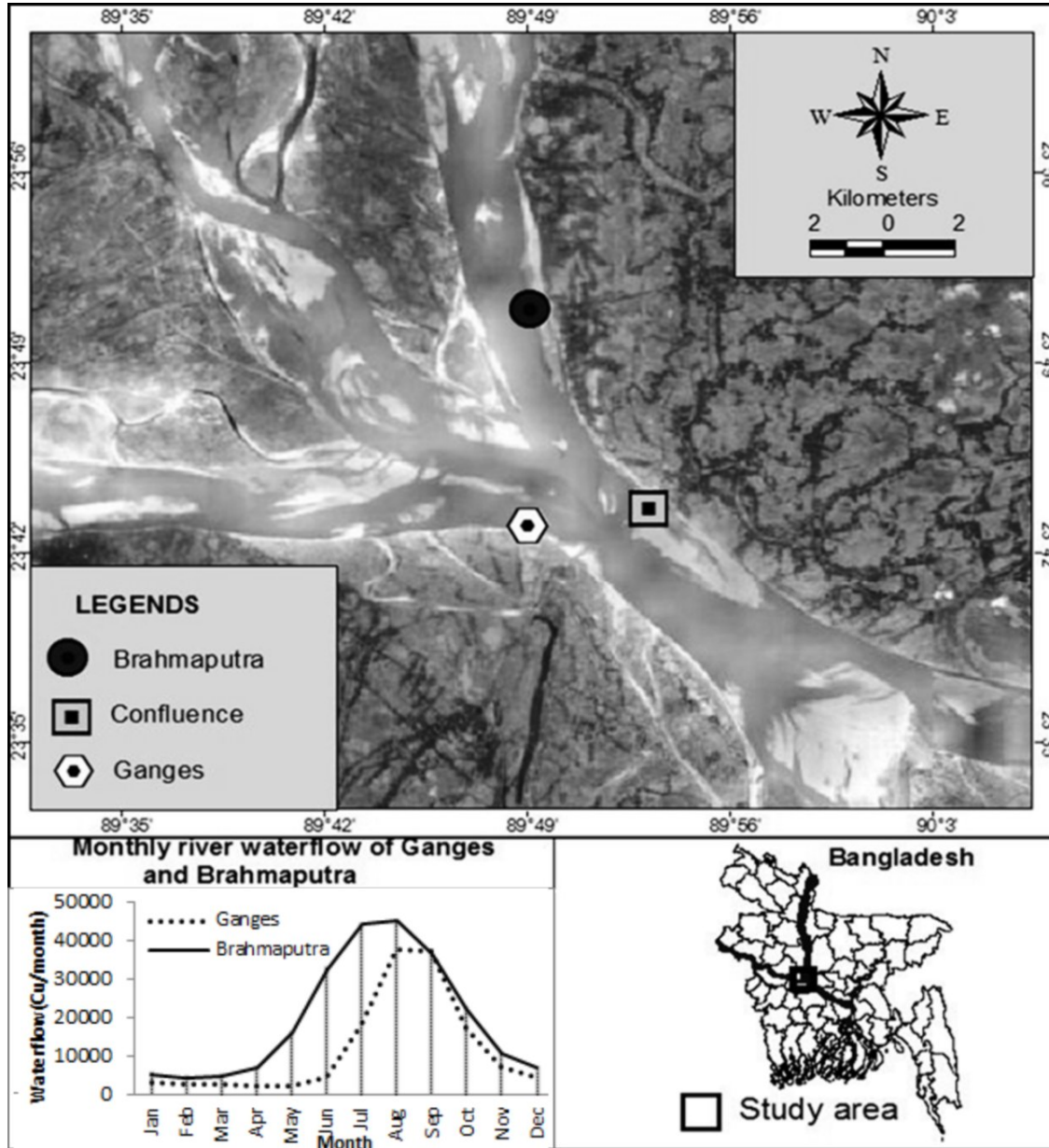


Figure 1. Maps showing three sampling locations in the Rivers Ganges, Brahmaputra and their confluence and average variations in water flow of the Ganges and Brahmaputra River. River discharge data obtained from Bangladesh Water Development Board.

Conductivity was measured at 25 °C in $\mu\text{S}/\text{cm}$, using an electric conductivity meter (HANNA, HI 8033). Turbidity of water was measured by using turbidity meter (HANNA, HI 93703). Biological Oxygen Demand (BOD) was done by 5-days incubation, 20°C method (APHA 1995), COD measured by closed reflux colorimetric method, Colorimeter (HACH, DR/890), Total coliform was measured by MPN - Most Probable Number method in the laboratory.

Results and Discussion

Variation in Physicochemical Parameters

The pH of the Ganges, Brahmaputra and confluence were ranged from 8.43 to 7.39, 8.36 to 6.8 and 8.55 to 7.51 with the average values of $7.87 \pm .31$, $7.66 \pm .4$ and $7.84 \pm .31$, respectively. The maximum values of pH were recorded during summer at all the sites; this may be due to the receipt of sewage/terrestrial runoff from nearby villages containing more carbonates and bicarbonates. The average values (Figure 2) showed that water was slightly alkaline and it was very useful for fresh water organism. Fluctuations in pH values during different season of the year were attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of waste with fresh water, reduction in salinity and temperature, and decomposition of organic matter (Rajasegar, 2003). The pH values of all the samples were within the pH range assigned by WHO as the standard for drinking water (6.5 - 8.5; WHO, 1984).

Electric conductivity of the Ganges, Brahmaputra and confluence were varied between 471 to 195, 237 to 120 and 222 to 120 $\mu\text{S}/\text{cm}$ with the average values were of 286 ± 68 , 168 ± 39 and 169 ± 36 $\mu\text{S}/\text{cm}$, respectively. High values were recorded during summer might be due to increased concentration of dissolved solids, relatively high flow of water, increased evaporation and input sewage. The values obtained in this study are within the recommended DoE standard of Bangladesh (GoB, ECR, 1997). The Redox potential is used to express the tendency of an environment to receive or supply electrons. The maximum Rh values of the Ganges, Brahmaputra and confluence were -28.6 mV, -20.0 mV & -23.4 mV with the average values were of -49 ± 16.74 mV, $-50. \pm 17.58$ mV and -54 ± 20.19 mV. Redox potentials in natural waters range from about -400 mV to +800 mV at pH 7 to 8. The values obtained in this study are within the recommended DoE standard of Bangladesh (GoB, ECR, 1997).

TDS values of the Ganges, Brahmaputra and confluence were varied from 376 to 102 mg/L, 245 to 62 mg/L and 231 to 61 mg/L with the average values of 260, 155 and 155 mg/L, respectively. TDS concentrations of the study areas were below the WHO (2004) maximum allowable limit (500 mg/L) as well as DoE standard of Bangladesh (1000 mg/L). The TDS mainly indicates the presence of various kinds of minerals like ammonia, nitrite, nitrate, phosphate, alkalis, some acids, sulphates and metallic ions etc which are comprised both colloidal and dissolved solids in water.

DO of the Ganges, Brahmaputra and confluence were ranged from 10.17 to 6.4 mg/L, 9.85 to 6.7 mg/L and 10.27 to 6.55 mg/L with the average values of 7.65 ± 1.14 mg/L, 7.52 ± 1.05 mg/L and 7.71 ± 1.17 mg/L, respectively, which were excellent for fresh water. According to the environmental quality standard (EQS), the following requirements for DO are prescribed: 6 mg/L for drinking, 4 to 5 mg/L for recreation, 4 to 6 mg/L for fish and livestock and 5 mg/L for

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industrial application. Dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. Oxygen is the single most important gas for most aquatic organisms; free oxygen (O₂) or DO is needed for respiration. DO levels below 1 mg/L will not support fish; levels of 5 to 6 mg/L are usually required for most of the fish population. The average value of DO levels indicates the average quality of river water (APHA, 2005). Figure3. showed that the highest DO values in winter and lowest values in summer season and it varied with the monsoon.

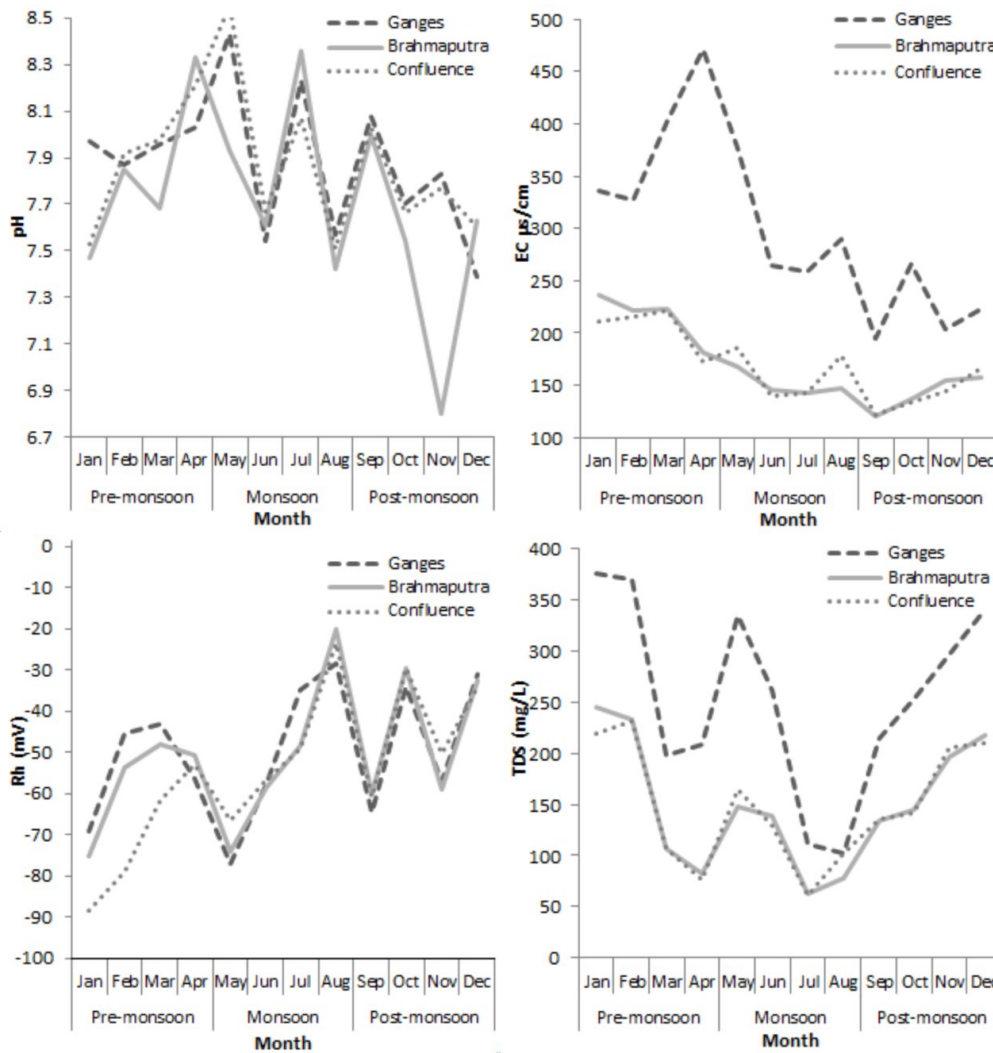


Figure 2. Seasonal variation of pH, redox potential (Rh), electric conductivity (EC, $\mu\text{S}/\text{cm}$), and total dissolve solid (mg/L) in the Ganges, Brahmaputra and confluence.

Turbidity values of the Ganges, Brahmaputra and confluence were ranged from 169.4 to 15.96, 168.92 to 10.82 and 152.48 to 8.37 FTU with the average values of 82.78 ± 55.61 FTU, 64.40 ± 57.71 & 76.39 ± 57.9 FTU. The values obtained in this study exceeded recommended DoE standard of Bangladesh (10 FTU). Turbidity in water is caused by suspended and colloidal matter such as clay, silts, finely divided organic and inorganic matter, plankton and other microscopic organisms. Higher turbidity in September can be caused by high turbulence of river water due to monsoon precipitations and human activity like cutting trees and removing vegetation. Vegetation helped to block mud and soil from washing into the water. Lower turbidity value might be due to the calm nature of river water and low evaporation rate in winter. The highest values of turbidity were observed in monsoon, due to high flow of monsoon precipitation from the river catchments.

BOD values of the Ganges, Brahmaputra and confluence were ranged from 4.53 to 1.10, 4.60 to 0.66 and 4.30 to 0.55 mg/L with the average values of 2.6 ± 1.13 mg/L, 2.63 ± 1.23 mg/L and $2.63 \pm .96$ mg/L. The permissible limit for BOD for drinking water is 0.2 mg/L, for recreation 3 mg/L, for fish 6 mg/L and 10 mg/L for irrigation (GoB, ECR, 1997). The BOD values obtained in the present study indicated that river water is suitable for fish culture and irrigation activities and not suitable for drinking purpose. These BOD values also indicate very low level of organic pollution. When BOD levels are high, dissolved oxygen (DO) levels decrease because the oxygen that is available in the water is being consumed by the bacteria (Sawyer et al., 2003) in the water. Fish and other aquatic organisms face difficulty at low DO level in aquatic environments. COD of the Ganges, Brahmaputra and confluence were varied from 103 to 15, 75 to 16, 102 to 13 mg/L with the average values of 51 ± 24.56 mg/L, 41 ± 18.33 mg/L and 43 ± 24.16 mg/L, respectively. The COD of the water samples of the study areas were exceeded the drinking water quality standards since the permissible limit of COD for drinking water is 4 mg/L (DoE/BEMP, 2003). The positive correlation between COD and BOD of these three sampling location throughout the year indicated that sources of organic material in river water are similar in nature.

Total coliform is indicator for pathogenic organisms. They are usually present in surface water, soil, and feces of humans and animals. Analytical result showed that the total coliform of the Ganges, Brahmaputra and confluence were varied from 1520 to 320, 1720 to 260 and 1880 to 210 CFU/mL with the average values of 928 ± 389 CFU/mL, 1046 ± 510 CFU/mL and 1015 ± 525 CFU/mL (Figure 4). The average values of total coliform exceed the limit of surface water quality standards (GoB, ECR, 1997). Summer maxima might be due to discharging of domestic wastes containing fecal matters to the river body and open defecation along the sides of river bank. Minimum values of total coliform during winter might be due to cold climatic condition, which is not been supportive for bacterial duplication in a greater extent.

Variation in Water Quality Index (WQI)

Water quality index (WQI) is a dimensionless number that combines multiple water quality parameters into a single number by normalizing values to subjective rating curves (Miller et al., 1986). Conventionally it has been used for evaluating the quality of water for water resources such as rivers, streams and lakes.

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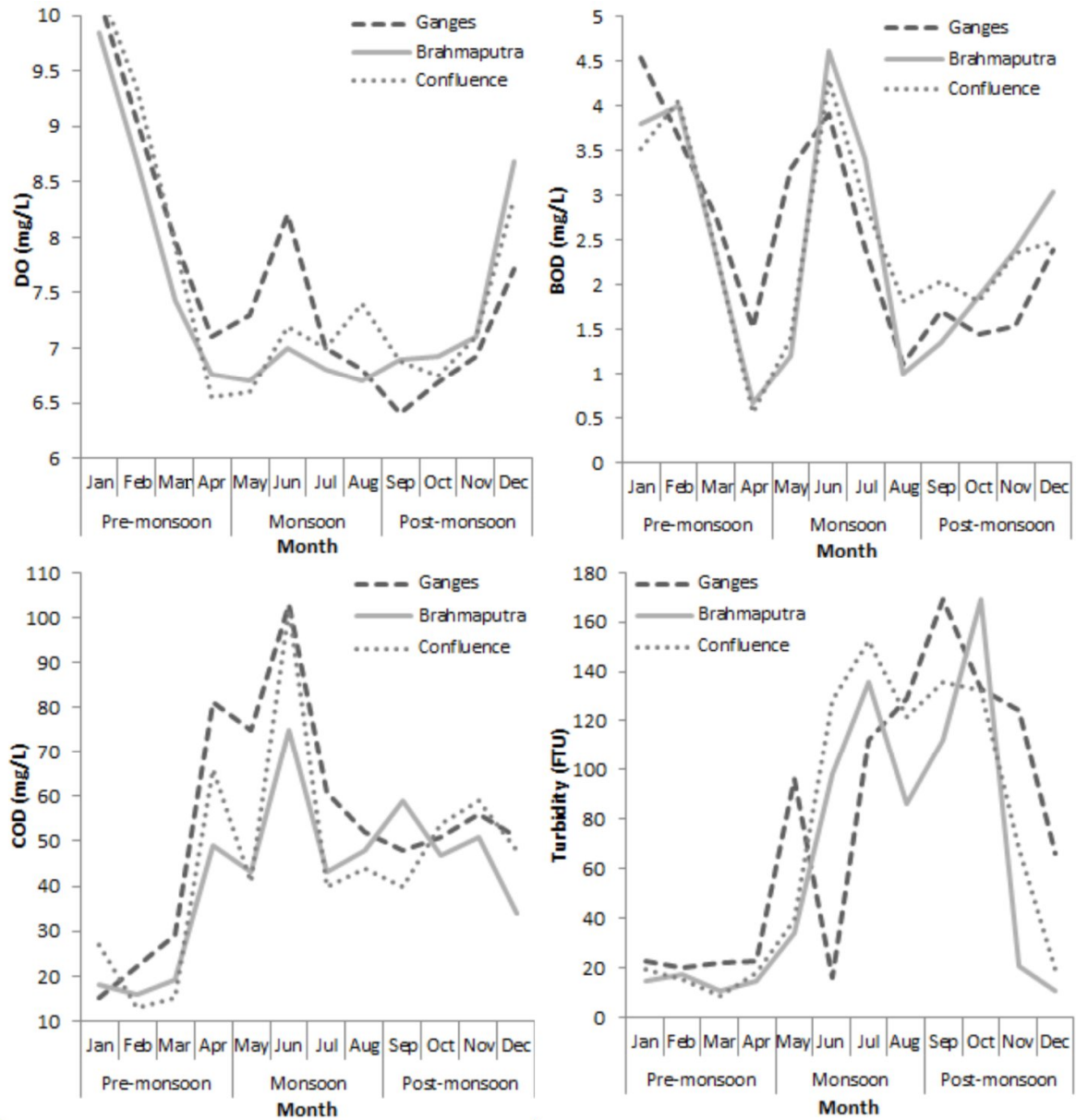


Figure 3. Seasonal variation of dissolved oxygen (DO), biological oxygen demand (BOD), Chemical oxygen demand (COD) and turbidity in the Ganges, Brahmaputra and confluence.

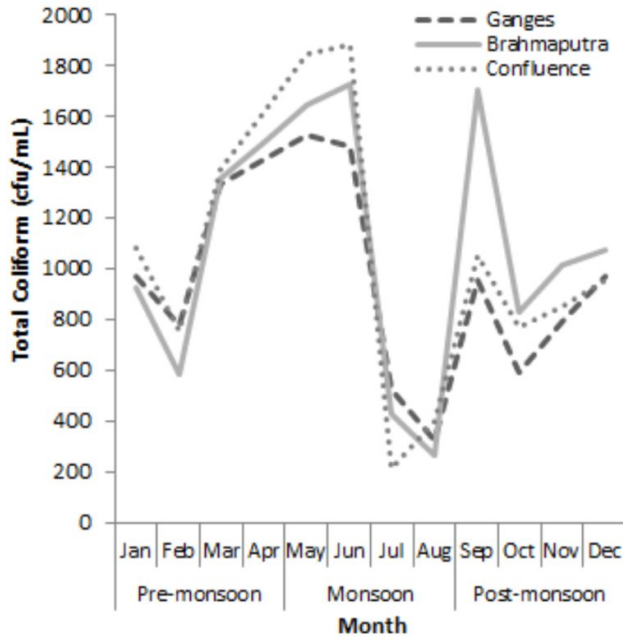


Figure 4. Seasonal variation of total coliform in the Ganges, Brahmaputra and confluence.

Parameters included in WQI vary depending upon the designated water uses of the water body and local preferences. Some of the physicochemical parameters include temperature, DO, pH, EC, TDS, Turbidity, Rh, BOD, COD and total coliform bacteria. These parameters are measured in different ranges and expressed in different units. The WQI takes the complex scientific information of these variables and synthesizes into a single number. Several researchers have worked on the this concepts and presented examples with case scenarios in the literature (Bolton et al. 1978; Bhargave, 1983; House, 1989; Mitchell and Stapp, 1996; Pesce and Winderlin, 2000; Cude, 2001; Liou et al. 2004; Said et al. 2004; Nasiri et al., 2007, NSF, 2007). Lal, 2011 reviewed and summarized most of the WQI and presented a case scenario for different WQI models using an example dataset.

The present study proposed a simple modified WQI considering local environments and hydrology of the Ganges and Brahmaputra River for drinking and irrigation purposes according the following equation.

$$WQI = \sum_{1}^{n} \frac{x_1 + x_2 + \dots + x_n}{n}$$

Where, n= total number of parameters, x = ratio of experimental value and maximum permissible limit of each parameter measured. A water quality index is a mean to summarize large amounts of water quality data into simple terms for reporting to management and the public in a consistent manner. It can tell us whether the overall quality of water bodies possess a potential threat to

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various uses of water, such as habitat for aquatic life, irrigation water for agriculture and livestock, recreation and aesthetics, and drinking water supplies. WQI is a single value indicator to the water pollution. It integrates the data pool generated after collecting due weights to the different parameters. The WQI values greater than one (>1) indicated polluted water whereas WQI value less than one (<1) indicated unpolluted water. The present study calculated WQI values of the Ganges, Brahmaputra and confluence of these two rivers based on weights of different parameters and maximum permissible limit of each parameter as listed in the Table1.

Table1: Different parameters used in WQI calculation and its maximum permissible limit

	DO (mg/l)	pH	EC (μ S/cm)	TDS (mg/l)	Turbidity (FTU)	Rh (mV)	Temp ($^{\circ}$ C)	BOD (mg/l)	COD (mg/l)	T C (CFU/ml)
Drinking Standard	6	7.5	700	1000	10	200	25	0.2	4	50
Irrigation Standard	5	7.5	700	1000	35	200	25	10	6	1000

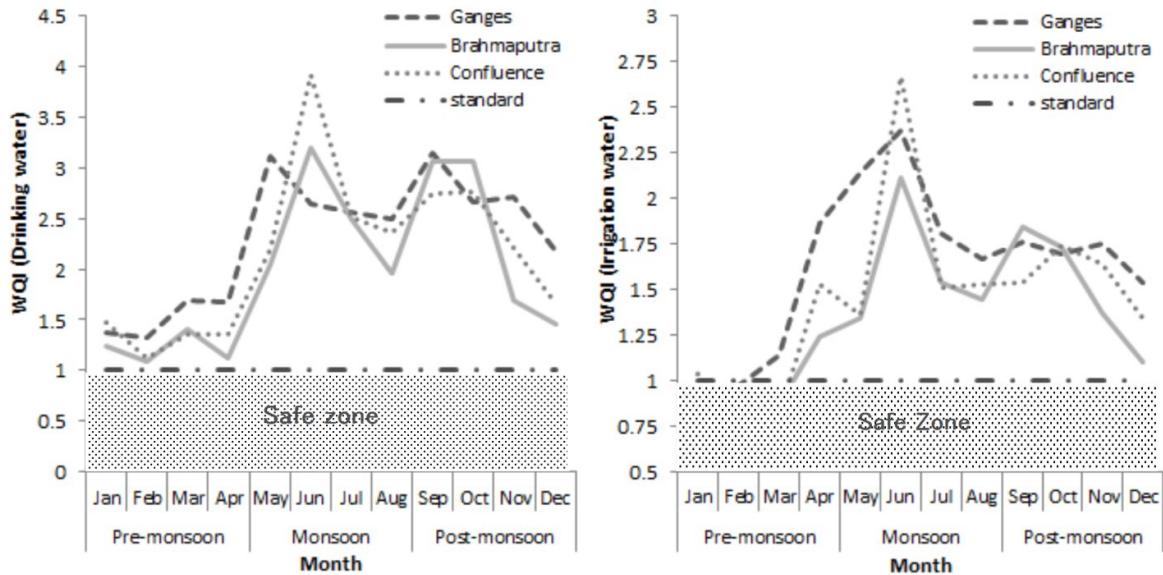


Figure 5. Seasonal variation of water quality index (WQI) in the Ganges, Brahmaputra and confluence

Seasonal variation in WQI of the Ganges, Brahmaputra and Confluence of these two rivers for drinking and irrigation water are shown in Fig.5. The variations of WQI showed similar distribution pattern with the river water discharges. The Ganges and Brahmaputra as well as its confluence were highly polluted during monsoon. River pollution strongly correlated to season of the study areas, especially monsoon. The seasonal order of pollution magnitude is monsoon>post-

monsoon>pre-monsoon. The water quality was degraded in monsoon due to huge catchment precipitation runoff into these rivers. The water quality index also indicates that the Ganges and Brahmaputra river water was suitable for fisheries, recreational, industrial and navigation purposes but not suitable for drinking purposes.

Conclusion

It has been found in the present study that the surface water of the Ganges, Brahmaputra and confluence of these two rivers in Bangladesh are polluted to some extent. Analytical result of the physicochemical analysis indicated that the pH, DO, EC, TDS, Rh within the permissible limits specified by National Guidelines and Standards for Water Qualities while BOD, COD, turbidity and total coliform were exceeded the specified permissible limits; DoE standard of Bangladesh (GoB, ECR, 1997) and WHO guidelines (2004). WQI calculated in this present study reveals an integrated scenario of water pollution the Ganges and Brahmaputra River in Bangladesh and also indicated that surface water is suitable for fisheries, recreational, industrial and navigation purposes but not suitable for drinking purposes. So, proper care should be taken to treat the surface water before use for drinking purposes. Proper care, maintenance, treatment, and disposal of sewage water and sludge are vital in this regard. Therefore, the river water should be subjected to suitable chemical or biological treatments especially for keeping different water quality parameters within the prescribed safe levels. The advantages of WQI include its ability to represent measurements of a variety of variables in a single number, its ability to combine various measurements in a variety of different measurement units in a single metric and its effectiveness as a communication tool.

Acknowledgement: We are grateful to the Ministry of Science and Technology, GoB for financial support of this study.

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