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Seasonal variation of physicochemical and toxic properties in three major rivers; Shitalakhya, Buriganga and Turag around Dhaka city, Bangladesh

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Key words: Seasonal variation, Water pollution, Heavy metal, WQI, Dhaka city.

Abstract

The indiscriminate dumping and release of wastes containing hazardous substances into rivers might lead to environmental disturbance which could be considered as a potential source of stress to biotic community. The purpose of this study was to investigate the seasonal variation in physicochemical and toxic metal concentrations of Shitalakhya, Buriganga and Turag river around Dhaka city as different kinds of industries dispose their waste into rivers. The results envisaged the, deteriorate of water quality with significant seasonal changes. In order to characterize the seasonal variability of surface water quality in these three rivers, Water Quality Index (WQI) was calculated from 14 parameters, periodically measured at three sampling sites of each river round a year. The results indicated a relatively good water quality was found in monsoon and the seasonal order of pollution magnitude is post-monsoon>pre-monsoon>monsoon. Water quality conditions were critical during post-monsoon, due to increase of anthropogenic interferences, low rainfall and river flow.

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Introduction

Water is undoubtedly the most precious natural resource that exists on the planet. It is the most valuable and vital resource for sustenance of life and also for any developmental activity (Kumar *et al.*, 2010). Bangladesh is a lowlying flat country with big inland water bodies, including some of the biggest rivers in the world and is extremely vulnerable because of its geographical characteristics (Matin and Kamal, 2010). Besides, increasing urbanization and industrialization of Bangladesh have negative implications for water quality where the industrial effluents directly discharge into the rivers without any consideration of the environment (BCAS, 2000). Surface water of Bangladesh is polluted in various ways such as; industrial wastes, agricultural inputs including fertilizers and pesticides, sewage slugs and domestic wastes etc. (De, 2005; Dara, 2006). This polluted water cannot be used for drinking, domestic and agricultural purposes because it has inherent health risk (Goel, 2006).

Dhaka is one of the most densely populated cities in the world, surrounded by number of rivers such as; the Buriganga, Turag, Shitalakhya, Balu, Bongshi, Karnatali etc. (GOB, 1997). But, most of them are biologically dead or about to die (Karn and Harada, 2001; Bangladesh River System, 2004).Huge quantities of industrial effluents, solid waste from river-side settlements, petroleum products from ships, launches, cargoes, boats, untreated sewage etc. regularly get dumped into these rivers (Khan *et al.*, 2007). The major polluting industries are tanneries, textiles, dying, pulp and paper and steel re-rolling mills, which are located besides the Buriganga, Turag and Shitalakshya rivers (Ahmed, 1985). These industries are discharging heavy metals like; Fe, Zn, Pb, Al, Co, Mo, Cd, Ni, Cr, As and Hg and some acids and solvents like; sulfuric acid, hydrochloric acid, Carboxilic acids, Phenol, Organic acids etc. (Ahmed and Reazuddin, 2000). The surface water along these peripheral rivers of Dhaka city is also known to be highly polluted due to municipal waste waters that are discharged into these rivers (Kamal *et al.*, 1999; Karn and Harada, 2001). Both organic and inorganic waste effluents adversely interact with the river system and deteriorating the water quality of these rivers. For this reason, water causes the adverse effect on surrounding land and aquatic ecosystem as well as subsequent impact on the livelihood of the local community (Rahman *et al.*, 2012; Meghla*et al.*, 2013). So a continuous monitoring of water quality is very essential to determine the state of pollution.

This information is important to be communicated to the general public and the Government in order to develop policies for the conservation of the precious fresh water resources (Ali *et al.*, 2000). Moreover, assessment of water quality of any region is an important aspect of developmental activities, as rivers are used for water supply to domestic, industrial, agricultural purposes (Jackher and Rawat, 2003). Keeping all this aspect in mind, the present study was designed to investigate seasonal variation of water quality, which could adversely affect the plants and animals, including aquatic habitat in this major rivers of Dhaka city.

Materials and methods

Sample collection

Water samples were collected from three locations of each river based on industrial density at their banks in three distinct seasons; pre-monsoon (March-May), Monsoon (June-August) and post-monsoon (December-February) in the year of 2014-2015. Sample location of Shitalakhaya, Burigangaand Turag rivers are shown in Fig. 1.

Geographical location of each sampling point was determined by GARMIN handheld global positioning system (GPS). During sampling, sample bottles were rinsed with river water to be sampled three times. Water samples were collected from two different layer 0-10 cm (Upper) and >3 m (Lower) below the river water surface and tries to avoided bubble formation and addition of suspended particles as possible. All the sampling were properly labeled and carried out using disposable hand gloves with proper care and stored in ice box. Samples were preserved in two methods, one for normal non-metallic and other for metallic analysis which was preserved by adding very few drops of concentrated $HNCO_3$ as reported by (Chapman, 1996).

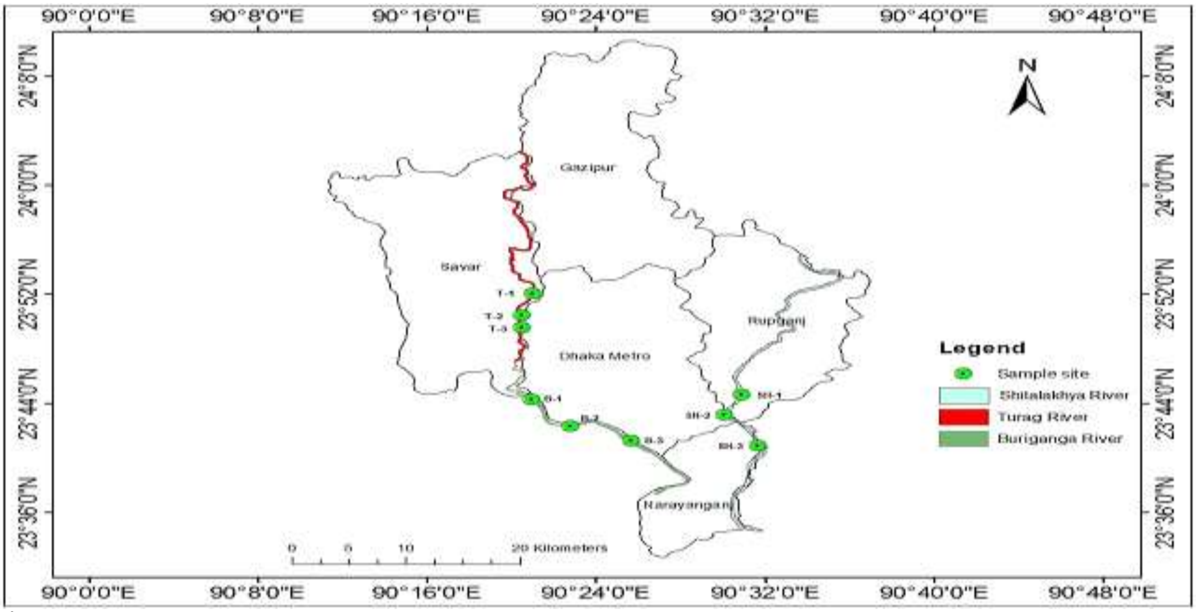


Fig. 1. Maps showing sampling point in the Shitalakhya, Buriganga and Turag River.

Laboratory analysis

Physicochemical parameters (pH, DO, TDS) of river water were measured on spot by using calibrated digital multimeter (HACH, 51910). Electric conductance (EC) was measured at 25 °C in µS/cm, using an electric conductivity meter (HANNA, HI 8033).Biological Oxygen Demand (BOD) was done by 5-days incubation, 20°C method (APHA,2005) and COD measured by closed reflux colorimetric method using Colorimeter (HACH, DR/890).Concentration of heavy metals such as; Fe, Zn, Cu, Ni, Al, Pb, Cr and Hg were estimated by using Atomic Absorption Spectrophotometer (AAS UNICAM 969) following the method of Clesceri *et al.* (1989).

Data processing tools

Arc.GIS (Version 10.1) has been used for mapping and showing sample locations. Water samples data were analyzed and presentusing the software MS Excel (2007).

Results and discussion

Variation in physicochemical parameters

pH

Aquatic organisms are affected by pH because most of their metabolic activities are dependent on it. pH of an aquatic system is an important indicator of the water quality and the extent pollution in the watershed areas (Kumar *et al.*, 2011). The average values of the pH of Shitalakshya, Buriganga and Turag river in three distinct seasons are 7.01, 6.08, 7.22 (pre-monsoon); 7.25, 7.18, 7.28 (monsoon) and 6.7, 4.05, 5.86 (post-monsoon) respectively. Optimal range of pH for sustainable aquatic life is 6.5-8 (ECR, 1997) and result showed that, pH values are within the permissible limit in pre-monsoon and monsoon period except Buriganga river. Fig. 2A shows, among all three rivers, pH values of Burigangais lowest and maximum values of pH were recorded during monsoon and minimum in post-monsoon seems to be due to greater input of waste from different type of industries. Fluctuations in pH values during different season of the yearwere also attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of waste with fresh water, reduction of temperature, and decomposition oforganic matter (Rajasegar, 2003).

Electrical conductivity (EC)

Conductivity itself is not a human or aquatic health concern, but it can serve as an indicator of other water quality problems. High values of EC show that a large amount of ionic substances are present in water (Kabir *et al*., 2002). Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials (Abida, 2008). The Seasonal averages of EC for Shitalakshya, Buriganga and Turag river in three distinct seasons are 1176 µS/cm,687.7 µS/cm,488.75 µS/cm (pre-monsoon); 986µS/cm, 555.3 µS/cm, 354.5 µS/cm (monsoon) and 2321 µS/cm, 853.25 µS/cm, 477.2 µS/cm (post-monsoon) respectively. Seasonal variations showed higher value of EC in post-monsoon and lower value in monsoon due to dilution with rain water. Among all three rivers, an EC value of Shitalakhya river is much higher and lowest in Turag river (Fig. 2B).The acceptable range of EC for recreational water is 500 µS/cm, irrigation is 750 µS/cm and aquaculture is 800-1000 µS/cm (ADB, 1994). From the study, the measured EC of Turag river was below than acceptable range.

Table 1. Different parameters used in WQI calculation and its maximum permissible limit.

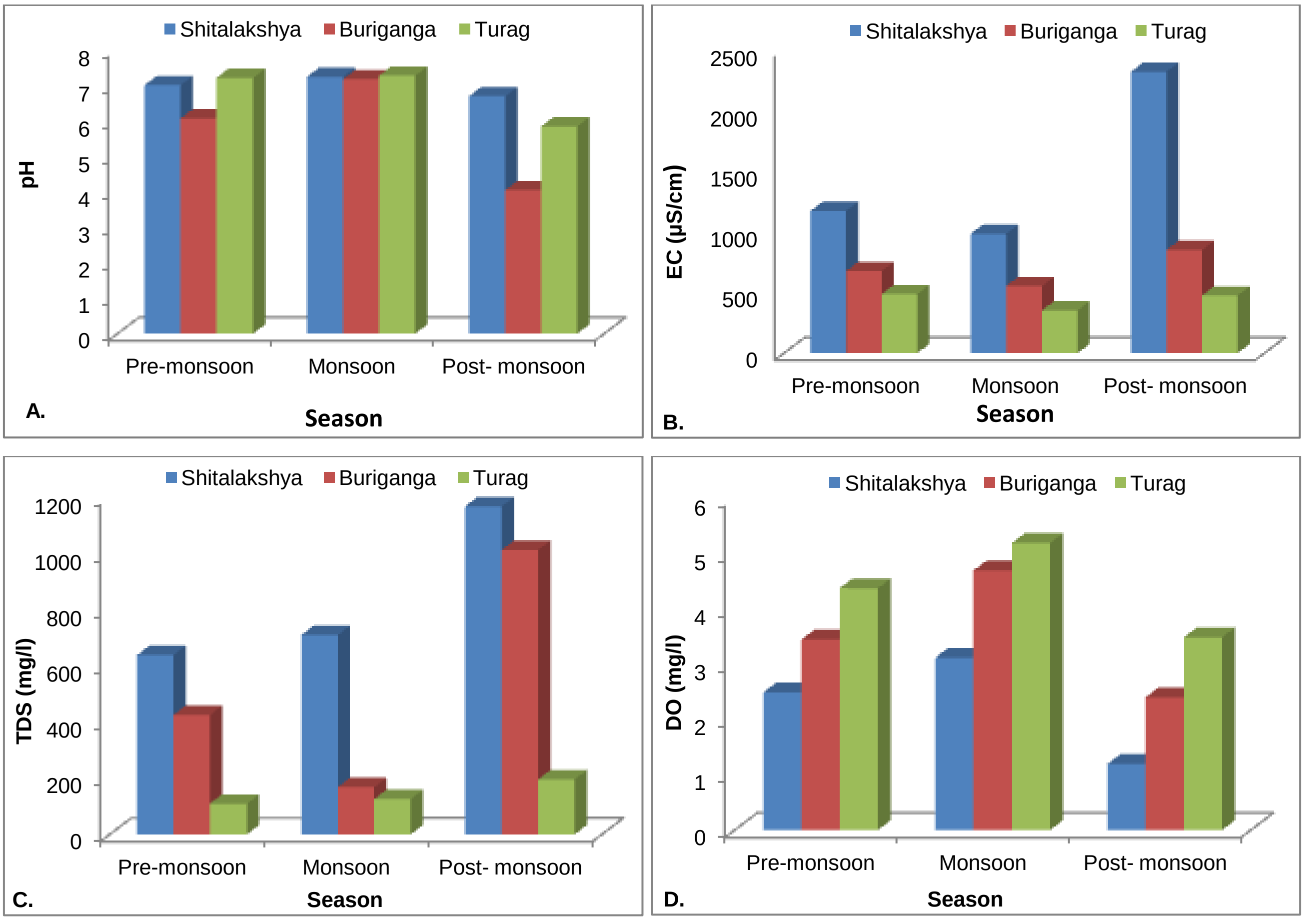
Parameters	Drinking standard	Irrigation standard
pH	7.5	7.5
EC (µS/cm)	700	700
TDS (mg/l)	1000	1200
DO (mg/l)	6	5
BOD (mg/l)	0.2	10
COD (mg/l)	4	6
Fe (mg/l)	0.65	2
Zn (mg/l)	5	10
Cu (mg/l)	1	3
Ni (mg/l)	10	1
Al (mg/l)	0.2	0.2
Pb (mg/l)	0.05	0.1
Hg (mg/l)	0.001	0.01
Cr (mg/l)	0.05	1

Total dissolved solids (TDS)

In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles (Mahananda, 2010). The maximum TDS were observed during the post-monsoon periodin study area (Fig. 2C) as large amount of sediment load were transported from the watershed during the rainy season. The average TDS values of Shitalakshya, Buriganga and Turagriver in three distinct seasons are 639.1 mg/l, 426.9 mg/l, 109.61 mg/l (pre-monsoon); 711mg/l, 169.03 mg/l, 126.41mg/l(monsoon) and 1171mg/l, 1015.1mg/l, 196.7 mg/l (post-monsoon) respectively and Shitalakshya showed the highest value (Fig. 2C).The acceptable standard of TDS for drinking water is 1000 mg/l, industrial water is 1500 mg/l, livestock is 5000 mg/l and irrigation is 2000 mg/l (ADB, 1994). The values of all measured samples were fall within permissible limit of drinking, industrial and agricultural use except post-monsoon season.

Dissolved oxygen (DO)

Dissolved oxygen is one of the most vital parameters in water quality assessment and reflects the physical and biological processes prevailing in the water (Trivedi and Goel, 1984). Where the rates of respiration and organic decomposition are high, the DO values usually remain lower, than where the rate of photosynthesis is high (Mishra *et al.*, 2009). When the water is polluted with large amount of organic matter, a lot of dissolved oxygen would be rapidly consumed in the biological aerobic decay which would affect the water quality and aquatic lives (Dara, 2007; Chhatwal, 2011). The average values of the DO of Shitalakshya, Buriganga and Turag river in three distinct seasons are 2.5 mg/l, 3.45 mg/l, 4.38 mg/l (pre-monsoon); 3.12 mg/l,4.7 mg/l, 5.2 mg/l (monsoon) and 1.2 mg/l, 2.41 mg/l, 3.49 mg/l (post-monsoon) respectively. It was observed that, during monsoon, river water found lower polluted and mostly polluted in post-monsoon period. In terms of DO level, Turag river showed better quality than others (Fig. 2D). According to the EQS (1997) DO level should be 6 mg/l for drinking, 4-5 mg/l for recreation, 4-6 mg/L for fish and livestock and 5 mg/l for industrial application. Results showed that all the rivers exceed the drinking standard.



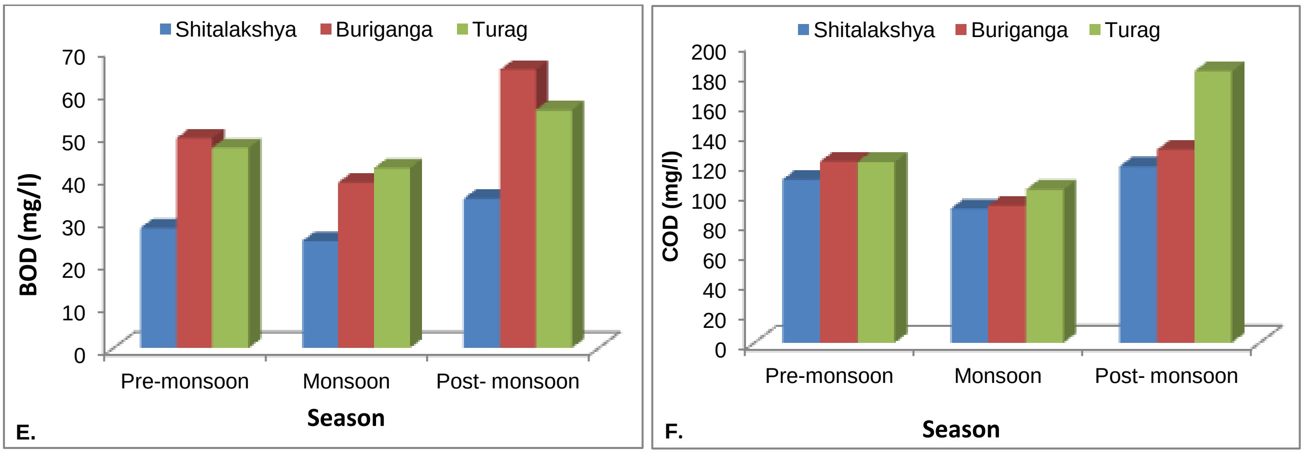
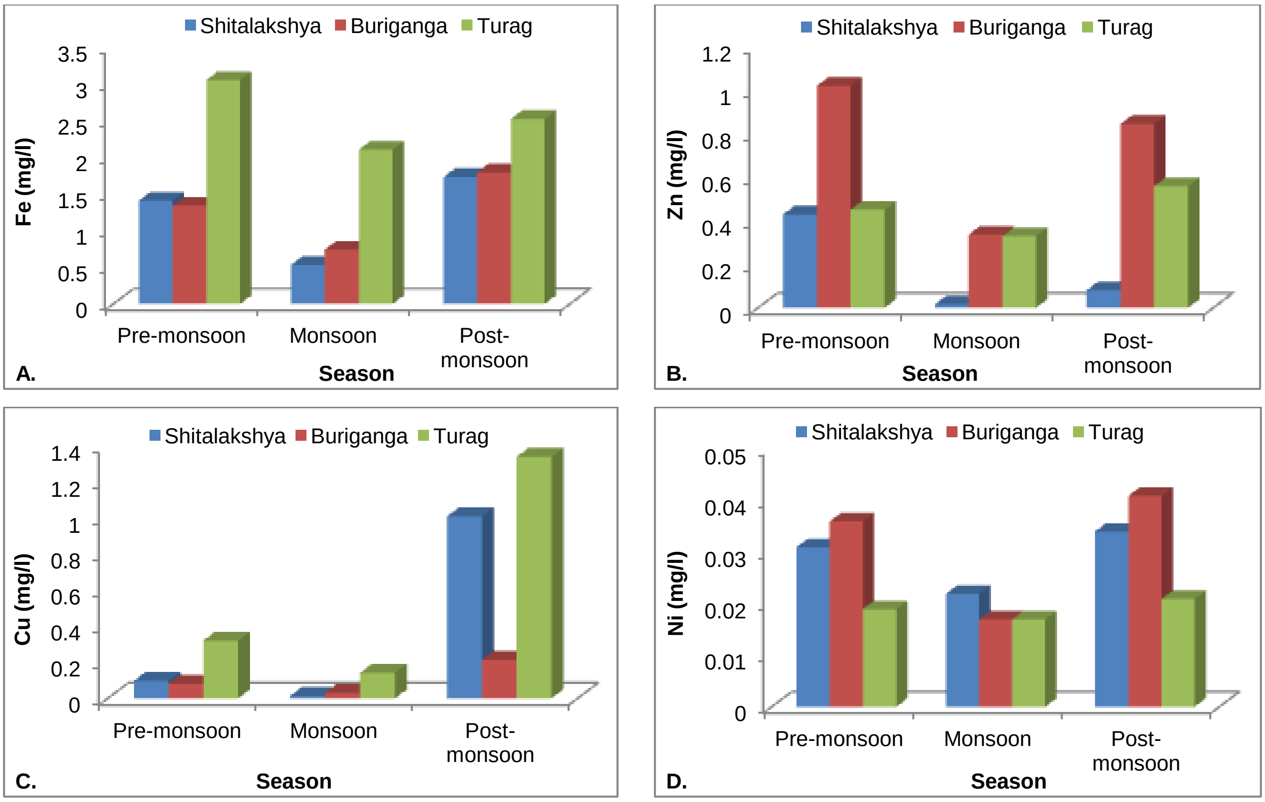


Fig. 2. Seasonal variation of (**A**) pH, (**B**) electric conductivity (EC), (**C**) total dissolve solid (TDS), (**D**) dissolved oxygen (DO), (**E**) biological oxygen demand (BOD),(**F**) chemical oxygen demand (COD) in the Shitalakhya, Buriganga and Turag River.



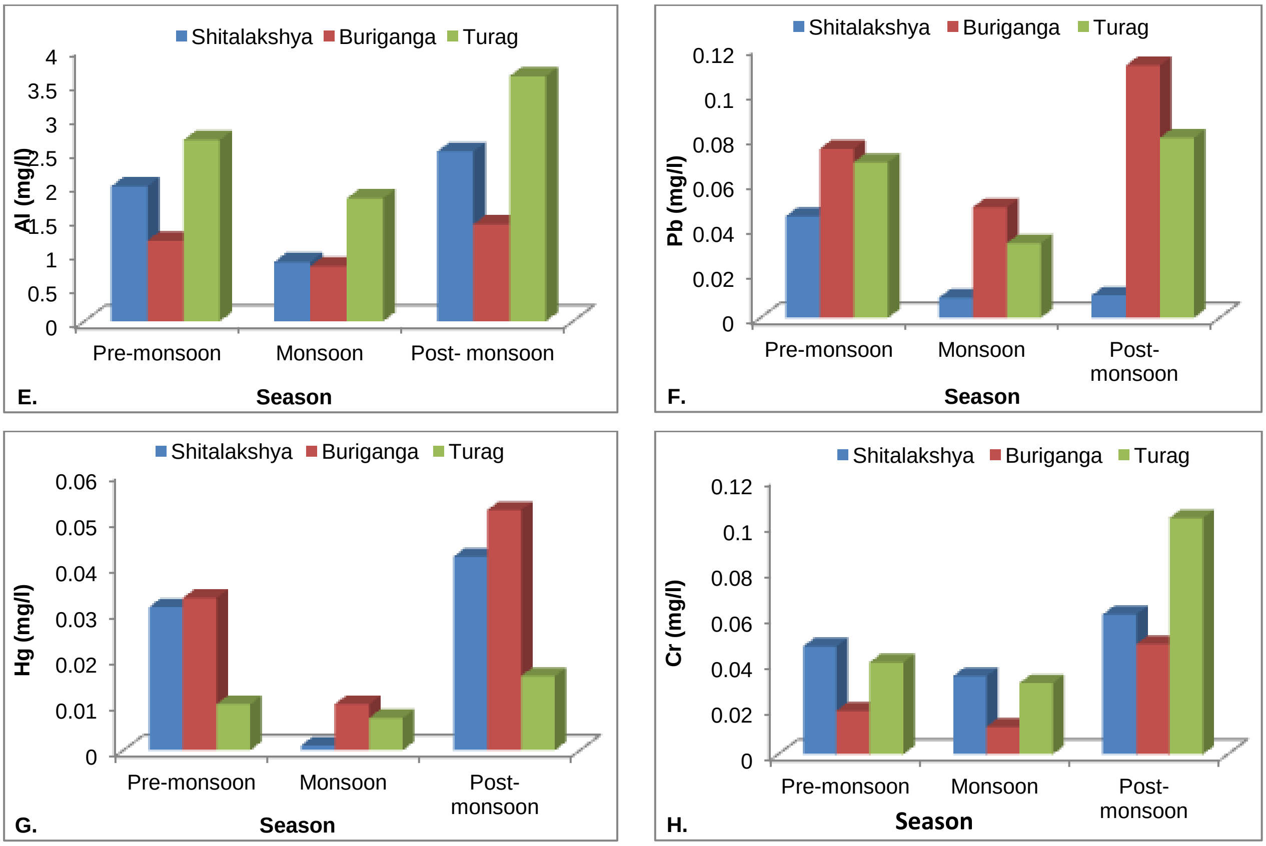


Fig. 3. Seasonal variation of (**A**) Fe, (**B**) Zn, (**C**) Cu, (**D**) Ni, (**E**) Al, (**F**)Pb, (**G**) Hg and (**H**) Cr in the Shitalakhya, Buriganga and Turag River.

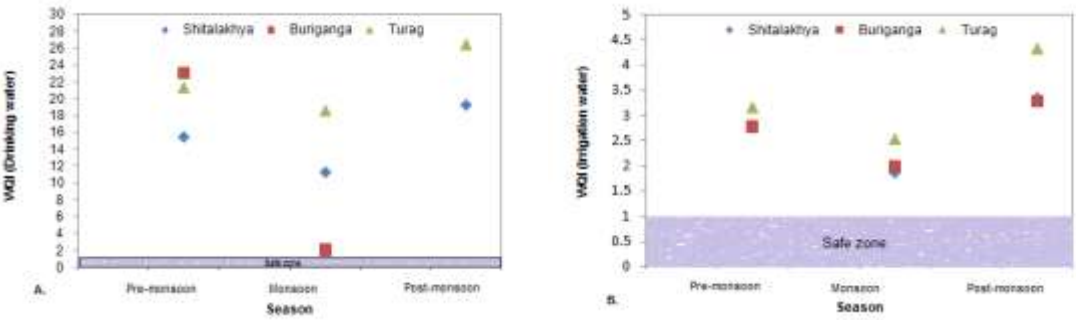


Fig. 4. Seasonal variation of WQI in the Shitalakhya, Buriganga and Turag River for (**A**) Drinking water and (**B**) Irrigation water.

Biochemical oxygen demand (BOD)

Biochemical oxygen demands a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in water and increases the biochemical oxygen demand (Abida, 2008). High BOD levels indicates lower in DO, because the oxygen that is available in the water is being consumed by the bacteria leading to the inability of fish and other aquatic organisms to survive in the river (Pathak and Limaye, 2011). The average values of the BOD of Shitalakshya, Buriganga and Turag river in three distinct seasons are 28.2 mg/l, 49.35 mg/l, 47.09 mg/l (pre-monsoon); 25.12 mg/l, 38.9 mg/l, 42.34 mg/l (monsoon) and 35.12 mg/l, 65.38 mg/l, 55.92 mg/l (post-monsoon) respectively and highest value showed in Burigangaand lowest in Shitalakhya river (Fig. 2E).The permissible limit for BOD for drinking water is 0.2 mg/l, for recreation 3mg/l, for fish culture 6 mg/l and 10 mg/l for irrigation (ECR, 1997).

The BOD values obtained inthe present study indicated that all the river water is unsuitable for uses.

Chemical oxygen demand (COD)

Chemical oxygen demand is a measure of the oxidation of reduced chemicals in water. It is commonly used to measure the amount of organic compounds present in water which makes COD as an indicator of organic pollution in surface water (Kumar *et al.*, 2011). COD pointing to a deterioration of the water quality caused by the discharge of industrial effluent (Mamais*et al.*, 1993). The average values of the COD of Shitalakshya, Buriganga and Turag river in three distinct seasons are 109.2 mg/l, 121.3 mg/l, 121.05 mg/l (pre-monsoon); 89.72 mg/l, 91.61 mg/l, 102.6 mg/l (monsoon) and 118.1 mg/l, 129.22 mg/l, 181.7 mg/l (post-monsoon) respectively.Seasonal averages of COD valueresults, higher in post-monsoonand lower during monsoon; and Buriganga river showed the highest COD value (Fig 2F).

Variation in toxic metals

Metal pollution in aquatic ecosystem is now a critical concern, as the effect of heavy metals toxicity and their accumulation in aquatic habitats (Waghmode and Muley, 2013), which occurs mainly throughnatural inputs such as weathering and erosion of rocksand anthropogenic sources including urban, industrialand agricultural activities, terrestrial runoff and sewage disposal (Çevik*et al.*, 2009). Metals are highly persistent, toxic in trace amounts and can potentially induce severe oxidative stress in aquatic organisms. Contamination of a river with heavy metals may cause devastating effects on the ecological balance of the aquatic environment and the diversity of aquatic organisms becomes limited with the extent of contamination (Ayandiran *et al.*, 2009). Heavy metal status and the seasonal variation of study Rivers are described below;

Iron (Fe)

The average values of the Fe in Shitalakshya, Buriganga and Turag River in three distinct seasons are 1.41 mg/l, 1.34 mg/l, 3.05 mg/l (pre-monsoon); 0.53 mg/l, 0.74 mg/l, 2.1 mg/l (monsoon) and 1.73 mg/l, 1.79 mg/l, 2.52 mg/l (post-monsoon).Seasonal variation showed that, lowest value of Fe in monsoon and the highest concentration are in Turag river (Fig. 3A). The permissible limit of Fe for drinking water is 0.3-1mg/l and for irrigation 2.0 mg/l. (ECR, 1997; Haq, 2003). In all cases Fe values obtained in the present study exceed the drinking water limit.

Zinc (Zn)

The average values of the Zn in Shitalakshya, Buriganga and Turag river in three distinct seasons are 0.0431mg/l, 1.021mg/l, 0.452 mg/l (pre-monsoon); 0.017 mg/l, 0.338 mg/l, 0.331 mg/l (monsoon) and 0.081 mg/l, 0.846 mg/l, 0.561 mg/l (post-monsoon).In all seasons, highest values of Zn showed in Buriganga riverand lowest in Shitalakhya. Seasonal variations showed lowest values of Zn in monsoon than others two seasons (Fig. 3B). The permissible limit of Zn for drinking water is 5 mg/l and for irrigation 10 mg/l. (ECR, 1997; Haq, 2003) and theresults obtained in all cases are within permissible limit.

Cupper (Cu)

The average concentrations of Cu from collected water samples of Shitalakshya, Buriganga and Turag river in three distinct seasons are 0.098 mg/l, 0.082 mg/l, 0.321 mg/l (pre-monsoon); 0.014 mg/l, 0.031 mg/l, 0.143 mg/l (monsoon) and 1.01 mg/l, 0.215 mg/l, 1.341 mg/l (post-monsoon). Seasonal averages of Cu value shows, higher in post-monsoon and lower during monsoon; and Turag river showed the highest value (Fig. 3C).

Nickel (Ni)

The average values of Ni in Shitalakshya, Buriganga and Turag river in three distinct seasons are 0.031 mg/l, 0.036 mg/l, 0.019 mg/l (pre-monsoon); 0.022 mg/l, 0.017 mg/l, 0.017 mg/l (monsoon) and 0.034 mg/l, 0.041 mg/l, 0.021 mg/l (post-monsoon). In all seasons, highest value of Ni showed in Buriganga river and lowest in Turag river. Seasonal variations showed lower values of Ni in monsoon than others two seasons (Fig. 3D).

Aluminum (Al)

The collected water samples from Shitalakshya, Buriganga and Turag river contained significant amount of Al and the average concentrations in three distinctseasons are 1.98 mg/l, 1.18 mg/l, 2.66 mg/l (pre-monsoon); 0.87 mg/l, 0.81 mg/l, 1.80 mg/l (monsoon) and 2.49 mg/l, 1.42 mg/l, 3.59 mg/l (post-monsoon). The permissible limit of Al is 0.2 mg/l. (ECR, 1997; Haq, 2003), which exceed limit in every case. Seasonal variations showed lower values of Al in monsoon and the higher in post-monsoon; and Turag river contained the highest concentration (Fig. 3E).

Lead (Pb)

The average values of the Pb in Shitalakshya, Buriganga and Turag river in three distinct seasons are 0.045 mg/l, 0.075 mg/l, 0.069 mg/l (pre-monsoon); 0.009 mg/l, 0.049 mg/l, 0.033 mg/l (monsoon) and 0.01 mg/l, 0.112 mg/l, 0.080 mg/l (post-monsoon).In every season, higher values of Pb showed in Buriganga and lower in Shitalakhya river. Seasonal variations showed lowest value of Pb in monsoon than others two seasons (Fig. 3F).

Mercury (Hg)

The average concentrations of Hg from collected water samples of Shitalakshya, Buriganga and Turag river in three distinct seasons are 0.031 mg/l, 0.033 mg/l, 0.010 mg/l (pre-monsoon); 0.001mg/l, 0.010 mg/l, 0.007 mg/l (monsoon) and 0.042 mg/l, 0.052 mg/l, 0.016 mg/l (post-monsoon). Seasonal averages of Hg value showed, higher in post-monsoon and lower during monsoon; and Buriganga river contained the highest concentration (Fig. 3G).

Chromium (Cr)

The average values of Cr in Shitalakshya, Buriganga and Turag river in three distinct seasons are 0.047 mg/l, 0.019 mg/l, 0.04 mg/l (pre-monsoon); 0.034 mg/l, 0.012 mg/l, 0.031 mg/l (monsoon) and 0.061 mg/l, 0.048 mg/l, 0.103 mg/l (post-monsoon). Seasonal averages of Cr showed higher values in post-monsoon and lower during monsoon (Fig. 3H).

The order of total seasonal average metal concentrations of Shitalakshya river are Al>Fe>Cu>Zn>Cr>Ni>Hg>Pb, in Buriganga Fe>Al>Pb>Zn>Cu>Hg>Ni>Cr and in Turag river Al>Fe>Cu>Zn>Pb>Cr>Ni>Hg.

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. WQI is a single value indicator to the water pollution, which integrates the data pool generated after collecting due weights to the different parameters. Several researchers have worked on the this concepts and presented examples with case scenarios in the literature (Bolton*et al.*, 1978; Liou *et al.*, 2004; Said *et al.*, 2004; Nasiri*et al.*, 2007;Lal, 2011).

The present study used a simple modified WQI (Tareq *et al.*, 2013) considering local environments and hydrology of the Shitalakhya, Buriganga and Turag river for drinking and irrigation purposes accordingthe following equation;

$$\mathrm{WQI}=\sum_{i=1}^{n}\frac{x_1+x_2+\cdots\ldots\ldots\ldots x_n}{n}$$

Where, n= total number of parameters, x= ratio of experimental value and maximum permissible limit of each parameter measured. The WQI values greater than one (>1) indicated polluted water, whereasless than one (<1) indicated unpolluted water. In present study calculated WQI values of the Shitalakhya, Buriganga and Turag river based on weights of different parameters and maximum permissible limit of each parameter are listed in the Table 1.

Seasonal variation of WQI in three rivers for drinking and irrigation water is shown in Fig. 4.

Results showed that, Shitalakhya, Buriganga and Turag rivers water are unsuitable for drinking and irrigational purposes and highly polluted during post-monsoon season. River pollution are strongly correlated with season of the study areas, and the seasonal order of pollution magnitude is post-monsoon>pre-monsoon>monsoon. The water quality was degraded in post-monsoon due to low rainfall and river flow.

Conclusion

From present study it has been found that the Shitalakhya, Buriganga and Turag rivers are strongly polluted and unsuitable for drinking and irrigational purposes. The analytical results of the physicochemical parameters i. e., pH, EC, TDS,DO, BOD, COD and toxic metal concentrations i. e., Fe, Zn, Cu, Ni, Al, Pb, Hg, Cr etc. are highest in Post-monsoon and lowest in monsoon.WQI calculation in this present study, reveals an integrated scenario of water pollution of the Shitalakhya, Buriganga and Turag rivers in Bangladesh. So, proper care should be taken when dispose of industrial effluent, sewage water and sludge to protect aquatic environment as well as existence of lives.

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