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INVESTIGATION OF SURFACE WATER QUALITY OF THE BURIGANGA RIVER IN BANGLADESH: LABORATORY AND SPATIAL ANALYSIS APPROACHES

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Key words: Surface water quality, Buriganga river, Laboratory and spatial analysis

Abstract

This work has been conducted to evaluate the water quality of the Buriganga river. *In situ* water quality parameters and water samples were collected from 10 locations in January 2016 and analyzed later in laboratory for water quality parameters such as pH, Eh, EC, TDS, cations (Na^{+}, K^{+}, Ca^{2+}, Mg^{2}, As^{3+}), anions (Cl^{-}, HCO_3^{-}, NO_2^{-}, NO_3^{-}, SO_4^{2-}, F^{-}, Br^{-}, PO_4^{3-}), heavy metals (Cr^{2+}, Pb^{2+}, Zn^{2+}, Cd^{+2}, Fe^{2+}, Mn^{2+}) to see whether or not the level of these parameters are within the permissible limits. The average values of pH, Eh, EC and temperature were 7.31, –214.9 mV, 928.9 µs/cm and 21.4°C, respectively; the average concentration of Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, and As^{3+} were 109.62, 13.38, 46.78, 13.98 and 0.018 mg/l, respectively, while the concentrations of Cl^{-},HCO_3^{-}, PO_4^{3-}, SO_4^{2-}, NO_3^{-}, NO_2^{-}, F and Br^{-} were 79, 331.06, 2.22, 84.32, 0.0254, 0.058, 0.224 and 0.073 mg/l, respectively; and the concentration of heavy metals Pb^{2+}, Zn^{2+}, Fe^{2+} and Mn^{2+}were 0.28, 0.053, 0.17 and 0.23 mg/l, respectively. The study indicates that most of the parameters are within the permissible limits set by Bangladesh water quality standard. The concentrations of K^{+}, Mn^{2+}, and Pb^{2+} were beyond the permissible limits meaning that that the water of Buriganga is not safe for drinking. The people living beside Buriganga river should be more cautious about using the polluted/contaminated river water. The concerned authorities should take urgent necessary steps to improve the degraded water quality of the river considering the ecological, environmental and economic implications associated with it.

Introduction

Bangladesh is the largest delta of the world with its 230 rivers flowing all over the country like a net. Although Bangladesh is predominantly a plain surface, it is criss-crossed by a very high density river system. For centuries, the river system has been a major part of the civilization in this part of the world. It is also a vital part of our environment. The aquatic ecosystem is closely integrated with these rivers. Moreover, in Bangladesh, the environment, economic growth and developments are all highly influenced by water - its regional and seasonal availability and the quantity of surface and groundwater(1).

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Buriganga river is originated from Dhaleshwari near Kalatia passing through west and south of Dhaka city, the capital of Bangladesh [2]. It is one of the most important rivers around Dhaka city with respect to irrigation, fisheries, transportation, and also for recreation. Buriganga river also plays a very vital role for supplying drinking water and balancing the environment of the densely populated Dhaka city. Nowadays, the Buriganga river is overwhelmed by the pollution from sewerage and industrial effluents. It is considered as one of the most polluted rivers in Bangladesh[3]. The Buriganga river water has been changing in terms of its quantity and quality[2]. The rapid development of industrialization, urbanization and other development activities around the Buriganga river are mainly responsible for the deterioration of water quality and reduction of water quantity [2, 4]. As most of the textile and garments-cum dying factories are situated on the bank of the Buriganga, they discharge heavy loads of both liquid and solid wastes into the river without treatment [5]. Besides, the urban sewage of the city is also being added to the river. This huge amount of effluents and solid wastes are getting mixed with the river water and sediments every day; more than 60,000 cubic meters (2,100,000 cubic feet) of toxic wastes from these sources are being discharged into the main water bodies of the river[6]. We measured *in situ* water quality parameters such as Eh, pH, EC and collected water samples from different locations through field work and later on analyzed various qualitative parameters of river water in the laboratory. One of the prime objectives of this study is to investigate the water quality of the Buriganga river in the year of 2016. The other target is to assess the qualitative parameters of Buriganga river water using GIS spatial analysis with support of ground *in situ* data.

The Buriganga river flows around the southwest outskirts of Dhaka city. The maximum and average depth of the river are about 18 and 7.6 m, respectively, and its length is about 18 km[6]. The Buriganga river encompasses the south-western periphery of Dhaka City [7]. In the distant past, a course of the Ganges river used to reach the Bay of Bengal through the Dhaleshwari river. When this course gradually shifted and ultimately lost its link with the main channel of the Ganges it was renamed as the Buriganga. The main flow of the Buriganga river comes from the Turag river. The area is surrounded by the residential areas on all of its sides. Our study area comprises an area of 1411.47 hectares (Fig. 1). The extent of the study area is from 90°20'09.46"E to 90°26'59.14"E longitude and 23°37'36.22"N to 23°47'08.27"N latitude. Rapid urbanization without considering the geological aspects has resulted in significant changes in the geo-environment of the study area. Waterlogging, pollution, changes in the hydrogeological system, localized land subsidence and building collapse are the hazards associated with these changes in the geo-environment.

Materials and Methods

Field investigation is important for evaluating any parameter of water quality. To conduct this work, ten water samples were collected from Buriganga river from ten different locations (upstream to downstream) (Fig. 2). Field works were conducted within the study area with sophisticated instruments such as handheld GPS, HANNA Pocket pH and Eh meter (model HI 98127), OAKTON waterproof pocket pH-EC comb. Meter (Model PC tester 35).

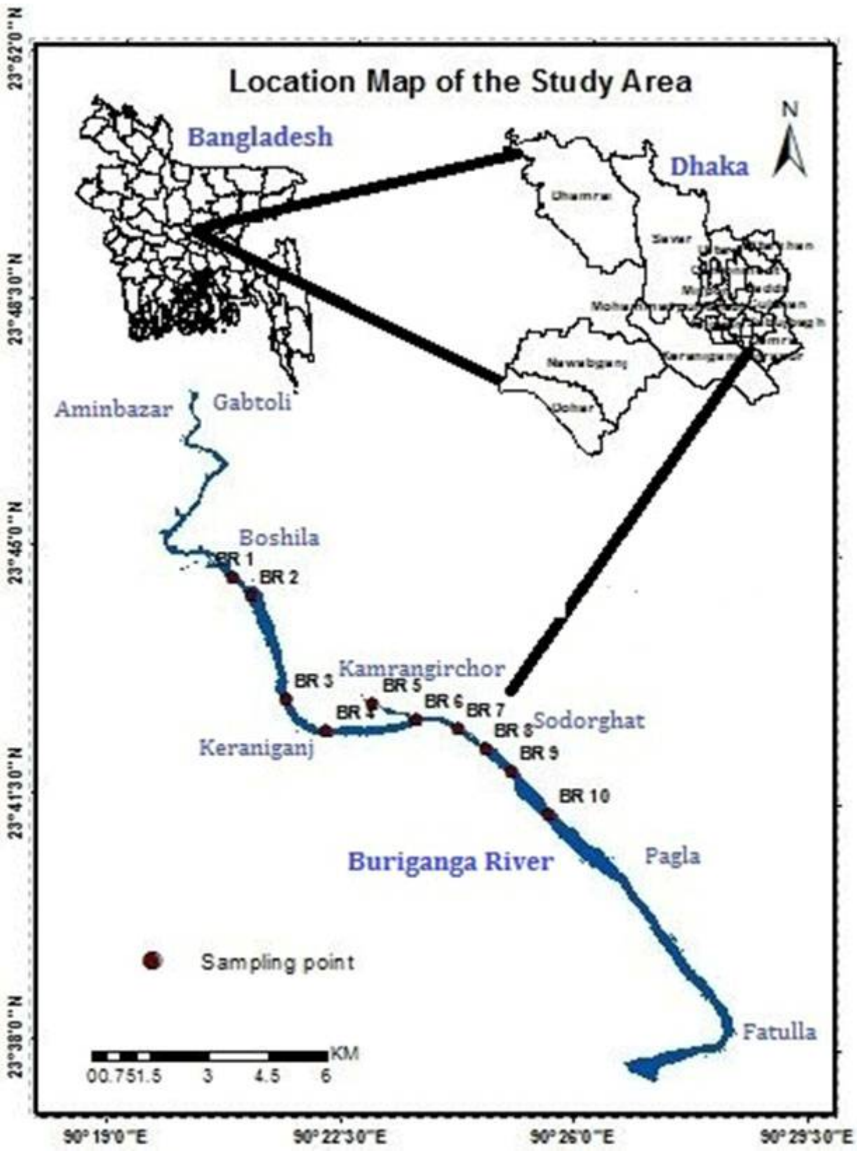

Fig. 1. Location map of the study area.

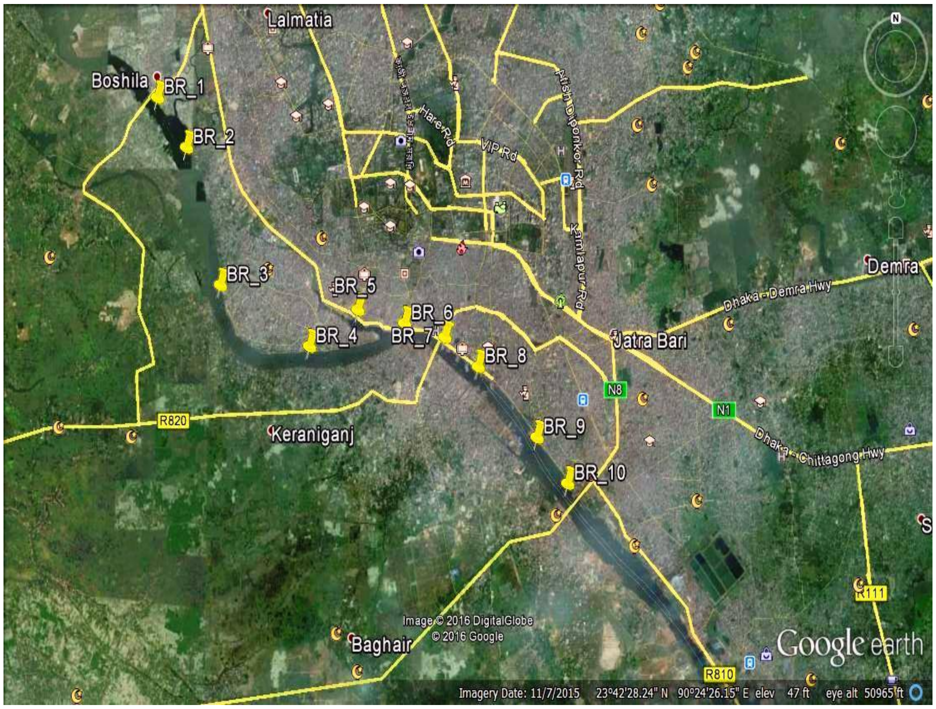

Fig. 2. Water sampling locations of the study area[8].

Two 125 ml PVC bottles were used for sampling. During sampling 0.45 μm membrane filters were used to filter water samples in order to remove colloidal materials and other unwanted particles. One bottle of sample was acidified using concentrated HNO_3 to lower the pH value to < 3 to avoid precipitation of the dissolved constituents from the samples. Sampling process was started by rinsing the sample bottles three times with the filtered water; then two-third of the 125 ml sample bottle was filled with the filtered water and it was acidified with concentrated HNO_3 and then the rest of the bottle was filled up leaving no empty space. Physico-chemical parameters like pH, Eh, electrical conductivity (EC), total dissolved solid (TDS) and temperature were measured in the field. Different methods were applied for determining the concentration of different chemical constituents of the sample waters; flame photometer (Jenway PFP-7) wavelength 769 nm for Na and K[9, 10]; atomic absorption spectrometer (GBC SensAA) for Ca, Mg, Fe and Mn and other heavy metals [11]; titration method for HCO_3 and Cl[12]; UV-Visible spectro-photometer (T60 PG) wavelength 410 nm for NO_3 and SO_4[11]. ArcGIS software was used for preparing maps such as location map and spatial distribution map. Rock Works 15 software was employed for piper diagram which describes hydrochemical facies analyses[13].

Results and Discussion

In the study area, the value of pH ranged from 6.88 to 7.60 and the average value were 7.31 which indicate that the river water was more or less neutral in character (Fig. 3A). The highest value of pH was 7.60 near Sadarghat boat terminal. The water samples were collected in January and at that time the volume of water was low. The value was high due to high base saturations with low volume of water. Tannery industries effluent discharged without any treatment might have contributed too. The lowest value of pH was 6.88 near Kamrangirchor Bridge (Fig. 3A). According to United States Environmental Protection Agency (USEPA), World Health Organization (WHO) and Department of Environment of Bangladesh(DoE), the standard pH value for Drinking water is from 6.5 to 8.5[14,15,16]. So all these pH values at different locations were within the permissible limit for drinking purpose. The Eh value from upstream to downstream was –94 to –250 mV and the average value was –214.9 mV (Fig. 3B). The highest value was –250 mV near Kamrangirchor Bridge and the lowest value was –94 mV near Sahid Buddhizibi Bridge road (Fig. 3B). The negative value indicates that the environment was reducing.

EC is an estimate of the total amount of dissolved ions in the water. The EC values of Buriganga river ranged from 860 to 1018 μs/cm and the average value was 928.9 μs/cm (Fig. 3C). The highest value of EC was recorded near Kamrangirchor Bridge and the lowest value was recorded near Shahid Buddhizibi Bridge road (Fig. 3C). It is known that in January (dry season) the river flow decreases. As a result EC increases[17,18]. Nevertheless, these values indicate that the river Buriganga might have received wastewater (industrial and sewage effluent) which contained high ionic concentration. The value of EC of a water body greater than 1000 mg/l is not suitable for agricultural, household,bathing and drinking purposes [19]. So, EC value is within the range, but near Kamrangichor Bridge, the value of EC is not within the limit due to the discharge of tannery effluent and metal plating industries. The investigated value of temperature was about 21.9°C where the maximum value was 24.4°C and the minimum value was 20.4°C. From the analysis, it was found that the water was hard and the hardness value in every sample exceeded the limit set by WHO where the standard value of hardness for drinking water is 0 to 75 mg/l. The maximum value was 204.88 mg/l in water. The concentration of arsenic was between 0.009 and 0.027 mg/l with a mean value of 0.018 mg/l (Fig. 3C). According to WHO, USEPA and DoE, the standard of arsenic is 0.01, 0.01 and 0.05 mg/l, respectively. So, the concentration of arsenic in the analyzed samples was within the limits.

The distribution of ions in the study area showed wide variations. The charge balance between cations and anions was within acceptable limits (less than 10%) confirming the reliability of the analytical results [20]. Among the anions, HCO_3^- was dominant and the concentration was between 318 and 357.125 mg/l with a mean value of 331.06 mg/l (Fig. 4). The highest value was near Kamrangirchor Bridge. Chloride varied between 67.72 and 105.96 mg/l with a mean value of 79 mg/l (Fig. 4). According to WHO, the standard concentration of Cl^- for drinking water is 250 mg/l and according to DoE, the value is 150 - 600 mg/l and below this limits it is not proper for drinking purpose and

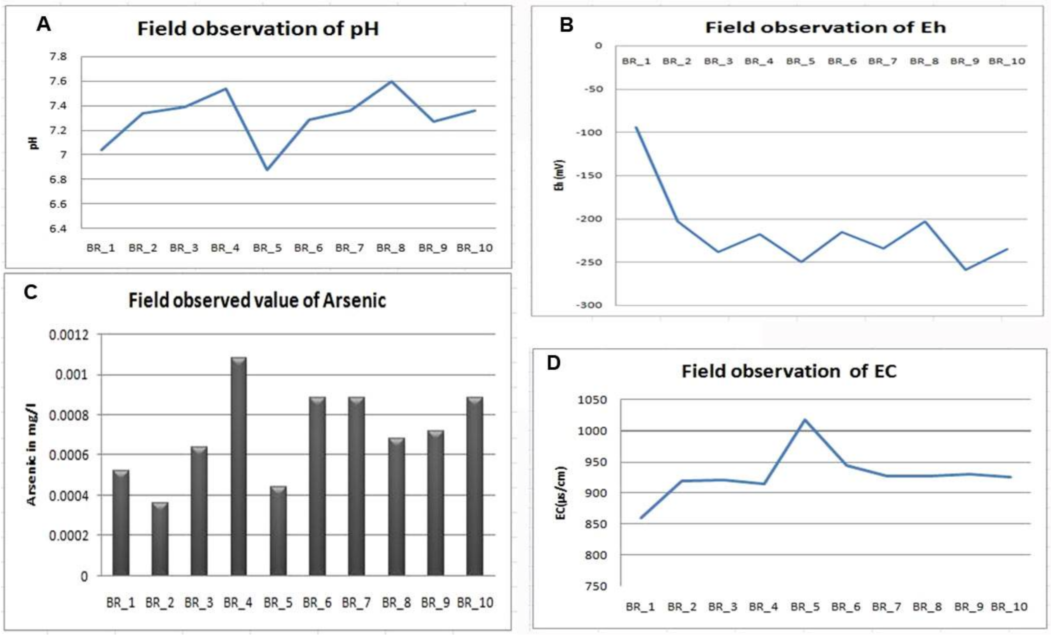

Fig. 3. *In situ* physical properties of the Buriganga river in 10 sampling points.

in this analysis Cl^- was beyond this limit [15, 16]. The PO_4^{3-} levels ranged from 0.94 to 5.62 mg/l with a mean value of 2.22 mg/l. The concentration of SO_4^{2-} ranged from 21.57 to 110.72 with a mean value of 84.32 mg/l and it was within the limit. Nitrate concentration was between 0.016 and 0.058 mg/l with a mean value of 0.0254 mg/l and was also within the limit. Besides the major anions there were some other anions. Flouride concentration ranged from 0.2 to 0.25 mg/l with a mean value of 0.224 mg/l. According to USEPA, WHO and DoE, the standard of F^- is 2, 1.5 and 1 mg/l, respectively and from the analysis it is found that it was within the limit. The concentration of Br^- was between 0.033 and 0.21 mg/l with a mean value to 0.073 mg/l. Nitrite was found in only one sample near Postogola Bridge and the concentration was 0.058 mg/l. According to USEPA and WHO, the maximum contamination level of nitrite is 10 and 50 mg/l, respectively and the nitrite concentration was within the limit.

Among the cations, Na^+ concentration was high and the concentrations were between 92.9 and 118.16 mg/l with a mean of 109.62 mg/l (Fig. 5). The higher concentration of sodium may have resulted from the sodium-rich effluent from nearby chemical, food, tannery and leather industries. According to DoE, the standard value of Na^+ is 200 mg/l and the values are within the limit[15]. The concentration of Ca^{2+} was between 40.62 and

54.37 mg/l with a mean value of 46.78 mg/l. The concentration of Mg^{2+} was between 12.15 and 16.78 mg/l with a mean value of 13.98 mg/l (Fig. 5). The K^{+} levels ranged from 12.58

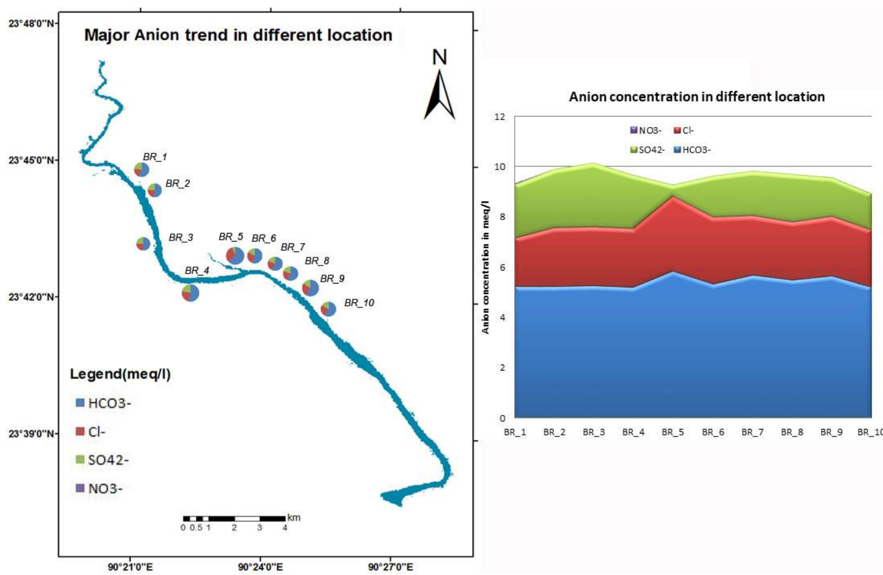

Fig. 4. Major anion concentration and its trend in the water bodies of the Buriganga river.

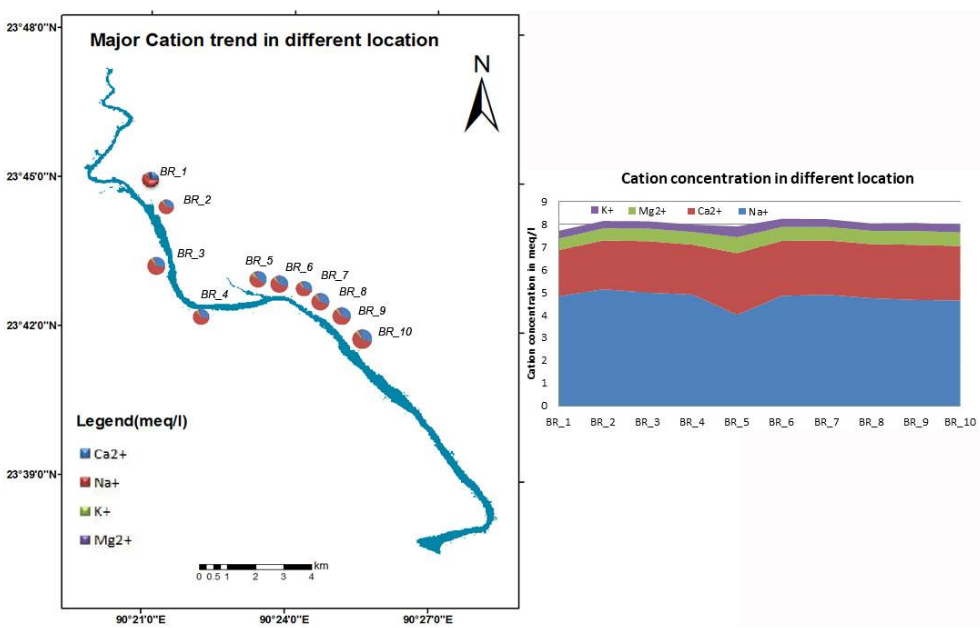

Fig. 5. Major cation concentration and its trend in the water bodies in the Buriganga river.

to 18.6 mg/l with a mean value of 13.83 mg/l which was beyond the limit. From the piper diagram, two types of mixed water have been found: one is Na-Ca-HCO_3-SO_4-Cl type and the other one is Na-Ca-HCO_3-Cl type (Fig. 6, Table 1)[13]. Results of another study showed that in both the dry and wet periods, Buriganga river water are of Ca-HCO_3 type [21]. According to WHO, the standard value of hardness for drinking water is 0 to 75 mg/l but, from the analysis, the Buriganga river water was found to be hard as it exceeded the standard limit[16].

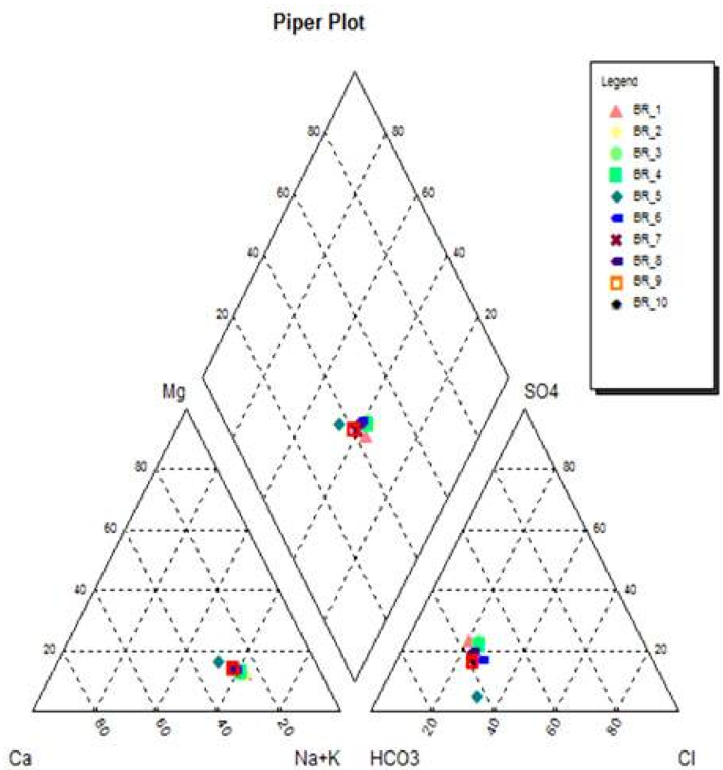

Fig. 6. Piper diagram of collected water samples from the Buriganga river[13].

The concentrations of six heavy metals, namely iron, manganese, zinc, lead, chromium and cadmium, were determined in the laboratory. The concentration of Fe^{2+} ranged between 0.08 and 0.28 mg/l with a mean value of 0.17 mg/l which is considered to be safe for drinking purpose (Fig. 7). Many pharmaceuticals, chemical and pesticides industries are located around the study area from which iron could come into the water. The Mn^{2+} levels were between 0.14 and 0.26 mg/l with a mean value of 0.23 mg/l, which exceeded the limit of DoE and WHO and not safe for drinking[15,16]. The analyzed concentration of Zn^{2+} was between 0.04 and 0.084 mg/l with a mean value of 0.053 mg/l. According to WHO, the standard concentration for zinc is from 3 to 5 mg/l and in the study area it is below the permissible level. The lower level of zinc could be attributed to the precipitation of Zn as $ZnCO_3$. Total lead concentrations in the analyzed water samples varied and all the samples exceeded the DoE standard as the concentration of total Pb^{2+} varied between 0.035 and 0.845 mg/l with a mean of 0.28 mg/l. The values increased from upstream to downstream. Chromium was within the acceptable limit in all the water samples, coming from painting industries and also from leather industries. Cadmium was also found to be within the acceptable level.

Table 1. The water properties found from Piper diagram[13].

Sample ID	Water type	Total hardness (mg/l $CaCO_3$)	Alkalinity (mg/l $CaCO_3$)
BR_1	Na-Ca-HCO_3-SO_4-Cl	152.48	262.70
BR_2	Na-Ca-HCO_3- Cl-SO_4	159.60	262.56
BR_3	Na-Ca-HCO_3-Cl-SO_4	167.85	263.59
BR_4	Na-Ca-HCO_3- Cl-SO_4	164.63	260.82
BR_5	Na-Ca-HCO_3-Cl	204.88	292.91
BR_6	Na-Ca-HCO_3-Cl	180.78	266.66
BR_7	Na-Ca-HCO_3-Cl	177.96	285.78
BR_8	Na-Ca-HCO_3- Cl-SO_4	176.57	275.07
BR_9	Na-Ca-HCO_3-Cl	181.30	283.68
BR_10	Na-Ca-HCO_3-Cl	178.94	261.64

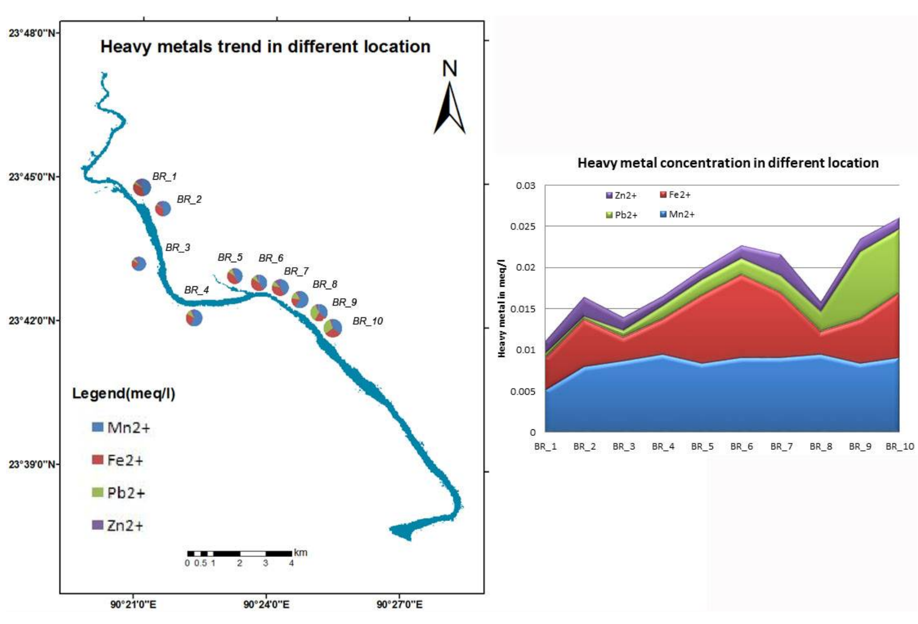

Fig. 7. Major heavy metal concentrations and its trend in the Buriganga river.

The TDS value ranged from 655 to 708 mg/l and the average value was 687.50 mg/l (Fig. 8). The highest value was near Aganagar Nodidhara Ghat, Keraniganj and the lowest value was near Postogola bridge. According to WHO, the maximum limit of TDS is 600 mg/l and according to USEPA, the maximum limit is 500 mg/l [14, 16]. From the present study it is found that all the samples crossed the limit which indicates a bad condition of the river. The water is certainly not safe for drinking purposes; but according to DoE, the value is 1000 mg/l, which implies that all the samples were within the limit. As it is known that the Buriganga river is surrounded by many industries, particularly tanneries, the tannery effluents are discharged without treatment and this makes the water more turbid and saline that has a detrimental effect on aquatic lives and, if applied in soil as irrigation water, the water may affect the crops as well.

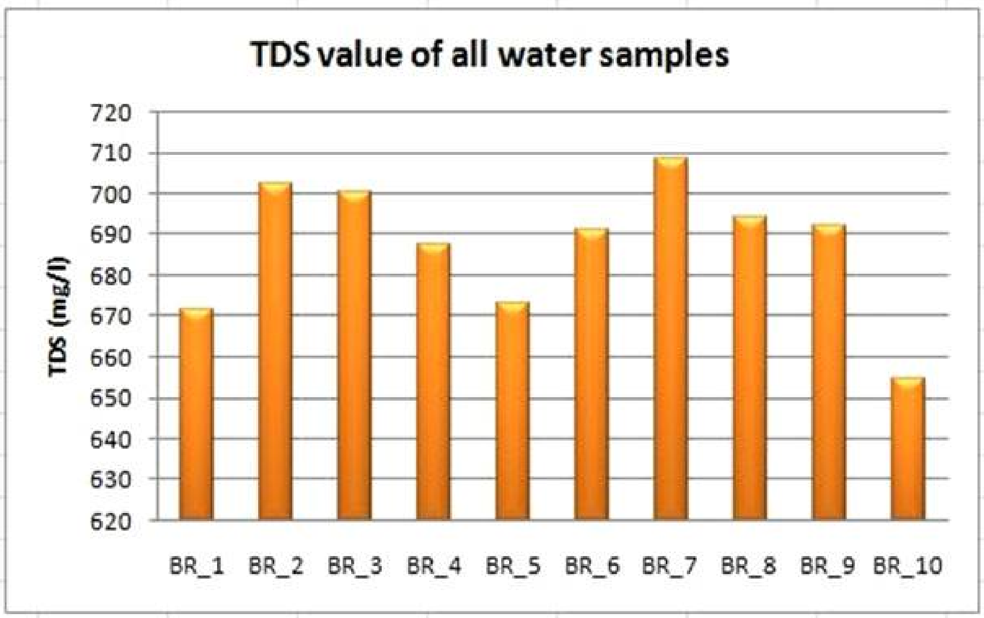

Fig. 8. Diagram showing the values of TDS in different location from upstream to downstream.

It is known that the water quality of Buriganga river has been degrading day by day but from data analysis in this study, it is found that some parameters are within the permissible limit set by DoE and WHO. Some of the parameters of the river water are beyond the limits. The acceptable water quality parameters are pH, Eh, EC, temperature, cations (Na^+, Ca^{2+}, Mg^{2+}, As^{3+}), anions (HCO_3^-, PO_4^{3-}, SO_4^{2-}, NO_3^-, NO_2^-, F^-, Br^-) and heavy metals (Fe^{2+}, Zn^{2+}). The parameters found beyond the permissible limits are K^+, Mn^{2+}, Pb^{2+}. Among all the parameters, Cl^- is the only element that was beyond the limit of WHO and DoE, which means that the water is not safe for drinking. Near Kamrangirchor bridge, the value of EC was high (1018 μS/cm) due to the discharge of tannery effluent and metal plating industries.The Buriganga river is not only the lifeline of the capital city but also a perennial source of natural beauty for the common people of the country. The present state of water pollution has given rise to an unhealthy environment of the city. It has now become an urgent issue for the concerned authority to undertake some comprehensive and holistic approaches to save this river.

Acknowledgements

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