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Contamination Status of Surface Water from the Balu River for Irrigation Usage in Bangladesh

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Abstract
An attempt was made to evaluate the contamination status of surface water collected from the Balu river for irrigation. Twenty samples were collected to analyze pH, EC, TDS and ions. Samples were slightly alkaline in nature. Water samples were from low to medium salinity and low alkalinity hazards (C1S1-C2S1). As per TDS values, samples were classified as freshwater. Considering SAR and SSP values, samples were excellent and good to permissible classes, respectively. Most of the water samples were free from RSC and all the samples were under moderately hard. The status of Cr and Mn ions in samples surpassed FAO guideline values indicating contaminants for long-term irrigation. The levels of other metal ions in samples were within acceptable levels and did not pose a threat to irrigated soil. This finding revealed that Cr and Mn ions were considered as contaminants in river water for irrigation posing harmful impact on soils and crops.

Key words: Balu river, Contamination, Irrigation, Metal ion, Surface water

Introduction

Surface water contamination, nowadays, has become a serious concern for human life due to the industrial burst. Among the surface water sources, rivers are the main choices to hold and bear the responsibility of contaminants especially in the developing countries like Bangladesh. River water has been a receiver of perilous materials from domestic, industrial and agricultural runoff (Dey *et al*., 2015; Saleem *et al*., 2015; Ali *et al*., 2016).Water contamination caused by chemical substances such as heavy metals affects river ecosystem. The industrial activities severely deteriorate surface water quality of rivers, lakes and wetlands thus posing dreadful risks to human health and the environment of the area. Large amount of industrial wastewaters or effluents are being discharged into river water without any treatment (Hossain *et al*., 2012; Rahman and Mondal, 2013). In present times, there has been an unprecedented increase in the level of metals due to human activities. Huge amounts of toxic heavy metals are discharged by man-made activities (Nduka and Orisakwe, 2011; Kibria *et al.,* 2016). Surface water quality is threatened by the industrial development on the river banks. This occurrence can lead a decline in crop production (Roy *et al*., 2015). The contamination of surface water by heavy metals is a serious ecological problem as some of them are toxic even at low concentrations, are non-degradable and can bio-accumulate through food chain (Abdullah, 2013).

The Balu river areas are surrounded by unplanned industries and this river is a recipient of the untreated industrial wastewaters or effluents resulting in surface water contamination. In the study areas, farmers usually depend on surface water irrigation for its availability and cost effectiveness though surface water is contaminated with industrial discharge. In the Balu river bank areas, agricultural lands are frequently irrigated to grow leafy vegetables and rice particularly in the dry season. Farmers often complain that contaminated water irrigation reduces rice and vegetable production even though more fertilizer doses are also their concern to get optimum production. In agro-ecosystem, contaminants from anthropogenic sources entering soil-water-plant systems through various matrices are anxiety for all communities. Accumulation of heavy metals in soils and plants could be led by the contaminated river water irrigation causing the development of serious health problems, such as kidney damage and cancer (Chojnacka *et al*., 2005; Sharma *et al*., 2009; Rahman *et al*., 2015; Samad *et al*., 2015).People in this locality are accumulating heavy metal in their body due to consumption of metal accumulated rice grains and vegetables. Considering these facts, the present study was focused on exploring the contamination status of surface water collected from the Balu river to provide sufficient reliable information for irrigation usage towards food safety for better management of surface water resources.

Materials and Methods

Water sampling site

In the present study, the selected areas were within segment of the Balu river (23°52.96´N-23°50.81´N and 90°27.65´E-90°28.37´E) as shown in Table 1. Twenty sampling points were documented from the adjacent agricultural crop fields irrigated with this river water. The exact location of each sampling site was determined using GPS (Fig. 1).

Table 1. Sampling sites of the Balu river

Sampling ID No.	Sampling area		Sampling ID No.	Sampling area	
	Latitude (N)	Longitude (E)		Latitude (N)	Longitude (E)
1	23°52.96´	90°27.65´	11	23°51.87´	90°28.37´
2	23°52.88´	90°27.70´	12	23°51.75´	90°28.45´
3	23°52.74´	90°27.75´	13	23°51.65´	90°28.50´
4	23°52.65´	90°27.79´	14	23°51.53´	90°28.48´
5	23°52.46´	90°27.88´	15	23°51.45´	90°28.45´
6	23°52.37´	90°27.96´	16	23°51.34´	90°28.45´
7	23°52.28´	90°28.07´	17	23°51.16´	90°28.45´
8	23°52.20´	90°28.17´	18	23°51.00´	90°28.39´
9	23°52.09´	90°28.27´	19	23°50.91´	90°28.39´
10	23°51.97´	90°28.34´	20	23°50.81´	90°28.37´

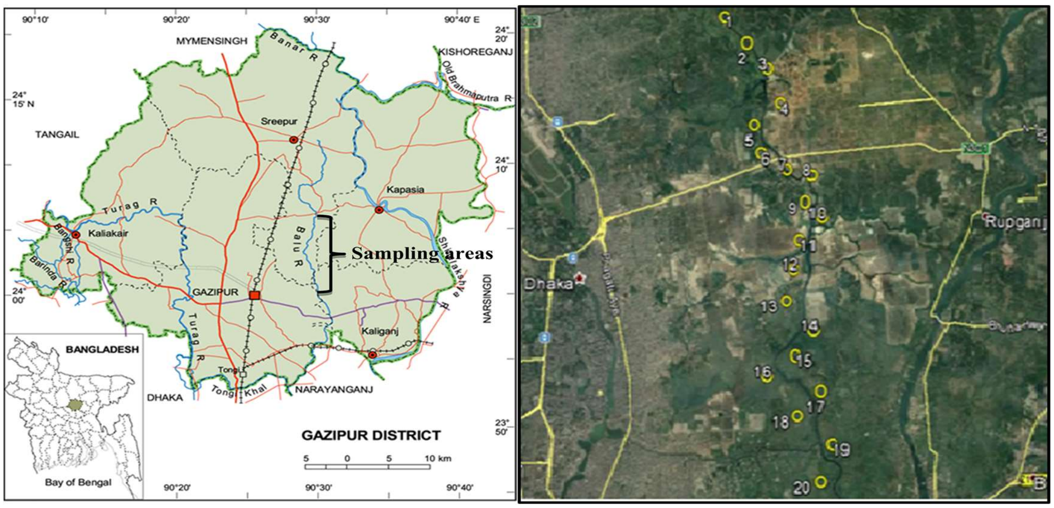

Fig. 1. Study areas of the Balu river in location map

Water sampling technique

Water sampling points were selected to collect samples from the Balu river and sampling was started from the upstream to downstream of river during dry season. Water samples were collected from each site in 500 mL plastic bottles. Each bottle were previously cleaned with dilute HCl (1:1) and then washed with distilled water. All the bottles were rinsed 3 to 4 times prior to water sampling. For metal analysis, water samples were acidified with HNO_3 (pH<2) to prevent the loss of metals by adsorption and/or ion exchange with the walls of sample containers (APHA, 2012). The samples were filtered through filter paper (Whatman No.:42) in the laboratory for subsequent chemical analysis.

Water analysis

pH and EC values of samples were measured by pH and EC meters (Model: sensION, Hach, USA) following the techniques as mentioned by Gupta (2013). Total dissolved solids (TDS) values of water samples were measured by TDS meter (Model: sensION, Hach, USA).In water samples, K and Na contents were measured by flame photometer (Model: PFP7, Jenway, UK) following the technique as reported by Gupta (2013). while the concentrations of Ca, Mg, Zn, Fe, Cu, Mn, Pb, Cd, Cr and Ni were determined by atomic absorption spectrophotometer (Model: AA-7000, Shimadzu, Japan) with a specific lamp for each metal (APHA, 2012).The amounts of CO_3 and HCO_3 in water samples were estimated by titrimetric method (Tandon, 2013). All the water samples were analyzed in triplicate in case of each ion.

Water contamination rating

To measure the contamination status of surface water from the river and its suitability for irrigation, the following chemical quality factors were calculated from water analytical results:

1) Sodium adsorption ratio (SAR)

High concentration of Na in water leads to development of alkalinity (Singh *et al.*, 2010). Alkalihazard is measured by the absolute and relative concentrations of cations expressing in terms of SAR as determined by the following formula:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$$

2) Soluble sodium percentage (SSP)

High concentration of Na in water used for irrigation causes the exchange of Na in water for Ca and Mg in soil eventually resulting in poor soil drainage. SSP is calculated by the following formula:

$$SSP = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \times 100$$

3) Residual sodium carbonate (RSC)

The quantity of HCO_3 and CO_3 in excess of Ca and Mg affects water suitability for irrigation purpose. The suitability of water for irrigation is evaluated by computing residual sodium carbonate (RSC) values as follows:

$RSC = (CO_3^{2-} + HCO_3^{-}) – (Ca^{2+} + Mg^{2+})$

4) Hardness (H_T)

Hardness of water is caused by the presence of divalent cations like Ca^{2+} and Mg^{2+}. Hardness of water is computed by the following formula:

$H_T = 2.5 \times Ca^{2+} + 4.1 \times Mg^{2+}$

All ionic concentrations are expressed as $meqL^{-1}$ but in the case of hardness, cationic concentrations are expressed as mgL^{-1}.

Statistical analysis

Statistical analysis was executed from the analytical results of different river water samples (Gomez and Gomez, 1984). For obtaining the interrelationships between metal ions and chemical quality factors of water samples, correlation studies were performed. All the statistical analysis was performed with SPSS (18.0 version) software.

Results and Discussion

The ionic contaminations in water samples of the Balu river have been presented in Tables 2 to 3. In all the studied water samples, the identified dominant ions such as Ca, Mg, K, Na, and HCO_3 were noted but CO_3 was not detected. In the present study, metal ions under consideration were found in water samples.

pH, EC and TDS values

pH value of water samples collected from the Balu river ranged from 7.52 to 7.68 showing slightly alkaline in nature (Table 2) and this was probably due to the abundance of some alkali metal ions *viz*., Ca, Mg, and Na (Todd and Mays, 2005).According to FAO (1992), the recommended pH range for irrigation water is from 6.5 to 8.4.All the water samples did not surpass the acceptable range and were not problematic for long-term irrigation. Water samples from the Shitalakha river in Bangladesh had similar pH values (Islam *et al*., 2014) as well as other water samples from the Bangshi river (pH=7.04-8.16; Mahbub *et al*., 2014). EC values of the collected water samples varied from 224.0 to 278.0$\mu S\ cm^{-1}$having an average value of 259.3$\mu S\ cm^{-1}$(Table 2). Among the river water samples, 6 samples were categorized as low (C1, EC=250.0 $\mu S\ cm^{-1}$) and the rest 14 samples were rates as medium (C2, EC=250.0-750.0 $\mu S\ cm^{-1}$) salinity hazards (Richards, 1968). This water could be safely used for agricultural crops on soils having moderate permeability. Tareq *et al*. (2013) reported more or less similar EC values (195.0-471.0 $\mu S\ cm^{-1}$) for water samples collected from the Ganges river, while EC values (104.0-141.0 $\mu S\ cm^{-1}$) of Jamuna river water samples were lower than those detected in the current study (Uddin *et al*., 2014). The estimated TDS values of water samples ranged from 146.0 to 180.0mgL^{-1}showing a mean value of 168.2mgL^{-1} (Table 2). All the samples were detected as freshwater because the recorded TDS values were below 1000 mgL^{-1}(Freeze and Cherry, 1979). TDS values (62.0-245.0 mgL^{-1}) of water samples collected from the Brahmaputra river were more or less similar to this study (Tareq *et al*., 2013) while TDS values (106.0-131.0 mgL^{-1}) from the Jamuna river were lower than those observed in the current study (Uddin *et al*., 2014).

Table 2. pH, EC, TDS and major ionic status of surface water samples collected from the Balu river

Sample ID No.	pH	EC µS cm^{-1}	TDS mg L^{-1}	Major ions (meq L^{-1})					
				Ca	Mg	K	Na	CO_3	HCO_3
1	7.58	276.0	179.0	1.10	0.89	0.56	0.84	BDL	4.20
2	7.60	275.0	173.0	1.13	0.97	0.53	0.74	BDL	4.00
3	7.65	277.0	178.0	1.16	0.98	0.57	0.76	BDL	2.20
4	7.62	278.0	174.0	1.10	0.86	0.55	0.50	BDL	2.00
5	7.60	274.0	180.0	0.87	0.88	0.54	0.72	BDL	3.60
6	7.67	273.0	175.0	1.07	0.82	0.54	0.77	BDL	2.10
7	7.52	268.0	176.0	1.60	0.95	0.53	0.79	BDL	2.00
8	7.61	272.0	177.0	1.38	0.93	0.56	0.74	BDL	3.20
9	7.62	270.0	172.0	1.13	0.78	0.54	0.72	BDL	4.00
10	7.65	224.0	146.0	1.16	0.81	0.43	0.73	BDL	1.60
11	7.68	246.0	161.0	1.19	0.83	0.49	0.58	BDL	2.40
12	7.60	251.0	163.0	1.24	0.91	0.50	0.76	BDL	2.00
13	7.61	255.0	168.0	1.19	0.84	0.51	0.72	BDL	3.20
14	7.62	256.0	157.0	0.98	0.92	0.52	0.59	BDL	2.80
15	7.56	248.0	166.0	1.02	0.88	0.48	0.77	BDL	2.40
16	7.62	253.0	161.0	1.10	0.75	0.50	0.71	BDL	4.00
17	7.61	252.0	165.0	1.19	0.79	0.52	0.72	BDL	2.40
18	7.59	244.0	167.0	1.14	0.97	0.49	0.71	BDL	1.60
19	7.67	246.0	161.0	1.20	0.89	0.48	0.76	BDL	2.40
20	7.66	248.0	164.0	1.10	0.92	0.50	0.90	BDL	3.20
Min.	7.52	224.0	146.0	0.87	0.75	0.43	0.50	-	1.60
Max.	7.68	278.0	180.0	1.60	0.98	0.57	0.90	-	4.20
Mean	-	259.3	168.2	1.15	0.88	0.52	0.72	-	2.76
SD	-	14.9	8.7	0.15	0.067	0.034	0.088	-	0.85
*FAO Guideline Value	6.5-8.4	-	-	20.0	5.0	0.50	40.0	0.10	1.50

**FAO (1992); BDL-Below Detection Limit*

Ca, Mg, K and Na status

In the analyzed water samples, the status of Ca, Mg, K, and Na were within the limits of 0.87 to 1.60, 0.75 to 0.98, 0.43 to 0.57 and 0.50 to 0.90meq$L^{-1}$with mean values of 1.15, 0.88, 0.52, and 0.72meqL^{-1}, respectively (Table 2). The concentration of Ca ion in water samples was found higher in respect of any other cation under investigation. According to FAO (1992), the permissible limits of Na, Ca, and Mg are 40.0, 20.0 and 5.0 meqL^{-1}, respectively whereas the acceptable limit of K for irrigation is 0.50 meqL^{-1}(FAO, 1992). Considering these recommended levels of alkali metals, these water samples had no any detrimental effect on soil properties as well as crop growth. In the analyzed samples, the concentrations of Ca, Mg, K, and Na ions of the Turag river in Bangladesh ranged from 4.49 to 6.41, 1.96 to 2.98, 0.70 to 0.81, and 0.54 to 0.61 meq$L^{-1}$with average values of 5.44, 2.53, 0.74and 0.58 meqL^{-1}, respectively, which was higher than the present study (Arefin *et al*., 2016a). In India, the detected values of Ca (0.25-1.70 meqL^{-1}) and Mg (0.25-0.99 meqL^{-1}) were found in surface water samples from the Bhagirathi and Kosi rivers and these values were more or less similar with our findings (Semwal and Jangwan, 2009). Kundu (2012) reported that the concentrations of Ca and Mg in surface waters of Ghaggar river system ranged from 34.50 to 85.50 and 13.60 to 48.20 mg L^{-1}, respectively for assessing its suitability for irrigation purpose and some documented values were higher than this study. Hossain *et al*. (2018) stated that the concentrations of Ca and Mg ions in all the samples collected from the Rupsha ranged from 2.96 to 3.60 and 3.28 to 4.80 meq L^{-1}, which was higher than the present findings. The concentrations of Ca, Mg, K and Na ions in the Buriganga river water samples were found to vary from 1.0 to 2.20, 1.60 to 3.10, 0.13 to 0.75 and 0.19 to 1.91 mg L^{-1}, respectively in winter season (Zaman *et al*., 2002) and these values are analogous to our study.

CO_3 and HCO_3 status

River water samples contained HCO_3varying from 1.60and 4.20meqL^{-1}showing an average value of 2.76meqL^{-1} (Table 2). The concentration of HCO_3identified in 20 samples crossed the acceptable limit (1.50 meqL^{-1}) for irrigation usage and was hazardous for irrigating soils and crops as long-term use (Evangelou, 1998). Semwal and Jangwan (2009) stated that HCO_3 concentration in water samples from the Kosi river, India ranged from 0.38 to 2.12 meq$L^{-1}$and these values were more or less similar to our study. In Bangladesh, the average status of HCO_3 in water samples of the Mayur river was 9.11 meq L^{-1}, which was higher than the present study (Zakir *et al*., 2015). But in case of the Karatoa river in Bangladesh, the average level of HCO_3 was 2.59 meqL^{-1}revealinglower than the values detected in the current study (Zakir *et al*., 2012). In this investigation, CO_3 was not detected in any of the water samples.

Fe, Mn, Cu and Zn status

In the studied samples, the concentration of Fe ranged from 0.10to2.30µg mL^{-1}having an average value of 0.90µg mL^{-1}(Table 3). On the basis of FAO (1992), the detected concentration of Fe in all the samples was within the recommended limit (5.00 µg mL^{-1}). In other Bangladesh river studies, Fe concentrations were more variable (Buriganga river; 0.12-8.59 µg mL^{-1}; Azim *et al*., 2009) or lower (Meghna river; 0.47-1.60 µg mL^{-1}; Hassan *et al*., 2015) than the present study. The status of Mn in all the water samples ranged between 0.15 and 0.66µg $mL^{-1}$with a mean value of 0.52µg mL^{-1}(Table 3). In our study, Mn content in 18 river water samples exceeded the permissible limit for irrigation (0.20 µg mL^{-1}; FAO, 1992) while only 2 river water samples were within the acceptable limit. Dominance of Mn status in river water was mainly prevalent by the industrial activities probably originating from dyeing and textile industries. Consequently, Mn ion was deliberated as chemical contaminant for long-term irrigation system. Similar findings were reported by Arefin *et al*. (2016b) and Hossain and Rahman (2020). In analogous studies of Bangladesh, Mn level was lower in all the samples from the Meghna river (0.0003-0.025 µg mL^{-1}; Hassan *et al*., 2015) and its content was nearly alike to water samples from the Turag river (0.35-0.92 µg mL^{-1}; Arefin *et al*., 2016a). In our study, Cu content in all the samples ranged from 0.024to 0.153µg mL^{-1}having average value of 0.094µg mL^{-1}(Table 3) and the recorded level of Cu was within the acceptable level (0.20 µg mL^{-1}; FAO, 1992). In previous Bangladesh river studies, Cu concentration was generally lower in water samples from the Buriganga river (107.38-201.29 µg mL^{-1}; Ahmed *et al*., 2010). The concentration of Zn in river water samples varied from 0.005 to 0.088µg $mL^{-1}$with a mean value of 0.036µg mL^{-1} (Table 3). The recorded Zn concentrations in water samples were within the safe limit for irrigation usage (2.00 µg mL^{-1}; FAO, 1992). Other Bangladesh studies revealed the higher (Buriganga river; 0.22-0.26 µg mL^{-1}; Mohiuddin *et al*., 2011) and lower (Balu river; 8.39-76.86 µg mL^{-1}; Islam *et al*., 2012) concentrations of Zn in water samples.

Table 3. Metal status of surface water samples collected from the Balu river

Sample ID No	Metal ions (µg mL^{-1})							
	Fe	Mn	Cu	Zn	Cr	Pb	Cd	Ni
1	0.49	0.15	0.024	0.005	0.12	0.62	BDL	BDL
2	0.60	0.50	0.026	0.019	0.15	0.64	BDL	BDL
3	0.53	0.51	0.033	0.016	0.16	0.65	BDL	BDL
4	0.10	0.16	0.037	0.008	0.17	0.78	BDL	0.12
5	1.08	0.55	0.048	0.034	0.19	0.70	BDL	BDL
6	0.13	0.53	0.081	0.026	0.24	BDL	BDL	BDL
7	0.86	0.56	0.087	0.032	0.22	BDL	BDL	BDL
8	0.62	0.54	0.093	0.029	0.26	BDL	BDL	BDL
9	0.95	0.57	0.092	0.035	0.25	BDL	BDL	BDL
10	0.08	0.39	0.093	0.023	0.30	BDL	BDL	BDL
11	0.23	0.55	0.101	0.028	0.29	0.02	BDL	0.32
12	1.54	0.62	0.106	0.035	0.31	BDL	BDL	BDL
13	0.18	0.60	0.110	0.031	0.32	BDL	BDL	BDL
14	1.63	0.62	0.128	0.088	0.30	BDL	BDL	0.24
15	1.22	0.61	0.125	0.042	0.28	BDL	BDL	BDL
16	1.69	0.60	0.127	0.037	0.30	BDL	BDL	BDL
17	1.50	0.63	0.130	0.043	0.34	BDL	BDL	BDL
18	1.80	0.64	0.136	0.043	0.35	BDL	BDL	BDL
19	2.30	0.66	0.153	0.077	0.38	0.04	BDL	BDL
20	0.38	0.65	0.151	0.059	0.40	0.06	BDL	0.05
Min.	0.10	0.15	0.024	0.005	0.12	BDL	-	BDL
Max.	2.30	0.66	0.153	0.088	0.40	0.78	-	0.32
Mean	0.90	0.52	0.094	0.036	0.27	0.44	-	0.18
SD	0.67	0.14	0.041	0.020	0.078	0.34	-	0.12
*FAO Guideline Value	5.00	0.20	0.20	2.00	0.10	5.00	0.01	0.20

**FAO (1992); BDL-Below Detection Limit*

Cr, Cd, Pb and Ni status

River water samples contained Cr ranging from 0.12 and 0.40µg $mL^{-1}$with a mean value of 0.27µg mL^{-1}(Table 3).Considering the permissible limit of 0.10 µg mL^{-1}(FAO, 1992), the detected Cr level in all the samples was treated as chemical contaminant for long-term irrigation system. Perhaps, Cr content in the contaminated river water was derived from the textile and leather tanning industries clearly indicating an anthropogenic supply of this heavy metal due to inconsiderate discharge of industrial effluents into the river. Similar annotations were reported by Alam *et al*. (2003), Ahmed *et al*. (2010), Islam *et al*. (2014), Arefin *et al*. (2016a), Hossain and Rahman (2020), who stated that Cr was considered as dominant heavy metal ion in water samples from peri-urban rivers *viz*., Bangshi, Buriganga, Turag, and Shitalakha in Bangladesh. In the studied river water samples, Cd content was below the detection limit indicating no hazardous impact on soils and crops (Table 3). Correspondingly, the concentrations of Cd in water samples collected from the Buriganga, Turag, and Shitalakha rivers in Bangladesh showed low Cd level (Ahmed *et al*., 2010; Islam *et al*., 2014). Conversely, the status of Cd ion in water samples collected the Rupsha river was from 0.016 to 0.035 µg mL^{-1} (Hossain *et al*., 2018), which was higher than the present study. The level of Pb in all the water samples ranged from BDL to 0.78 µg mL^{-1} with an average value of 0.44 µg mL^{-1}(Table 3), which were far below the acceptable limit (5.00 µg mL^{-1}; FAO, 1992) posing no risk to the safety of irrigation water. In other water samples from Bangladesh river Pb levels were very low as observed by Alam *et al*. (2003) and Ahmed *et al*. (2010) while Islam *et al*. (2015) reported that the Karatoa river contained Pb ranging from 8.00 to 64.00 µg mL^{-1}. The concentration of Ni in water samples was found to vary from BDL to 0.32µg mL^{-1} with an average value of 0.18µg mL^{-1}(Table 3). In the analyzed samples, Ni concentration of 2 samples surpassed the safe limit (0.20 µg mL^{-1}; FAO, 1992), 2 samples were within the acceptable limit whereas the rest 16 samples were below detection limit of Ni. As compared to the present study, Ni concentrations were found higher in water samples from the Buriganga river (7.15-10.32 µg mL^{-1}; Ahmed *et al*., 2010) and the Karatoa river (9.30-66.00 µg mL^{-1}; Islam *et al*., 2015).

SAR, SSP, RSC and hardness values

The calculated values of SAR, SSP and RSC varied from 0.40 to 0.72, 34.1 to 41.6%, and -0.55 to 3.21 meq L^{-1}, respectively (Table 4). River water samples were considered as excellent in terms of alkalinity hazard (S1) because the recorded SAR values are less than 10 (Richards, 1968). Considering SSP values, 16 samples were considered as good (SSP=20-40%) and only 4 samples were permissible (SSP=41-60%) class (Todd and Mays, 2005). According to the classification suggested by Schwartz and Zhang (2012), 15 samples were under suitable (RSC<1.25 meq L^{-1}) whereas the rest 4 samples were under marginal (RSC=1.25-2.50 meq L^{-1}) except 1 sample for irrigation usage. As per SAR values, water samples of the Buriganga river in Bangladesh were excellent in quality and were free from RSC indicating suitable for irrigation usage (Zaman *et al*., 2002). The computed SSP values in the Rupsha water samples ranged from 25.26 to 30.63% and these values were lower than current study (Hossain *et al.*, 2018). RSC values of water samples in the Turag river varied from -8.15 and -5.53 meq L^{-1} (Arefin *et al*., 2016a), which was lower than the current study. In all the studied river water samples, hardness (H_T) values ranged from 87.8 to 126.7 mg L^{-1} (Table 4). Sawyer and McCarty (1967) proposed a classification for irrigation water based on hardness and according to this classification, all the samples were moderately hard (H_T=75-150 mg L^{-1}) in quality. This finding might be due to the presence of Ca and Mg ions in water samples (Todd and Mays, 2005). Hardness (H_T) values of the Rupsha river water samples ranged from 327.67 to 391.51 mg L^{-1} (Hossain *et al*., 2018), which were also higher than the present investigation. Similar findings were reported by Zaman *et al*. (2001), who stated that most of the water samples collected from the Buriganga river were classified as moderately hard in quality.

Table 4. Contamination rating of surface water samples collected from the Balu river

Sample ID No.	SAR		SSP		RSC		H_T	
	Ratio	Class	%	Class	meq L^{-1}	Class	mg L^{-1}	Class
1	0.68	Ex.	41.5	Perm.	3.21	Unsuit.	98.8	MH
2	0.56	Ex.	37.7	Good	1.90	Mar.	104.0	MH
3	0.58	Ex.	38.0	Good	-0.15	Suit.	107.0	MH
4	0.40	Ex.	35.0	Good	0.04	Suit.	97.3	MH
5	0.62	Ex.	41.6	Perm.	1.83	Mar.	87.8	MH
6	0.63	Ex.	41.0	Perm.	0.11	Suit.	93.8	MH
7	0.55	Ex.	34.1	Good	-0.55	Suit.	126.7	MH
8	0.54	Ex.	36.0	Good	0.89	Suit.	114.0	MH
9	0.58	Ex.	40.0	Good	2.09	Mar.	94.9	MH
10	0.55	Ex.	37.0	Good	-0.37	Suit.	97.9	MH
11	0.46	Ex.	34.6	Good	0.38	Suit.	100.0	MH
12	0.58	Ex.	37.0	Good	-0.15	Suit.	107.0	MH
13	0.57	Ex.	38.0	Good	1.17	Suit.	101.0	MH
14	0.49	Ex.	37.0	Good	0.90	Suit.	94.3	MH
15	0.64	Ex.	40.0	Good	0.50	Suit.	94.3	MH
16	0.59	Ex.	38.0	Good	2.16	Mar.	91.4	MH
17	0.57	Ex.	38.5	Good	0.42	Suit.	98.4	MH
18	0.56	Ex.	36.3	Good	-0.51	Suit.	105.0	MH
19	0.59	Ex.	37.2	Good	0.31	Suit.	104.0	MH
20	0.72	Ex.	41.0	Perm.	1.18	Suit.	100.0	MH
Min.	0.40	-	34.1	-	-0.55	-	87.8	-
Max.	0.72	-	41.6	-	3.21	-	126.7	-
Mean	0.57	-	38.0	-	0.76	-	100.8	-
SD	0.071	-	2.26	-	1.03	-	8.64	-

Legend:*Ex.= Excellent; Perm.= Permissible; Suit.= Suitable; Mar.=Marginal; Unsuit.=Unsuitable & MH= Moderately Hard*

Relationships between chemical quality parameters of river water samples

The results in Table 5 showed that the relationships between chemical quality parameters *viz*., EC, TDS, SAR, SSP, RSC and H_T were established. Among the combination, three significant positive correlations existed between EC vs TDS, SAR vs SSP, and SSP vs RSC but only one negative significant correlation existed among the combination of SSP vs H_T. These results revealed positive significant correlations indicating synergistic relationship between the chemical parameters under consideration. In rest of the combinations, the relationships between chemical quality parameters were insignificant because their respective calculated r values were below the tabulated values of *r* at both 1% and 5% levels of significance.

Table 5. Relationships between chemical quality parameters of the Balu river water samples

Parameters	TDS	SAR	SSP	RSC	Hardness
EC	0.939^{**}	-0.050^{NS}	0.177^{NS}	0.329^{NS}	0.099^{NS}
TDS	-	0.040^{NS}	0.200^{NS}	0.245^{NS}	0.150^{NS}
SAR	-	-	0.793^{**}	0.421^{NS}	-0.145^{NS}
SSP	-	-	-	0.563^{**}	-0.642^{**}
RSC	-	-	-	-	-0.283^{NS}

Legend:***Significant at 1% level;* ^{NS}*Non-significant; Tabulated values of r with 18 df are 0.444 and 0.561 at 5% and 1% levels of significance, respectively*

Conclusion

From the present findings, it is concluded that among the detected ions under study, Cr and Mn ions were above the allowable limits for long-term irrigation and these metal ions were considered as chemical contaminants in water samples of the Balu river for irrigating soils and crops. Therefore, these detected ions should be considered for long-term irrigation having the risk of contamination of these metal ions in soil environment eventually exhibiting crop toxicities and thereby affecting human health through food chain.

References

Abdullah, E.J. 2013. Quality assessment for Shatt Al-Arab river using heavy metal pollution index and metal index. *J. Environ. Earth Sci.,* 3:114–120.

Ahmed, M..K.; Islam, S.; Rahman, S.; Haque, M.R. and Islam, M.M.2010. Heavy metals in water, sediment and some fishes of Buriganga river, Bangladesh. *Inter. J. Environ. Res.,* 4:321–332.

Alam, A.M.S.; Islam, M.A.; Rahman, M.A.; Siddique, M.N. and Matin, M.A.2003. Comparative study of the toxic metals and non-metal status in the major river system of Bangladesh. *Dhaka Univ. J. Sci.,* 51:201–208.

Ali, M.M.; Ali, M.L.; Islam, M.S. and Rahman, M.Z.2016. Preliminary assessment of heavy metals in water and sediment of Karnaphuliriver, Bangladesh. *Environ. Nanotechnol. Monit. Manag.,* 5:27–35.

APHA (American Public Health Association) 2012. *Standard Methods for the Examination of Water and Wastewater*. 22nd edn., American Water Works Association & Water Environment Federation, Washington, USA. pp. 1–39 ~ 3–14.

Arefin, M.T.; Rahman, M.M.;Zaman, M.W. and Kim, J.E. 2016a. Heavy metal contamination in surface water used for irrigation: Functional assessment of the Turagriver in Bangladesh. *J.Appl. Biol. Chem.,* 59:83–90.

Arefin, M.T.; Rahman, M.M.; Zaman, M.W. and Kim, J.E. 2016b. Appraisal of heavy metal status in water for irrigation usage of the Bangshiriver, Bangladesh. *Appl. Biol. Chem.,* 59: 729–737.

Azim, M.A.; Quraishi, S.B. and Islam, R. 2009. Impact of dumping untreated waste water on water quality of the river Buriganga, Bangladesh. *Dhaka Univ. J. Sci.,* 57:101–106.

Chojnacka, K.; Chojnacki, A.; Gorecka, H. and Gorecki, H.2005. Bioavailability of heavy metals from polluted soils to plants. *Sci. Total Environ.,* 337:175–182.

Dey, S.; Das, J. and Manchur, M.A.2015. Studies on heavy metal pollution of Karnaphuliriver, Chittagong, Bangladesh. *J. Environ. Sci. Toxicol. Food. Technol.,* 9:79–83.

Evangelou, V.P. 1998.*Environmental Soil and Water Chemistry: Principles and Applications*. John Wiley & Sons, Inc., New York, USA. pp. 478–485.

FAO (Food and Agriculture Organization) 1992.*Wastewater Treatment and Use in Agriculture*. FAO Irrigation and Drainage Paper 47, Italy. pp. 30–32.

Freeze, A.R. and Cherry, J.A. 1979. *Groundwater*. Prentice Hall Inc., Englewood Cliffs, New Jersey, USA.

Gomez, K.A.and Gomez, A.A. 1984.*Statistical Procedures for Agricultural Research*. 2nd ed., John Wiley & Sons, Inc., UK.pp. 357–371.

Gupta, P.K. 2013.*Soil, Plant, Water and Fertilizer Analysis*. 2nd ed., Agrobios Agrohouse, New Delhi, India. pp. 254–262.

Hassan, M., Rahman, M.A.T.M.T.; Saha, B. and Kamal, A.K.I.2015. Status of heavy metals in water and sediment of the Meghnariver, Bangladesh. *American J. Environ. Sci.,* 11:427–439.

Hossain, M.D.; Rahman, M.M.; Chandra, J.B.; Shammi, M. and Uddin, M.K.2012. Present status of water quality of the Bangshiriver, Savar, Dhaka, Bangladesh. *Bangladesh J. Environ. Res.,* 10:17–30.

Hossain, M.K.; Rahman, M.M. and Haque, S. 2018. Quantitative assessment of water contaminants in the Rupsha river of Khulna region for irrigation usage. *J. Environ. Sci. &Natural Resources,*11: 145–151.

Hossain, F.N. and Rahman, M.M. 2020. Appraisal of ionic contamination in water of the Bangshi river for irrigation usage towards food safety. *J. Bangladesh Agril. Univ.,* 18: 86–93.

Islam, M.Z., Noori, A., Islam, R., Azim, M.A. and Quraishi, S.B.2012. Assessment of the contamination of trace metal in Balurive rwater, Bangladesh. *J. Environ. Chem. Ecotoxicol.,* 4:242–249.

Islam, M.S.; Han, S.; Ahmed, M.K. and Masunaga, S.2014. Assessment of trace metal contamination in water and sediment of some riversin Bangladesh. *J. Water Environ. Technol.,* 12:109–121.

Islam, M.S., Ahmed, M.K., Raknuzzaman, M., Mamun, M.H.A. and Islam, M.K.2015. Heavy metal pollution in surface water and sediment: A preliminary assessment of an urban river in a developing country. *Ecol. Indicators,* 48:282–291.

Kibria, G.; Hossain, M.M.; Mallick, D.; Lau, T.C. and Wu, R. 2016. Monitoring of metal pollution in waterways across Bangladesh and ecological and public health implications of pollution. *Chemosphere,* 165: 1–9.

Kundu, S.2012. Assessment of surface water quality for drinking and irrigation purposes: a case study of Ghaggarriver system surface waters. *Bull. Environ. Pharmacol. Life Sci.,* 1:1–6.

Mahbub, A.; Tanvir, H.M.D. and Afrin, L.T. 2014. An evaluation of environmental and social impact due to industrial activities – A case study of Bangshiriver around Dhaka Export Processing Zone (DEPZ), Bangladesh. *Inter. Res. J. Environ. Sci.,* 3:103–111.

Mohiuddin, K.M.; Ogawa, Y.; Zakir, H.M.; Otomo, K. and Shikazono, N. 2011. Heavy metals contamination in water and sediments of an urbanriver in a developing country. *Inter. J. Environ. Sci. Technol.,*8: 723–736.

Nduka, J.K. and Orisakwe, O.E. 2011. Water quality issues in the Niger Delta of Nigeria: A look at heavy metal levels and some physicochemical properties. *Environ. Sci. Pollu. Res.,* 18: 237–246.

Rahman, M. and Mondal, M.S.2013. Impact of the Bangshiriver water quality on irrigated soil and rice in Bangladesh. *Asian J. Water Environ. Pollu.,* 10:129–139.

Rahman, M.T.; Ziku, A.L.M.E.; Choudhury, T.R.; Ahmad, J.U. and Mottaleb, M.A.2015. Heavy metals contaminations in irrigated vegetables, soils and river water: A compressive study of Chilmari, Kurigram, Bangladesh. *Inter. J. Environ. Ecol. Family Urban Stud.,* 5:29–42.

Richards, L.A.(ed.) 1968.*Diagnosis and Improvement of Saline and Alkaline Soils.* Agricultural Handbook 60, Oxford and IBH Publishing Co. Ltd., Calcutta, India. pp. 98–99.

Roy, K.; Ansari, M.S.; Karim, M.R.; Das, R.; Mallick, B. and Gain, A.K. 2015. Irrigation water quality assessment and identification of river pollution sources in Bangladesh: implications in policy and management. *J. Water Resour. Hydrol. Eng.,* 4:303–317.

Saleem, M.; Iqbal, J. and Shah, M.H. 2015.Geochemical speciation, anthropogenic contamination, risk assessment and source identification of selected metals in fresh water sediment - A case study from Mangla lake, Pakistan. *Environ. Nanotechnol. Monit. Manag.,* 4:27–36.

Samad, M.A.; Mahmud, Y.; Adhikary, R.K.; Rahman, S.B.M.; Haq, M.S. and Rashid, H. 2015. Chemical profile and heavy metal concentration in water and freshwater species of Rupshariver, Bangladesh. *American J. Environ. Protect.,* 3:180–186.

Sawyer, C.N. and McCarty, P.L. 1967.*Chemistry for Salinity Engineers*. 2nd edn., McGraw Hill, New York, USA. p. 518.

Schwartz, F.W. and Zhang, H. 2012. *Fundamentals of Ground Water*. Wiley India Pvt. Ltd. New Delhi, India. pp. 374-377.

Semwal, N. and Jangwan, J. S. 2009. Major ion chemistry of river Bhagirathi and river Kosi in the Uttarakh and Himalaya. *Inter. J. Chem. Sci.,* 7:607–616.

Sharma, R.K.; Agrawal, M. and Marshall, F.M.2009. Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. *Food Chem. Toxicol.,* 47:583–591.

Tareq, S.M.; Rahaman, M.S.; Rikta, S.Y.; Islam, S.M.N. and Sultana, M.S.2013. Seasonal variations in water quality of the Ganges and Brahmaputra river, Bangladesh. *Jahangirnagar Univ. Environ. Bull.,* 2:71–82.

Tandon, H.L.S. (ed.) 2013. *Methods of Analysis of Soils, Plants, Waters, Fertilizers and Organic Manures*. Fertilizer Development and Consultation Organization, New Delhi, India.

Todd, D.K. and Mays, L.W. 2005. *Groundwater Hydrology*. 3rd ed., John Wiley and Sons Inc., New York, USA.

Uddin, M.N.; Alam, M.S.; Mobin, M.N. and Miah, M.A. 2014. An assessment of the river water quality parameters: A case of Jamuna river. *J. Environ. Sci. & Natural Resources,* 7: 249–256.

Zakir, H.M.; Sattar, M.A. and Quadir, Q.F. 2015. Cadmium pollution and irrigation water quality assessment of an urban river: A case study of the Mayur river, Khulna, Bangladesh. *J. Chem. Biol. Phys. Sci.,* 5: 2133–2149.

Zakir, H.M.; Rahman, M.M.; Rahman, A.; Ahmed, I. and Hossain, M.A.2012. Heavy metals and major ionic pollution assessment in waters of midstream of the river Karatoa in Bangladesh. *J. Environ. Sci. & Natural Resources,* 5: 149–160.

Zaman, M.W.; Islam, M.J. and Rahman, M.M.2001. Seasonal fluctuation of water toxicity in the Burigangariver. *Bangladesh J. Train. Dev.,* 14:153–160.

Zaman, M.W.; Rahman, M.M. and Islam, M.J.2002. Freshwater toxicity of the Burigangariver during monsoon and winter seasons. *Bangladesh J. Agric. Sci.,* 29: 165–171.