Appraisal of ionic contamination in water of the Bangshi river for irrigation usage towards food safety

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ABSTRACT

Ionic contamination has become a serious environmental problem due to long-term disposal of untreated industrial effluent containing metal ions in river water ecosystem when applied to soil system as irrigation water. Considering this issue, an attempt was made to explore ionic contamination in water samples collected from the adjacent crop fields irrigated with the contaminated river during dry season towards food safety. Fifteen water samples were collected randomly from the upstream to downstream of the Bangshi river to determine ions in order to categorize these samples on the basis of their applicability for irrigation usage. The chemical analyses included pH, electrical conductivity (EC), total dissolved solids (TDS), cations (Ca, Mg, K, Na, Cd, Cr & Mn) and anions (CO₃, HCO₃, CI & PO₄). pH values of river water samples ranged from 6.5 to 7.6 indicating slightly acidic to slightly alkaline in nature. All the water samples were categorized as fresh water (TDS<1,000 mg L⁻¹) in quality. River water samples were medium salinity (C₂, EC=250-750 μS cm⁻¹) hazard and were low alkalinity (S₁, SAR<10) hazard expressing as C₂S₁. Regarding sodium adsorption ratio (SAR) values, samples were under excellent class (SAR<10) and as per soluble sodium percentage (SSP) values, all the samples were classified as permissible (SSP=40-60%) to doubtful (SSP=60-80%) classes. River water samples under consideration were free from residual sodium carbonate (RSC) and belonged to suitable (RSC<1.25 meq L⁻¹) class. On the basis of hardness (H₂), all the collected water samples were moderately hard (H₂=75-150 mg L⁻¹) in quality. Regarding the obtained permeability index (PI) values, water samples were under class-II implying 25% of maximum permeability when applied to soil system as irrigation water. The concentrations of Ca, Mg, K, Na, Cd, HCO₃⁻, Cl and PO₄ in the studied water samples were within the acceptable limit and these ions were non-problematic for irrigation. Among the detected ions in river water samples, Cr and Mn ions were above the permissible limits for long-term irrigation usage and these ions were treated as chemical contaminants. The relationships between chemical quality parameters of river water such as EC, TDS, SAR, SSP, RSC, H₂ and PI were established. Among the combination, significant correlation was existed between SAR vs SSP, TDS vs RSC, SSP vs PI, RSC vs H₂ and RSC vs PI. Therefore, it is concluded from the present findings that among the detected ions, only two metals viz. Cr and Mn should be considered as chemical contaminants for long-term irrigation system towards food safety.

Introduction

Rivers are the important surface water sources and are being used for various agricultural purposes especially for irrigation. Ionic contamination of riverine ecosystems has become a serious environmental problem due to the rapid urbanization and industrialization. Due to uncontrolled rapid industrialization, river water pollution is posing an increasing threat to surface water irrigation in Bangladesh and degradation of water quality is likely to cause toxic effects on crops (Anny et al., 2017; Hafizur et al., 2017). The indiscriminate discharge of crudely treated and untreated industrial wastewater introduces toxic substances into aquatic environments degrading water quality to the extent that surface water is unsuitable for agricultural irrigation (Qadir et al., 2010; Ouali et al., 2018). If the contaminated water is used for irrigation, some metal ions may accumulate in soil and create crop toxicity resulting contamination in food chain.

Savar area of Dhaka is one of the major industrial zones in Bangladesh, as the country’s second largest Dhaka Export Processing Zone (DEPZ) is located there and the largest industrial belt of Bangladesh at present houses 92 industrial units which are categorically the leading pollution creators. These industrial units include textile/knitting plastic goods, footwear/leather goods, metal products, electronic goods, paper products, chemicals and fertilizers and miscellaneous products (Khanam et al., 2011). All these industrial activities severely deteriorate water quality of the Bangshi river, lakes, waterways, and wetlands that are either inside or adjacent to Savar industrial areas, thus posing dreadful risks to human health and environment of the area (Rahman et al., 2008; Ahmed et al., 2009a). Usually,
water quality assessment is practiced by comparing measured physicochemical parameters with threshold values, recommended by national or international bodies (Bhuiyan et al., 2011).

Recently, special attention has been given to some problematic ions in water for management of these ions to reduce environmental problems related to soil properties and food quality. In the study areas, farmers are utilizing water of the Bangshi river for irrigation purpose due to scarcity of other sources of fresh water. For this purpose, water analyses are very important for evaluating its quality for irrigation and understanding of soil and water management. Keeping this fact in mind, a research work was undertaken to assess the ionic contamination of water in the selected sites of the Bangshi river for irrigation purpose towards food safety.

Materials and Methods

Water sampling area

Water sampling sites were concentrated at different locations of the Bangshi river at Savar upazila under Dhaka district of Bangladesh. The exact location of each sampling point was determined using GPS. Accordingly, the entire sampling sites were confined between 22°46'18.7" to 22°49'08.7"N latitude and 89°33'49.5" to 89°35'21.8"E longitude. The sampling locations have been identified using GPS. The detailed water sampling sites have been illustrated in Fig. 1. This sampling was carried out in the month of February, 2018.

![Study area](image)

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

Water sampling technique

Considering the crop fields irrigated with this river water, fifteen water samples were collected randomly in 500 mL plastic bottles previously washed with diluted HCl (1:1) from the upstream to downstream of this river. All the bottles were rinsed 3 to 4 times before water sampling. For metal analysis, the collected water samples were acidified (pH<2) with HNO₃ to prevent the loss of metal ion following the sampling technique of APHA (2012). All the plastic bottles were sealed tightly and transferred to the Postgraduate Research Laboratory, Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh for chemical analysis. All the samples were kept in a cool, clean, and dry place. River water samples were filtered through filter papers (Whatman No.: 1 and 42) to remove undesirable solids, sediments and suspended materials or chemicals before commencing the chemical analysis.

Water analytical methods

pH, EC and TDS values of water samples were measured electrometrically as outlined by Gupta (2013). Ethylene diamine tetraacetic acid (EDTA) titrimetric method was used to determine the concentrations of Ca and Mg ions in water samples (Tandon, 2013). In river water samples, the contents of K and Na ions were determined by flame photometer (model: Jenway PEP7, UK) while the levels of Cd, Cr, and Mn ions were analyzed directly by atomic absorption spectrophotometer (model: Shimadzo AA7000, Japan) as described by APHA (2012). Titrimetric method was used to determine the concentrations of Cl and HCO₃⁻ ions from water samples (Gupta et al., 2012; Tandon, 2013). The status of PO₄³⁻ ion in river water samples was determined by spectrophotometer (model: TG-60U, UK) following the method of APHA (2012).

Ionic contamination rating

The following chemical quality factors were considered for assessing major ionic contamination of water samples by the interpretation of analytical result:

i) Sodium adsorption ratio (SAR)

\[
\text{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}
\]

ii) Soluble sodium percentage (SSP)

\[
\text{SSP} = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100
\]

iii) Residual sodium carbonate (RSC)

\[
\text{RSC} = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})
\]

iv) Hardness (Hₑ)

\[
H_e = 2.5 \times Ca^{2+} + 4.1 \times Mg^{2+}
\]
Ionic contamination of the Bangshi river water

v) Permeability index (PI)
\[ PI = \left[ (Na^+ + \sqrt{HCO_3^-}) / (Ca^{2+} + Mg^{2+} + Na^+) \right] \times 100 \]
Whereas, all the ionic concentrations were expressed as meq L\(^{-1}\) but in case of hardness, cationic concentrations were expressed as mg L\(^{-1}\) (Raghunath, 1987).

Statistical analysis
Statistical analyses of analytical results obtained from river water samples were performed according to Gomez and Gomez (1984). MS Excel programs were used for correlation studies.

Results and Discussion

**pH, EC and TDS values**

PH value of the selected water samples from the Bangshi river ranged from 6.5 to 7.6 indicating slightly acidic to slightly alkaline in nature (Table 2). According to FAO (1992), the recommended pH range for irrigation water is from 6.5 to 8.4. Results revealed that all the samples were within the acceptable range and were not problematic for long-term irrigation. Arefin et al. (2016a) reported that pH value of the Turag river was from 7.40 to 7.79, which was higher than the present findings. Hossain et al. (2018) stated that pH value of the Rupsha river varied from 7.34 to 7.56, which was higher than the current study. An investigation was conducted on the Buriganga river by Fatema et al. (2018), who found that pH value ranged from 7.61 to 8.97. These values were also higher than the present study.

The results in Table 2 showed that electrical conductivity (EC) values of all the collected water samples fluctuated from 604.0 to 740.0 µS cm\(^{-1}\) with a mean value of 693.4 µS cm\(^{-1}\). According to Wallender and Tanji (2011), all the samples under test were rated in C2 category (EC=250.0-750.0 µS cm\(^{-1}\)) indicating medium salinity (Fig. 2). Considering EC values, all the water samples could be safely used for moderate salt tolerance crops growing on soils with moderate level of permeability. EC values of the Buriganga river samples ranged from 180.0 to 598.0 µS cm\(^{-1}\) (Fatema et al., 2018), which was lower than the present investigation. Another study was conducted by Hossain et al. (2018), who found that EC values of the Rupsha river fluctuated from 899.0 to 1,409.0 µS cm\(^{-1}\), which was higher than the current study. EC values of surface water of the Shitalakhyia river were found to range from 131.6 to 2,292.0 µS cm\(^{-1}\) (Mottalib et al., 2016).

Total dissolved solids (TDS) values of water samples were within the range of 442.0 to 556.0 mg L\(^{-1}\) having an average value of 518.13 mg L\(^{-1}\) (Table 2). According to Freeze and Cherry (1979), all the samples were classified as fresh water (TDS<1,000 mg L\(^{-1}\)) in quality. These water samples would not affect soil properties and plant growth as irrigation water. Another investigation was conducted by Rehnuma et al. (2016), who found that TDS values of the same river fluctuated from 408.0 to 561.0 mg L\(^{-1}\) during dry season. Hossain et al. (2018) reported that TDS values of water samples in the river Rupsha were within the range of 600.0 to 940.0 mg L\(^{-1}\), which was higher than the present study. Tareq et al. (2013) observed that TDS values in water samples of the Brahmaputra river ranged from 62.0 to 245.0 mg L\(^{-1}\), which was lower than the current investigation. TDS values in water samples of the Jamuna river varied from 106.0 to 131.0 mg L\(^{-1}\) (Uddin et al., 2014). All these values were lower than the present study.

Table 2. pH, EC, TDS and anionic constituents of the Bangshi river water samples

| Sample ID No. | pH    | EC (µS cm\(^{-1}\)) | TDS (mg L\(^{-1}\)) | Major anions (meq L\(^{-1}\)) | Minor anion (µg mL\(^{-1}\)) |
|---------------|-------|---------------------|---------------------|-------------------------------|-------------------------------|
|               |       |                     |                     | Cl                           | HCO\(_3^-\)                   |
| 1             | 7.4   | 695                 | 445                 | 0.90                          | 0.17                          |
| 2             | 7.6   | 724                 | 550                 | 1.86                          | 0.20                          |
| 3             | 6.5   | 652                 | 442                 | 0.90                          | 0.10                          |
| 4             | 6.8   | 690                 | 484                 | 1.00                          | 0.20                          |
| 5             | 7.5   | 680                 | 550                 | 1.70                          | 0.38                          |
| 6             | 7.6   | 736                 | 544                 | 1.50                          | 0.72                          |
| 7             | 7.3   | 680                 | 484                 | 1.24                          | 0.58                          |
| 8             | 7.4   | 673                 | 538                 | 1.26                          | 0.44                          |
| 9             | 7.5   | 674                 | 540                 | 1.82                          | 0.89                          |
| 10            | 7.3   | 685                 | 556                 | 1.32                          | 1.00                          |
| 11            | 7.6   | 740                 | 552                 | 1.38                          | 2.40                          |
| 12            | 7.3   | 604                 | 506                 | 1.24                          | 2.10                          |
| 13            | 7.2   | 712                 | 505                 | 1.18                          | 1.40                          |
| 14            | 7.5   | 728                 | 525                 | 1.16                          | 1.80                          |
| 15            | 7.6   | 728                 | 551                 | 1.60                          | 2.20                          |
| Min.          | 6.5   | 604                 | 442                 | 0.90                          | 1.00                          |
| Max.          | 7.6   | 740                 | 556                 | 1.86                          | 2.40                          |
| Mean          | 7.0   | 693.4               | 518.13              | 1.39                          | 1.74                          |
| SD            | 6.345 | 38.79               | 0.29                | 0.38                          | 0.17                          |

\(^{8}\)FAO (1992)

**Cl, HCO\(_3^-\) and PO\(_4^{3-}\) levels**

Water samples collected from the Bangshi river contained Cl ion within the range of 0.90 to 1.86 meq L\(^{-1}\) with a mean value of 1.39 meq L\(^{-1}\) (Table 2). The recommended maximum concentration of Cl in irrigation water is 4.00 meq L\(^{-1}\) (FAO, 1992). On the basis of the acceptable range, all the water samples were within the acceptable range and this anion was not problematic for irrigation usage. Hossain et al. (2018) evaluated that water samples collected from the Rupsha river contained Cl ion within the limit of 16.00 to 24.99 meq L\(^{-1}\), which was higher than the current study. Rout (2017) found that Cl content in water samples of the Yamuna river in Haryana, India fluctuated from 24.5 to 26.0 meq L\(^{-1}\) and these limits were also higher than the present investigation. The concentration of Cl ion in all the samples collected from the Kuroorthodu river in India ranged from 3.5 to 9.9 mg L\(^{-1}\) in monsoon and 7.0 to 37.5 mg L\(^{-1}\) in post-monsoon (Paul et al., 2018). All these values were higher than the present study.

The results in Table 2 revealed that the concentration of HCO\(_3^-\) ion in the collected water samples fluctuated from 1.00 to 2.40 meq L\(^{-1}\) with an average value of 1.74 meq L\(^{-1}\). According to FAO (1992), maximum permissible limits of HCO\(_3^-\) ion for irrigation water used
continuously on soil is 1.5 meq L\(^{-1}\). As per this acceptable range, HCO\(_3\) status of 11 water samples was above the recommended limit and these samples were not suitable for irrigation purpose. The concentration of HCO\(_3\) ion in the collected water samples of the Rupsha river fluctuated from 0.05 to 0.09 meq L\(^{-1}\) (Hossain et al., 2018) and these values were lower from the present investigation. In water samples of the Kosi river in India, HCO\(_3\) concentration was found to vary between 0.38 and 2.12 meq L\(^{-1}\) (Semwal and Jangwan, 2009). These limits were more or less similar to the current study. Arefin et al. (2016a) reported that in the Turag river, the concentration of HCO\(_3\) ranged from 0.80 to 2.40 meq L\(^{-1}\). All these values of this anion were more or less similar to the current study.

The level of PO\(_4\) ion in the selected water samples varied from 0.36 to 0.92 µg mL\(^{-1}\) having an average value of 0.59 µg mL\(^{-1}\) (Table 2). The permissible limit of PO\(_4\) ion in irrigation water is 2.00 µg mL\(^{-1}\) (FAO, 1992). As per the acceptable range, all the water samples were suitable for irrigation having no hazard effects on soil properties and crop growth in the study area. The level of PO\(_4\) ion in water samples varied from 0.25 to 1.47 µg mL\(^{-1}\) in the Rupsha river (Hossain et al., 2018), which was more or less similar to the present study. A research work was performed by Pia et al. (2018), who stated that the range of PO\(_4\) ion fluctuated from 392.4 to 401.2 µg L\(^{-1}\) in the Shitalakshya river and these levels were higher than the current study. Dunca et al. (2018) conducted a research work on water samples of the Timis river in Romania and reported that PO\(_4\) level of 10 sampling sites was from 0.042 to 0.437 µg mL\(^{-1}\), which was lower from the current findings.

**Ca, Mg, K and Na levels**

The concentrations of Ca and Mg ions in all the samples fluctuated from 1.14 to 1.94 and 0.88 to 1.50 meq L\(^{-1}\) with mean values of 1.48 and 1.10 meq L\(^{-1}\), respectively (Table 3). Water containing less than 20.00 meq L\(^{-1}\) of Ca and 5.00 meq L\(^{-1}\) of Mg ions is suitable for irrigating agricultural crops (FAO, 1992). Considering the limits of these ions, water samples of the study area could safely be applied for long-term irrigation without any harmful effect on soil properties and crop growth. Hossain et al. (2018) stated that the concentrations of Ca and Mg ions in all the samples of the Rupsha river were found to vary from 2.96 to 3.60 and 3.28 to 4.80 meq L\(^{-1}\), respectively, which was higher than the present findings. Semwal and Jangwan (2009) studied that Ca concentration in water samples of the Kosi river in India varied from 0.25 to 1.70 meq L\(^{-1}\), which was more or less similar to the present study. They also stated that Mg concentration in water samples of the Bhagirathi river in India varied from 0.25 to 0.99 meq L\(^{-1}\), which was lower than the present study. The results in Table 3 reported that the contents of K and Na ions in all the samples ranged from 0.68 to 0.98 and 2.18 to 5.40 meq L\(^{-1}\) with average values of 0.87 and 3.54 meq L\(^{-1}\), respectively. On the basis of FAO (1992), water containing less than 0.50 meq L\(^{-1}\) of K and 40.00 meq L\(^{-1}\) of Na ions is suitable for irrigating agricultural crops. As per the limits of these alkali metals, water samples could safely be applied for long-term irrigation but in case of K ion, all the collected river water samples might be problematic for irrigation. In the Rupsha river sample, the concentration of K ion was found to vary from 0.10 to 0.16 meq L\(^{-1}\) (Hossain et al., 2018) and these levels were lower than the current study. Semwal and Jangwan (2009) investigated that K level in water samples of the Kosi river in India varied from trace to 0.10 meq L\(^{-1}\), which was lower than the present finding. Hossain et al. (2018) stated that the concentration of Na ion in the Rupsha river varied from 2.33 to 3.23 meq L\(^{-1}\), which was more or less similar to the present findings. Semwal and Jangwan (2009) stated that the contents of Na ions in water samples of the Bhagirathi river in India varied from 0.04 to 0.22 meq L\(^{-1}\), which was lower than the present study.

### Table 3. Cationic constituents of the Bangshi river water samples

| Sample ID | Major ions (meq L\(^{-1}\)) | Metal ions (µg mL\(^{-1}\)) |
|-----------|--------------------------|---------------------------|
|           | Ca | Mg | K | Na | Cd | Cr | Mn | |
| 1         | 1.64 | 1.36 | 0.70 | 5.20 | BDL | 0.53 | 0.46 |
| 2         | 1.59 | 1.10 | 0.92 | 3.90 | BDL | 0.56 | 0.40 |
| 3         | 1.69 | 1.26 | 0.86 | 2.60 | BDL | 0.52 | 0.38 |
| 4         | 1.44 | 1.10 | 0.68 | 2.18 | BDL | 0.48 | 0.44 |
| 5         | 1.24 | 1.50 | 0.96 | 3.04 | BDL | 0.52 | 0.42 |
| 6         | 1.49 | 1.10 | 0.84 | 2.30 | BDL | 0.45 | 0.30 |
| 7         | 1.29 | 1.16 | 0.87 | 3.13 | BDL | 0.48 | 0.34 |
| 8         | 1.94 | 0.96 | 0.88 | 3.90 | BDL | 0.42 | 0.32 |
| 9         | 1.20 | 1.00 | 0.89 | 3.47 | BDL | 0.50 | 0.35 |
| 10        | 1.34 | 1.14 | 0.90 | 4.24 | BDL | 0.47 | 0.32 |
| 11        | 1.39 | 1.20 | 0.94 | 3.47 | BDL | 0.44 | 0.34 |
| 12        | 1.64 | 0.88 | 0.96 | 2.60 | BDL | 0.40 | 0.30 |
| 13        | 1.79 | 0.92 | 0.90 | 5.40 | BDL | 0.33 | 0.29 |
| 14        | 1.44 | 0.96 | 0.89 | 4.34 | BDL | 0.36 | 0.30 |
| 15        | 1.14 | 1.00 | 0.98 | 3.69 | BDL | 0.28 | 0.22 |

**Cd, Cr and Mn levels**

The concentration of Cd ion in water samples of the Bangshi river was found below detection level (Table 3). According to FAO (1992), the permissible limit of Cd ion in water used for irrigation is 0.01 µg mL\(^{-1}\). Similar findings were observed in water samples of the Bangshi, Buriganga, Turag and Shitalaksha rivers (Hossain et al., 2012; Islam et al., 2014). Das et al. (2011) reported that the level of Cd ion in the Buriganga river varied from 0.11 and 2.37 µg mL\(^{-1}\) and these values were higher than the current study. The concentration of Cd ion in water samples of the Rupsha river varied from 0.016 to 0.035 µg mL\(^{-1}\) (Hossain et al., 2018), which was higher than the present study. The recorded level of Cr ion in river water samples ranged from 0.28 to 0.56 µg mL\(^{-1}\) having a mean value of 0.44 µg mL\(^{-1}\).
According to FAO (1992), the permissible limit of Cr in irrigation water is 0.10 µg mL⁻¹. On the basis of this limit, the detected level of this metal ion exceeded the permissible limit and all the water samples under investigation were problematic for soils and crops grown in the irrigated areas. So, this metal ion was considered as chemical contaminants for long-term irrigation towards food safety. The anthropogenic supply of this heavy metal was possibly due to the uncontrolled discharge of untreated industrial effluents from the textile and leather tanning industries into this river water. Similar findings were observed by Rahman and Mondal (2013) and Arefin et al. (2016b). Another observation was reported by Arefin et al. (2016a), who found that the concentration of Cr in the Turag river varied from 0.23 to 0.47 µg mL⁻¹. The status of Cr ion in water samples of the Buriganga river was between 2.75 and 7.00 µg mL⁻¹ and these values were higher than the current study (Das et al., 2011). Ahmed et al. (2009b) reported that the concentration of Cr ion in the Dhaleshwari river ranged from 378.87 to 501.11 µg L⁻¹ and these values were more or less similar to the current study. The status of Mn in all the water samples under investigation ranged from 0.22 to 0.46 µg mL⁻¹ with an average value of 0.34 µg mL⁻¹. The permissible limit of Mn in water used for irrigation is 0.20 µg mL⁻¹ (FAO, 1992). As per this limit, the recorded limit of this metal ion in water samples exceeded the acceptable range and this ion was treated as chemical contaminants. So, water samples could not be safely applied for long-term irrigation. Industrial activities were mainly responsible for the high level of Mn in this river water probably originating from dyeing and textile industries. Similar observations were reported by Rahman and Mondal (2013) and Arefin et al. (2016b). The concentration of Mn ion ranged from 0.35 to 0.92 µg mL⁻¹ in Turag river (Arefin et al., 2016a), which was higher than the current finding. Zakir et al. (2012) reported that the concentration of Mn in water samples collected from the Karatao river in Bangladesh varied from trace to 0.32 µg mL⁻¹. These values were more or less similar to the present study. The concentration of Mn ion in water samples collected from the Halda river varied between 0.05 and 0.28 µg mL⁻¹ (Bhuyan and Bakar, 2017).

**SAR, SSP, RSC, Hardness and PI values**

The calculated SAR values of river water samples varied from 1.93 to 4.64 having a mean value of 3.13. (Table 4). Water used for irrigation having SAR less than 10 might not be harmful for agricultural crops (Todd and Mays, 2005). Considering this classification, all the samples were rated as low alkalinity hazard (S1, SAR<10) class reflecting excellent for irrigation as illustrated in Fig. 2. Hossain et al. (2018) found that in the Rupsha river water samples, SAR values ranged from 1.23 to 1.63, which was lower than the present study. SAR values of water samples collected from the Turag river varied between 0.27 and 0.33 (Arefin et al., 2016a), which were lower than the current investigation.

As regards to SAR value, water samples collected from the Buriganga river were excellent in quality (Zaman et al., 2002).

The results in Table 4 reflected that the computed SSP values of water samples in the investigated river fluctuated from 52.96 to 69.92% with an average value of 62.55% (Table 4). According to water classification proposed by Todd and Mays (2005), 5 samples were classified as permissible (SSP=40-60%) and 10 samples were classified as doubtful (SSP=60-80%). Arefin et al. (2016a) observed that in the Turag river water samples, the computed SSP values fluctuated from 12.45 to 15.70%, which was lower than the current study. The computed SSP values in the Rupsha water samples ranged from 25.26 to 30.63% (Hossain et al., 2018). All these values were lower than the present study. RSC values of the collected water sample from the study area fluctuated from -1.95 to 0.06 meq L⁻¹ with an average value of -0.84 meq L⁻¹ (Table 4). As per classification suggested by Schwartz and Zhang (2012), all the water samples were rated as suitable class (RSC<1.25 meq L⁻¹). For this reason, all the river water samples might not be problematic for irrigation usage. RSC values of water sample collected from the Rupsha river ranged from -7.78 to -6.51 meq L⁻¹ (Hossain et al., 2018), which was lower than the present study. 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.

The obtained results in Table 4 revealed that hardness (H₅) values of the collected water samples ranged from 106.20 to 148.91 mg L⁻¹ having a mean value of 128.77 mg L⁻¹. Sawyer and McCarty (1967) suggested a classification for irrigation water based on hardness and according to this classification, all the samples were moderately hard (H₅=75-150 mg L⁻¹) in quality. Arefin et al. (2016a) reported that in the Turag river water samples, hardness (H₅) values varied between 336.68 and 465.15 mg L⁻¹, which were higher than the current study. The hardness (H₅) 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. The computed permeability index (PI) values were found to vary from 64.86 to 88.73% having an average value of 78.90% (Table 4). Accordingly, PI values indicated the suitability of water for irrigation purpose (Vasanthavigar et al., 2010).

Regarding the obtained PI values, all the water samples were under class-III implying 25% of maximum permeability when applied to soil system as irrigation water as presented in Fig. 3. Hossain et al. (2018) stated that the computed PI values of the Rupsha river water samples were found to vary from 27.55 to 32.42%, which was lower than the current study. In the monsoon season, PI values of the Shailmari river water varied from 62.70 to 80.34% (Islam et al., 2016) and these values were more or less similar to the present study.
Fig. 2. Diagram for classifying river water used for irrigation (Wallender and Tanji, 2011)

Fig. 3. Diagram for classifying river water based on permeability index (Vasanthavigar et al., 2010)
Table 4. Ionic contamination rating of the Bangshi river water samples with their suitability for irrigation

| Sample ID No. | SAR | SSP | RSC | Hr | PI |
|---------------|-----|-----|-----|----|----|
|               | %   | Class | meqL⁻¹ | Class | mg L⁻¹ | % | Class |
| 1             | 66.29 | Doubt. | -1.40 | Suit. | 148.91 | MH | 78.84 | Class-III |
| 2             | 64.18 | Doubt. | -0.69 | Suit. | 133.62 | MH | 80.64 | Class-III |
| 3             | 53.98 | Perm. | -1.95 | Suit. | 146.49 | MH | 64.86 | Class-III |
| 4             | 52.96 | Perm. | -1.34 | Suit. | 126.12 | MH | 69.40 | Class-III |
| 5             | 59.35 | Perm. | -0.84 | Suit. | 135.80 | MH | 76.44 | Class-III |
| 6             | 54.80 | Perm. | -0.49 | Suit. | 128.62 | MH | 76.67 | Class-III |
| 7             | 62.02 | Doubt. | -1.05 | Suit. | 121.57 | MH | 77.30 | Class-III |
| 8             | 62.24 | Doubt. | -1.20 | Suit. | 144.23 | MH | 76.53 | Class-III |
| 9             | 66.46 | Doubt. | -0.40 | Suit. | 109.20 | MH | 84.86 | Class-III |
| 10            | 67.45 | Doubt. | -0.88 | Suit. | 123.09 | MH | 81.92 | Class-III |
| 11            | 63.00 | Doubt. | -0.19 | Suit. | 128.54 | MH | 82.82 | Class-III |
| 12            | 58.55 | Perm. | -0.42 | Suit. | 125.30 | MH | 79.08 | Class-III |
| 13            | 69.92 | Doubt. | -1.31 | Suit. | 134.76 | MH | 81.17 | Class-III |
| 14            | 68.55 | Doubt. | -0.60 | Suit. | 119.23 | MH | 84.30 | Class-III |
| 15            | 68.58 | Doubt. | 0.06  | Suit. | 106.20 | MH | 88.73 | Class-III |

Legend: Ex.=Excellent; Doubt.= Doubtful; Perm.= Permissible; Suit.= Suitable & MH= Moderately Hard

Table 5. Correlation matrix among chemical quality parameters of the Bangshi river water samples

| Parameters | TDS | SAR | SSP | RSC | Hr | PI |
|------------|-----|-----|-----|-----|----|----|
| EC         | 0.399 NS | - | - | - | - | - |
| TDS        | 0.101 NS  | 0.347 NS | - | - | - | - |
| SAR        | 0.941 *   | - | - | - | - | - |
| SSP        | 0.324 NS  | - | - | - | - | - |
| RSC        | -0.737 ** | - | - | - | - | - |
| Hr         | -0.629 *  | - | - | - | - | - |

Legend: NS=Not significant; **Significant at 5% level & *Significant at 1% level.

Relationships between chemical quality parameters

The relationships between chemical quality parameters viz., EC, TDS, SAR, SSP, RSC, Hr and PI were studied (Table 5). Significant positive correlation was existed between TDS vs RSC, TDS vs PI, SAR vs SSP, SAR vs PI, RSC vs PI and SSP vs PI, whereas negative significant correlation was existed among the combinations of TDS vs Hr, RSC vs Hr and Hr vs PI. In rest of the combinations, the relationship between quality criteria was insignificant as their respective calculated correlation coefficient (r) values were below the tabulated values of r at both 1% and 5% levels of significance.

Conclusion

Among the detected ions under investigation, Cr and Mn ions were above the permissible limits for long-term irrigation and these ions were treated as chemical contaminants in water samples of the Bangshi river for irrigating soils and crops. The detected ions as chemical contaminants should be considered for long-term irrigation purpose towards food safety.

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References

Ahmed, G., Uddin, M.K., Khan, G.M., Rahman, M.S. and Chowdhury, D.A. 2009a. Distribution of trace metal pollutants in surface water system connected to effluent disposal points of Dhaka Export Processing Zone (DEPZ), Bangladesh: A statistical approach. Journal of Nature Science and Sustainable Technology, 3: 293-304. http://dx.doi.org/10.3839/jnast.2016.015

Ahmed, M.K., Ahamed, S., Rahman, S., Haque, M.R. and Islam, M.M. 2009b. Heavy metals concentration in water, sediments and their bioaccumulations in some freshwater fishes and mussels in Dhaleshwari river, Bangladesh. Terrestrial and Aquatic Environmental Toxicology, 3: 31-41. http://dx.doi.org/10.1007/s12205-011-0179-y

Anny, F.A., Kabir, M.M. and Bodrud-Doza, M. 2017. Assessment of surface water pollution in urban and industrial areas of Savar Upazila, Bangladesh. Pollution, 3: 243-259. http://dx.doi.org/10.3839/jabc.2016.015

APHA (American Public Health Association). 2012. Standard Methods for the Examination of Water and Wastewater. 22nd Edn., AWWA and WEF, Washington, USA, pp. 1-39 ~ 3-17.

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 Turag river in Bangladesh. Journal of Applied Biological Chemistry, 59: 83-90. https://doi.org/10.3839/jabc.2016.015

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 Bangshi River, Bangladesh. Applied Biological Chemistry, 59: 729-737. https://doi.org/10.1007/s13765-016-0219-y

Bhuyian, M.A.H., Rakib, M.A., Dampare, S.B., Ganyaglo, S. and Suzuki, S. 2011. Surface water quality assessment in the central part of Bangladesh using multivariate analysis. KSCE Journal of Civil Engineering, 15: 995-1003. https://doi.org/10.1007/s12205-011-0179-y

Bhuyian, M.S. and Bakar, M.A. 2017. Seasonal variation of heavy metals in water and sediments in the Halda River, Chattagong, Bangladesh. Environmental Science and Pollution Research, 25(4): 2177-2186. https://doi.org/10.1007/s11356-016-6823-9
Das, M., Ahmed, M.K., Islam, M.S., Islam, M.M. and Akter, M.S. 2011. Heavy metals in industrial effluents (tannery and textile) and adjacent rivers of Dhaka city, Bangladesh. *Terrestrial and Aquatic Environmental Toxicology*, 5: 8-13.

Dunca, A.M. 2018. Water pollution and water quality assessment of major transboundary rivers from Banat (Romania). *Journal of Chemistry*, 1-8. https://doi.org/10.1155/2018/9073763

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

Fatema, K., Begum, M., Zahid, A. and Hossain, M.E. 2018. Water quality assessment of the river Buriganga, Bangladesh. *Journal of Biodiversity, Conservation, Bioresources Management*, 4: 47-53. https://doi.org/10.3329/jbcbm.v4i1.137876

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 Edn., A Wiley-Interscience Publication, New York, USA, pp. 442-443.

Gupta, I.C., Yaduvanshi, N.P.S. and Gupta, S.K. 2012. Standard Methods for Analysis of Soil, Plant and Water. Scientific Publishers, Jodhpur, India, pp. 32-36.

Gupta, P.K. 2013. Soil, Plant, Water and Fertilizer Analysis. 2nd Edn., Agrobios, Jodhpur, India, pp. 254-263.

Hafizur, R.M., Nuralam, H.M. and Rumainul, I.M. 2017. Investigation of physicochemical parameter, heavy metal in Turag river water and adjacent industrial effluent in Bangladesh. *Journal of Science, Technology and Environment Informatics*, 5: 347-360. https://doi.org/10.18801/jsesi.2017.11.30

Hossain, M.D., Rahman, M.M., Chandra, J.B., Shammi, M. and Uddin, M.K. 2012. Present status of water quality of the Bangshi river, Savar, Dhaka, Bangladesh. *Bangladesh Journal of Environmental Research*, 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. *Journal of Science and Natural Resources*, 11: 145-151. https://doi.org/10.3329/jesnr.v11i2.43381

Islam, M.S., Han, S., Ahmed, M.K., Masunaga, S. 2014. Assessment of trace metal contamination in water and sediment of some rivers in Bangladesh. *Journal of Water and Environment Technology*, 12: 109-121. https://doi.org/10.1016/j.jmet.2014.109

Islam, M.M., Azad, A.K., Ara, M.H., Rahman, M., Hassan, N., Swarnokar, S.C. and Rabeya, I. 2016. Environmental study on a coastal river of Bangladesh with reference to irrigation water quality assessment: A case study on Shailmari River, Khulna. *Journal of Geoscience and Environment Protection*, 4: 41-64. https://doi.org/10.4236/gep.2016.410003

Khanam, D., Rahman, S.H., Islam, M.S., Alsan, M.A., Shaha, B., Akbor, M.A., Beg, R.U. and Advel, T.M. 2011. Seasonal implication of heavy metal contamination of surface water around Dhaka Export Processing Zone (DEPZ), Savar, Bangladesh. *Jahangirnagar University Journal of Science*, 34; 21-35.

Mottalib, M.A., Al-Razeec, A.N.M., Aser M.N. and Aman E.U.M. 2016. Assessment of physico-chemical properties of surface water of Shitalakshya river near Polash, Narsingdi, Bangladesh. *International Journal of Advanced Research*, 4: 915-924. https://doi.org/10.21747/IJAR01/1288

Ouali, N., Belabed, B.E. and Chenchoui, H. 2018. Modelling environment contamination with heavy metals in flathead grey mullet Mugil cephalus and upper sediments from North African coasts of the Mediterranean Sea. *Science of the Total Environment*, 639:156-174. https://doi.org/10.1016/j.scitotenv.2018.04.377

Paul, J.M., Jose J., Suresh, L.A., George, M. and Syamkrishna P.S. 2018. Evaluation of water quality index of surface water in Kuruorothu river, Kothamangalam, Kerala, India. *IOSR Journal of Mechanical and Civil Engineering*, 15, 1-6. https://doi.org/10.1155/2018/8971079

Pia, H.I., Akhter, M., Sarkar, S., Hossain, M., Rayhan, A.B.M.S., Islam, M.M. and Hassan, M.A. 2018. Contamination level (Water quality) assessment and agro-ecological risk management of Shitalakshya ariver of Dhaka, Bangladesh. *Hydrology: Current Research*, 9:1-4.

Qadir, M., Wichelns, D., Raschid, S.L., Cornick, P.G., Drechsel, P., Bahri, A. and Minhas, P.S. 2010. The challenges of wastewater irrigation in developing countries. *Agricultural Water Management*, 97: 561-568. https://doi.org/10.1016/j.agwat.2008.11.004

Rahman, S.H., Neelormi, S. and Tareq, S.M. 2008. Environmental impact assessments of textile and dyeing industries on ecosystem of Karnopara canal at Savar, Bangladesh. *Jahangirnagar University Journal of Science*, 31: 19-32.

Rahman, M. and Mondal, M.S. 2013. Impact of the Bangshi river water quality on irrigated soil and rice in Bangladesh. *Asian Journal of Water, Environment and Pollution*, 10: 129-139.

Raghunath, H.M. 1987. Groundwater. 2nd Edn., Wiley Eastern Ltd., New Delhi, India.

Rehnuma, M., Islam, M.S., Meghla, N.T. and Kabir, M.H. 2016. Investigation of water quality from Bangshi river at Tangail in Bangladesh. *Journal of Science and Technology*, 6: 153-160.

Rout, G. 2017. Assessment of water quality of river Yamuna. *International Journal of Earth Sciences and Engineering*, 10: 398-403. https://doi.org/10.21276/ijece.2017.10.0234

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 Uttarakhand Himalaya. *International Journal of Chemical Science*, 7: 607-616.

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.

Tareq, S.M., Rahman, M.S., Rüka, S.Y., Islam, S.M.N. and Sultana, M.S. 2013. Seasonal variations in water quality of the Gandes and Brahmaputra River, Bangladesh. *Jahangirnagar University Environmental Bulletin*, 2: 7-82. https://doi.org/10.3329/jueb.v2i0.16332

Todd, D.K. and Mays, L.W. 2005. Groundwater Hydrology. 3rd Edn., 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. *Journal of Environmental Science & Natural Resources*, 7: 249-256. https://doi.org/10.3329/jesnr.v7i1.42179

vasanthavigar, M.I., Srinivasamoorthy, K., Vijayaragavan, K., Ganith, R.R., Chidambaran, S., Anandhan, P., Manivannan, R. and Vasudevan, S. 2010. Application of water quality index for groundwater quality assessment: Thirumangalur sub-basin, Tamilnadu, India. *Environmental Monitoring and Assessment*, 171: 595-609. https://doi.org/10.1007/s10661-009-1302-1

Wallender, W.W. and Tanji, K.K. 2011. Agricultural Salinity Assessment and Management. 2nd Edn., American Society of Civil Engineers, Reston, Virginia, USA.

Zakir, H.M., Rahman, M.M., Rahman, A., Ahmed, I. and Hossain, M.A. 2012. Heavy metals and major ion pollution assessment in waters of midstream of the river Karatoa in Bangladesh. *Journal of Environmental Science & Natural Resources*, 5: 149-160. https://doi.org/10.3329/jesnr.v5i2.14806

Zaman, M.W., Rahrun, M.M. and Islam, M.J. 2002. Freshwater toxicity of the Buriganga River during monsoon and winter seasons. *Bangladesh Journal of Agricultural Science*, 29: 165-171.